Research Note NC-201

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108

1976

WISCONSIN SAW LOG PRODUCTION BY COUNTY AND SPECIES, 1973

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and
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ABSTRACT.--Shows 1973 saw log production by county of origin for 24 species groups. Discusses production changes since 1967, the last year of detailed data, in major species and reasons for the change.

OXFORD: 526(775):792. KEY WORDS: red oak, aspen, elm, hard maple, white pine, lumber.

In 1973 Wisconsin loggers harvested 386.5 million board feet of saw logs, 42 percent more than in 1967, the last year of detailed data. The large log harvest was in response to the heavy demand for railroad ties and lumber for furniture, flooring, pallets, crating, and construction. Lumber inventories were low during 1973 because sawmills had difficulty meeting the demand.

Principal species cut were red oak (84.7 million board feet), aspen (74.3 million board feet), elm (58.1 million board feet), hard maple (39.1 million board feet) and white pine (23.6 million board feet) (table 1).

Wisconsin mills received nearly all the saw logs cut in 1973; only 3.8 million board feet of logs were shipped out of State, primarily to mills in Michigan, Iowa, and Minnesota.

Major production gains since 1967 were in aspen (43.6 million board feet), elm (27.2 million board feet), and red oak (11.6 million board feet). Aspen has found widespread acceptance as pallet lumber and for furniture parts since 1967. In addition, more aspen is used in housing construction since it became eligible for construction lumber grading under softwood rules. Elm harvesting increased because Dutch Elm Disease spread in Wisconsin and many dead and dying trees were salvaged for saw logs. Red oak harvesting increased to meet greater demands for furniture stock and railway ties.

Northeast Wisconsin furnished 38 percent of the saw log volume. Ten of the 15 large Wisconsin sawmills (those cutting 5 million board feet or more of lumber annually) are in the Northeast Unit and received large volumes of logs from that area. Half of the aspen was cut in the Northeast, 48 percent of the elm, and 55 percent of the hard maple. Pulpwood and veneer logs are in heavy demand in this Unit, also.

Top-producing counties were Shawano (including Menominee County), Forest, Marathon, and Oneida. Saw logs were harvested in every county except Kenosha.

These results came from a study of Wisconsin industrial roundwood production in 1973. The study was a cooperative effort between the Wisconsin Department of Natural Resources (DNR) and the North Central Forest Experiment Station. Sawmills using Wisconsin logs and bolts reported their roundwood receipts by species and county of origin in Wisconsin. Their cooperation is gratefully acknowledged. Special thanks are given to Area Foresters and Assistant Area Foresters of the Wisconsin DNR for personally canvassing the Wisconsin mills.

Table 1.--*Saw log production by*
(In thousand boar

UNIT AND COUNTY	BALSAM FIR	CEDAR	HEMLOCK	JACK PINE	RED PINE	WHITE PINE	SPRUCE	TAMARACK	ASH	ASPEN
NORTHEASTERN										
FLORENCE	0	3	442	0	79	397	30	0	74	1037
FOREST	10	185	2468	200	812	1912	48	0	312	7986
LANGLADE	23	51	145	0	47	92	34	0	278	436
LINCOLN	5	5	94	5	196	331	2	1	388	1004
MARINETTE	34	89	151	181	697	1436	6	0	226	5294
OCONTO	0	15	61	3	455	504	0	0	150	4587
ONEIDA	27	35	156	435	1548	1699	0	0	19	10321
SHAWANO[1]	0	125	2754	12	38	4411	11	12	659	1615
VILAS	20	3	99	450	1552	2330	42	0	3	4633
UNIT TOTAL	119	511	6370	1286	5424	13112	173	13	2109	36913
NORTHWESTERN										
ASHLAND	115	50	9	29	300	320	28	0	92	3023
BARRON	0	0	0	3	77	405	0	0	56	571
BAYFIELD	9	4	0	148	575	1195	2	0	27	3990
BURNETT	0	0	0	182	122	227	0	0	33	170
DOUGLAS	194	0	0	0	113	150	10	0	0	797
IRON	5	35	60	0	200	212	25	0	45	252
POLK	0	0	0	0	48	383	0	1	101	362
PRICE	1	0	0	6	38	194	10	0	467	4300
RUSK	0	0	10	5	34	241	0	0	281	3488
SAWYER	0	0	14	9	449	755	0	0	219	5398
TAYLOR	4	0	91	4	7	71	0	0	252	1178
WASHBURN	0	0	0	235	256	175	0	0	0	2833
UNIT TOTAL	328	89	184	621	2219	4328	75	1	1573	26362
CENTRAL										
ADAMS	0	0	0	7	9	76	0	0	18	131
CHIPPEWA	0	0	0	0	11	357	0	0	145	2850
CLARK	0	0	10	40	25	529	0	0	226	1116
EAU CLAIRE	0	0	0	2	0	150	0	0	39	104
JACKSON	0	0	0	441	96	356	0	0	79	1385
JUNEAU	0	0	0	134	111	204	0	0	148	629
MARATHON	0	17	229	34	29	371	11	30	1003	970
MARQUETTE	0	0	0	0	7	42	0	0	12	45
MONROE	0	0	0	5	31	70	0	0	49	415
PORTAGE	0	0	0	45	62	444	0	0	10	125
WAUPACA	0	0	110	0	89	1426	0	12	540	627
WAUSHARA	0	22	4	5	87	181	0	0	50	0
WOOD	0	0	10	325	80	162	0	0	227	617
UNIT TOTAL	0	39	363	1038	637	4368	11	42	2546	9014

and species groups, Wisconsin, 1973
ational 1/4-inch rule)

BEECH	WHITE BIRCH	YELLOW BIRCH	COTTON-WOOD	ELM	HICKORY	HARD MAPLE	SOFT MAPLE	RED OAK	WHITE OAK	WALNUT	OTHER HARD-WOODS	ALL SPECIES
4	63	246	0	869	0	2823	76	93	0	0	16	6895
30	288	722	0	1721	0	4847	384	282	0	0	32	23742
72	128	200	0	3960	26	3723	393	505	70	0	44	11060
0	415	384	0	2364	11	1288	565	1005	16	0	33	8882
148	385	21	8	1839	0	540	595	1593	330	0	0	13899
100	197	41	47	2153	0	774	455	1184	255	0	6	11272
0	739	1107	12	383	0	889	1150	473	0	0	0	19133
596	527	912	8	14545	105	6267	1968	2877	272	0	109	40348
3	590	412	12	70	0	494	401	226	0	0	9	11418
953	3332	4045	87	27904	142	21645	5987	8238	943	0	249	146649
0	132	209	0	186	0	505	132	389	63	0	0	6024
0	17	1	16	292	0	260	70	1201	151	0	0	3409
0	570	5	0	17	0	162	0	39	1	0	0	6877
0	4	0	0	74	0	64	7	1614	106	0	7	2686
0	0	0	0	0	0	0	0	54	60	0	0	1378
0	45	169	0	122	0	453	31	98	0	0	0	1951
0	51	0	14	324	16	373	109	1532	372	0	3	3967
0	471	222	0	604	4	797	493	332	64	0	0	8279
0	277	251	0	590	0	727	307	684	205	0	1	7493
0	129	97	0	287	0	936	84	505	34	0	0	9268
0	137	84	0	1003	0	580	425	369	58	0	0	4801
0	67	1	0	11	0	42	0	1155	46	0	0	5703
0	1900	1039	30	3510	20	4899	1658	7972	1160	0	11	61836
0	28	0	0	30	3	19	48	928	186	0	0	1502
0	134	38	0	978	0	571	506	1773	119	0	14	8549
0	84	39	15	1510	40	505	631	1345	287	0	0	6912
0	6	8	0	86	0	87	66	619	172	0	12	1433
0	197	80	30	800	1	270	600	3249	562	0	134	8452
0	72	0	0	128	71	97	265	2187	721	0	0	4834
187	343	398	0	7509	70	2483	1266	2545	378	0	109	19346
0	11	0	15	16	28	8	35	1188	315	3	0	1731
0	24	20	4	325	48	306	414	2625	525	0	0	4988
0	2	2	70	182	1	152	202	790	245	0	0	2385
338	125	127	0	2399	7	774	939	2264	544	0	118	11270
0	0	0	0	268	0	21	90	1247	241	0	0	2226
0	126	15	0	317	0	321	408	1065	231	0	0	4059
525	1152	727	134	14548	269	5614	5470	21825	4526	3	387	77687

TABLE 1 CONTINUED ON NEXT PAGE

TABLE 1 CONTINUED

UNIT AND COUNTY	BALSAM FIR	CEDAR	HEMLOCK	JACK PINE	RED PINE	WHITE PINE	SPRUCE	TAMARACK	ASH	ASPEN	BALSAM POPLAR	BASSWOOD	BEECH	WHITE BIRCH
SOUTHWESTERN														
BUFFALO	0	0	0	0	0	9	0	0	11	183	0	164	0	23
CRAWFORO	0	0	0	0	0	0	0	0	81	60	0	269	0	2
OUNN	0	0	0	0	6	259	0	0	90	285	0	810	0	5
GRANT	0	0	0	0	3	14	0	0	20	81	0	155	0	0
IOWA	0	0	0	0	0	0	0	0	19	13	0	91	0	0
LACROSSE	0	0	0	0	2	22	0	0	55	108	0	323	0	34
LAFAYETTE	0	0	0	0	0	0	0	0	21	0	0	73	0	0
PERIN	0	0	0	0	0	8	0	0	60	73	0	331	0	11
PIERCE	0	0	0	0	0	40	0	0	115	100	0	708	0	15
RICHLANO	0	0	0	0	0	39	0	0	133	46	0	533	0	0
ST.CROIX	0	0	0	0	7	63	0	0	50	22	0	222	0	10
SAUK	0	0	0	0	0	14	0	0	133	223	0	230	0	26
TREMPEALEAU	0	0	0	0	55	42	0	0	40	133	0	218	0	26
VERNON	0	0	0	0	0	3	0	0	137	168	0	629	0	31
UNIT TOTAL	0	0	0	0	73	513	0	0	965	1495	0	4756	0	183
SOUTHEASTERN														
BROWN	0	35	28	0	3	219	0	0	154	69	22	206	124	39
CALUMET	0	3	2	0	0	8	0	0	65	34	0	59	17	2
COLUMBIA	0	0	0	0	6	103	0	0	63	91	0	39	0	7
OANE	0	0	0	0	0	0	0	0	45	8	0	16	0	0
OOOGE	0	0	0	0	0	0	0	0	34	0	0	29	0	0
OOOR	1	143	24	0	14	114	0	6	34	98	61	81	28	61
FONO OU LAC	0	0	0	0	0	0	0	0	18	1	0	25	0	0
GREEN	0	0	0	0	0	0	0	0	1	2	0	2	0	0
GREEN LAKE	0	0	0	0	0	2	0	0	0	0	0	0	0	0
JEFFERSON	0	0	0	0	0	0	0	0	0	0	0	4	0	0
KEWAUNEE	0	16	12	0	0	15	0	0	58	22	22	83	59	29
MANITOWOC	0	38	40	0	0	195	0	7	227	157	0	210	216	69
MILWAUKEE	0	0	0	0	0	0	0	0	5	0	0	0	0	0
OUTAGAMIE	0	5	2	0	0	335	0	0	176	60	16	165	50	22
OZAUKEE	0	2	0	0	0	0	0	0	41	5	0	20	0	0
RACINE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHEBOYGAN	0	0	0	0	0	42	0	0	166	1	0	67	34	0
WALWORTH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WASHINGTON	0	3	0	0	0	0	0	0	314	0	0	318	0	0
WAUKESHA	0	0	0	0	0	0	0	0	54	0	0	0	0	0
WINNEBAGO	0	0	6	0	5	270	0	0	21	7	0	39	23	1
UNIT TOTAL	1	245	114	0	28	1303	0	13	1476	555	121	1363	551	230
STATE TOTAL	448	884	7031	2945	8381	23624	259	69	8669	74339	382	21258	2029	6797

TABLE 1 CONTINUED BELOW

TABLE 1 CONTINUED

UNIT AND COUNTY	YELLOW BIRCH	COTTONWOOD	ELM	HICKORY	HARD MAPLE	SOFT MAPLE	RED OAK	WHITE OAK	WALNUT	OTHER HARDWOODS	ALL SPECIES
SOUTHWESTERN											
BUFFALO	0	144	185	15	30	123	6057	735	2	23	7704
CRAWFORO	0	55	277	27	254	66	2634	1021	200	23	4969
OUNN	0	29	587	15	696	111	2561	246	0	30	5730
GRANT	0	77	200	12	174	40	1451	819	359	22	3427
IOWA	0	3	95	2	122	40	596	425	105	3	1514
LACROSSE	0	55	493	42	187	273	3282	651	193	149	5869
LAFAYETTE	0	10	56	3	62	0	244	125	75	1	670
PEPIN	0	26	305	15	305	85	541	66	0	37	1863
PIERCE	10	270	627	35	670	130	669	86	0	25	3500
RICHLANO	0	6	293	80	847	135	2537	1048	0	5	5702
ST.CROIX	0	10	258	10	195	18	244	57	0	5	1171
SAUK	0	13	258	137	292	638	4907	1363	0	3	8237
TREMREALEAU	0	45	253	51	72	127	8500	1381	0	30	10973
VERNON	0	42	720	86	1137	254	6956	1630	0	25	11818
UNIT TOTAL	10	785	4607	530	5043	2040	41179	9653	934	381	73147
SOUTHEASTERN											
BROWN	0	311	1483	0	213	539	192	113	0	6	3756
CALUMET	0	19	431	0	62	182	46	122	1	2	1055
COLUMBIA	0	41	118	41	55	151	1635	492	33	20	2895
OANE	0	42	151	4	38	50	604	206	45	17	1226
OOOGE	0	20	95	325	38	27	424	360	10	18	1380
OOOR	11	22	238	0	162	27	65	16	0	1	1207
FONO DU LAC	0	5	168	54	27	24	94	75	0	10	501
GREEN	0	0	23	1	0	5	144	60	270	0	508
GREEN LAKE	0	0	0	0	0	0	108	7	0	0	117
JEFFERSON	0	0	66	0	41	0	102	55	0	0	268
KEWAUNEE	11	27	716	0	166	270	162	108	0	10	1786
MANITOWOC	1	30	1399	0	307	637	199	150	0	4	3886
MILWAUKEE	0	0	0	0	5	0	2	3	1	0	16
OUTAGAMIE	0	38	1552	0	61	451	563	270	0	0	3766
OZAUKEE	0	0	32	0	22	0	26	2	0	0	150
RACINE	0	0	30	0	0	0	60	60	0	0	150
ROCK	0	0	38	0	0	0	30	7	0	0	75
SHEBOYGAN	0	0	257	1	194	83	325	69	0	19	1258
WALWORTH	0	0	0	0	0	0	5	5	0	0	10
WASHINGTON	0	5	335	0	417	0	363	9	0	3	1767
WAUKESHA	0	0	5	0	60	28	89	11	3	0	250
WINNEBAGO	0	2	358	8	47	147	217	45	0	1	1197
UNIT TOTAL	23	562	7495	434	1915	2621	5455	2245	363	111	27224
STATE TOTAL	5844	1598	58064	1395	39116	17776	84669	18527	1300	1139	386543

[1] Includes Menominee County.

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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE
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RELEASE ACCELERATES GROWTH OF YELLOW-POPLAR--AN 18-YEAR LOOK

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ABSTRACT.--Yellow-poplar seedlings that germinated and were completely released from woody competition in 1957 (the first year after a harvest cut) were four times taller and five times larger in diameter after the 1973 growing season than seedlings that were not released.

OXFORD: 236.1:231:231.331:176.1 *Liriodendron tulipifera*. KEY WORDS: *Liriodendron tulipifera* L., germination date, seedbed scarification, natural regeneration, harvest cutting method.

Yellow-poplar (*Liriodendron tulipifera* L.) reproduction is usually abundant immediately after harvest cuts if seed is adequate. However, yellow-poplar will not grow well in the new stand unless the environment is favorable.

Results from a study in southern Indiana show that young yellow-poplar trees will survive under a high overstory but grow much faster if released. So if yellow-poplar is wanted in the new forest, stands containing yellow-poplar should be clearcut when harvested. Residual trees larger than 5 feet tall should be cut or killed.

METHODS

The study was conducted in a mixed hardwood stand on the Hoosier National Forest near Oriole, Indiana. The area is a broad ridge on Zanesville soil that has a site index of 60 for black oak and 70 for yellow-poplar. A harvest cut in the fall of 1956 reduced basal area from about 100 to 40 square feet per acre. The area had been heavily seeded by nearby yellow-poplar seed trees, and in the spring of 1957, about 10,000 yellow-poplar seedlings per acre were counted in the study area.

In July 1957, twelve 0.1 acre plots were established to find out how overhead release would affect survival and development of the new seedlings. Three intensities of release were tried:

1. Complete release--all woody vegetation over 5 feet tall was cut or frill girdled and poisoned, leaving a basal area of 0.

2. High release--all residual trees larger than 6 inches d.b.h. were cut or girdled and poisoned. Residual basal area of trees less than 6 inches was about 17 square feet per acre.

3. Check--no release, other than the timber harvest made in the fall of 1956, which left about 40 square feet of basal area per acre, mostly in cull and nonmerchantable trees. Normally, cull trees are girdled and poisoned following harvest cuts.

The three treatments were replicated four times. Reproduction was sampled in six permanent, randomly located, circular, milacre "quadrats" in each plot. Each of the 72 "quadrats" was established at least 20 feet from the plot boundaries.

When the initial germination counts were made in July 1957, three seedbed conditions were recognized: (1) undisturbed litter, (2) scarified organic matter (usually strips along skid trails and around stumps), and (3) mineral soil (usually skid trails and loading areas). Each "quadrat" was diagrammed to show seedbed condition classes and slash accumulation.

Yellow-poplar stocking on the 72 "quadrats" averaged more than 10,000 seedlings per acre in July. Seedling distribution varied, however, according to ground scarification and slash accumulation, from 0 to 61 seedlings per "quadrat." When the "quadrats" were remeasured in September 1957, 88 percent of them contained at least one yellow-poplar seedling and 74 percent were stocked with more than one. The largest number of yellow-poplar seedlings germinated the first year after the harvest cut. But a substantial number germinated the second year and several germinated as late as the fifth year after the cut (table 1). In the spring of 1959, 78 percent of the "quadrats" were stocked with at least one seedling that germinated in 1958. And in the spring of 1962, 49 percent of the "quadrats" were stocked with one or more seedlings that germinated between 1959 and 1961.

Table 1.--*Yellow-poplar seedlings per acre by release treatment and the year germinated*

(In numbers)

Year seed germinated	Years after harvest cut	Release treatment		
		Check	High	Complete
1957	1	7,583	13,500	10,750
1958	2	7,875	6,668	3,208
1959-1961	3-5	3,125	1,792	1,582

RESULTS

Survival.--Eighteen-year results show that yellow-poplar seedlings that germinate immediately after logging have a much better chance of becoming established in the new stand than seedlings that germinate later, even if only 1 year later (table 2). Although survival of the 1957 seedling crop seems low, there are still about 1,100, 1,800, and 1,100 trees per acre remaining in the check, high release, and complete release plots, respectively.

Table 2.--*Survival of yellow-poplar seedlings at 18 years by release treatment and year the seed germinated*

(In percent)

Year seed germinated	Release treatment		
	Check	High	Complete
1957	14	13	10
1958	7	4	4
1959-1961	7	0	3

Late germinators survived best in the unreleased plots. During the winter of 1958-1959 more than 20 percent of the mortality on the released plots was caused by mice, while no mouse damage was found on the unreleased plots. Apparently, the heavier ground cover of grass, herbs, and slash on the released plots provided a better habitat for mice than the more sparse ground cover on the unreleased plots.

Scarification greatly affected initial germination. When the study was established in 1957, three-quarters of the seedlings were found on the disturbed forest floor[1] (scarified organic matter and mineral soil) which made up only a little more than one-quarter of the area (table 3). However, degree of scarification had no effect on long-term survival; 18 years after the harvest cut survival of the 1957 seedling crop was 14 percent in the undisturbed litter, 13 percent in the scarified organic, and 14 percent in the mineral soil.

Table 3.--*Initial surface condition classes and distribution of yellow-poplar seedlings*

Seedbed	Area	Number of seedlings	Seedlings per acre
	Percent	*Percent*	*Number*
Undisturbed	73	23	3,200
Scarified	17	50	30,900
Mineral	10	27	27,200
Total	100	100	

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[1] Engle, LaMont G. and Robert D. Williams. 1957. Scarifying seedbed boosts yellow-poplar germination. USDA For. Serv., Cent. States For. Exp. Stn. Stn. Note 110, 2 p.

"Quadrats" stocked with one or more seedlings, regardless of year germinated, decreased from 92 percent to 62 percent from the 5th to the 18th year. Nevertheless, yellow-poplar remains a major component of the new stand. Thirty-one percent of the trees on the check plots and 40 percent of those on both the high and complete release plots are yellow-poplar. And if present, yellow-poplar is the tallest species on 67 percent of the check plot "quadrats," 81 percent of the high release "quadrats," and 75 percent of the complete release "quadrats."

Growth.--Eighteen years after the harvest cut, the tallest 1957 trees in the complete release plots are more than four times taller than the 1957 trees in the check plots (table 4). Also, the tallest yellow-poplar trees of those that germinated the first year after the harvest cut are more than twice as tall as the tallest of those that germinated only 1 year later, regardless of release treatment.

Eighteen years after the cut, 38 of the 72 "quadrats" contained at least 1 yellow-poplar from the 1957 crop. Only 1 of these 38 "quadrats" contained a later germinator that was taller than the 1957 tree.

Degree of scarification had little effect on height growth. Height of the tallest yellow-poplar in each ground condition class averaged 19 feet for the undisturbed litter, 18 feet for the scarified organic, and 16 feet for the mineral soil.

Table 4.--*Mean height of tallest yellow-poplar per "quadrat" by release treatment and age of the tree 18 years after the harvest cut*

Year seed germinated	Tree age	Release treatment: Check	High	Complete
		- - - - -	*Feet*	- - - - - -
1957	17	6.1	14.8	25.0
1958	16	2.7	4.6	10.4
1959-1961	13-15	1.4	--	0.4
1962-1973	1-12	3.5	--	--

Diameter growth was increased by release, too. Mean diameter of the largest trees in the complete release plots is about five times greater than that of the largest trees in the check plots (fig. 1). Mean d.b.h. of the largest yellow-poplar per quadrat is 0.5 inch in the check plots, 1.1 inch in the high release, and 2.7 inches in the complete release.

CONCLUSIONS

Eighteen years after a timber harvest, several facts concerning the reproduction, survival, and growth of yellow-poplar are evident:

Figure 1.--*Completely released yellow-poplar (left) are typically much larger than unreleased trees (right) that survive under an overstory*

1. Yellow-poplar germinates best on a scarified seedbed, but neither survival nor growth are dependent on the degree of scarification.

2. Yellow-poplar will survive under a partial overstory (40 sq. ft. of basal area), but growth is very slow. Trees completely released are four times taller and five times larger in diameter than unreleased trees.

3. Although there is no difference in survival between high release trees and completely released trees, the difference in growth is notable. Completely released trees are almost twice as tall and their diameter is more than twice that of the high release trees.

4. Yellow-poplar competes well with other species, especially in openings. Yellow-poplar has a better than average chance of being taller than its neighbor under a partial overstory, but if released, yellow-poplar may be taller than its neighbor 75 percent of the time.

5. Yellow-poplar that germinated the first growing season after a cut has a much better chance of becoming established in the new stand.

6. Yellow-poplar seedlings can be released, but the cheapest way to favor yellow-poplar in the new stand, when seed trees are nearby, is to completely clear the regeneration area when the old stand is harvested. Because viable yellow-poplar seed accumulates in the litter, the seed trees may be cut when the rest of the stand is harvested.[2]

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[2] Clark, F. Bryan and Stephen G. Boyce. 1964. Yellow-poplar seed remains viable in the forest litter. J. For. 62(8): 564-568, illus.

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Research Note NC-203

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55108

1976

WEED CONTROL IN BLACK WALNUT PLANTATIONS

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ABSTRACT.--Weeds must be controlled for at least 3 years to successfully establish walnut plantations. Whether by cultivating or applying chemicals, a strip or spot 4 feet wide is sufficient the first 2 years, followed by a 6-foot spot or strip for the third and fourth years.

OXFORD: 236.1:176.1 (*Juglans nigra*). KEY WORDS: herbicides, cultivation, *Juglans nigra*, ground preparation, chemical.

Weed control in walnut plantations is now considered standard operating procedure. Landowners and plantation managers who ignore or try to shortcut this important step soon discover that in a race with the weeds for moisture, nutrients, and light, walnut trees seldom win. The type and amount of weed control depends on whether the site is a field or cut-over forest, the other cultural operations planned, and the owners' objectives.

MECHANICAL VERSUS CHEMICAL CONTROL

Cultivation and/or chemicals can be used successfully to control weeds in walnut plantations. Mechanical control is more costly, but if the landowner has a tractor and cultivator, this may be the best alternative. To keep weeds from getting taller than 6 inches, three to six cultivations per year are necessary. A disc or rototiller can be used, but be careful not to damage the stems and shallow feeder roots.

Mowing does little to reduce the competition for moisture and nutrients and so is not a substitute for cultivation or chemical weed control. When weeds are controlled in strips or around individual trees, tall grass and weeds between the rows can protect walnut trees from wind (Schneider *et al.* 1968). On the other hand, however, mowing may be helpful by making it easier to walk through the plantation for other cultural operations and by reducing the fire hazard by keeping the vegetation on the ground.

Mulching with plastic, sawdust, bark and wood chips can control weeds, but these materials have some disadvantages. Plastic is expensive, takes a lot of time to install, may cause heat girdling damage, and provides cover for mice that girdle small trees. Wood chips, sawdust, and bark also take a long time to apply and may tie up soil nitrogen adversely affecting the trees. Trees usually grow slower when mulched than when cultivated or chemically treated (Bey *et al.* 1976, Erdmann 1967, von Althen 1971).

Herbicides have been used successfully for weed control in walnut plantations. However, herbicides can be used only if it so specifies on the container label and is not limited by a State or Federal regulation.[1] Don't assume from general statements on the label that the herbicide may be used indiscriminantly. For example, some chemicals designated as weed killers and/or soil sterilants may kill your walnut trees, too. If you have any doubt about proper use, check with an herbicide authority before proceeding.

Simazine is registered for weed control in walnut plantations that have been established 1 year or more. It is a pre-emergent chemical that acts primarily on germinating seeds. Rates of 4 pounds per acre are recommended for sandy-loam soils and 5 pounds per acre for the heavier clay-loam soils. Simazine is partially effective in killing established grasses but not woody perennials such as trumpet vine. Grasses are easily killed by dalapon at a rate of 5 to 10 pounds per acre. At present, dalapon is not registered for use in walnut plantations, but Dow Chemical Company[2] is considering a label change to include dalapon for use in walnut plantations. Phenoxy chemicals such as 2,4-D will kill a variety of annual and biennial broadleaf weeds. However, if sprayed on the leaves or injected into the trunk, they will also kill trees. Although these chemicals are registered for use on weeds in golf courses, parks, and cemeteries, the container labels for these chemicals do not say "walnut plantations" *per se*.

SOD VERSUS PREPLANT TILLING

Although plowing and discing before planting are not necessary for successful plantation establishment, trees planted in plots prepared by plowing or discing will eventually outgrow those planted in sod. (fig. 1). In our studies the differences between sod and plowed plots did not show up until the third or later years. Jaciw (1974) also reports better performance of young walnut trees planted on cultivated rather than sod plots.

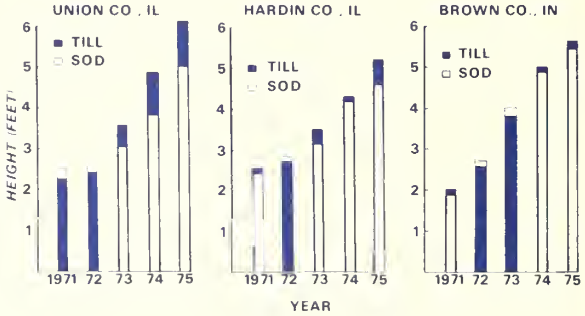

Figure 1.--*After 5 years, height growth of walnut trees was greater in plots that were tilled before planting than in plots where trees were planted in sod.*

One effect of plowing grassy fields before planting is the conversion of the ground vegetation to predominantly broadleaf weeds. Simazine works effectively on germinating weed seeds, so weed control with simazine is more complete on areas prepared by plowing than on established sod (Erdmann 1967). On the other hand, plowing may encourage the development of trumpet vine, a weed that can be troublesome in plantations for 10 years.

COMPLETE VERSUS PARTIAL CONTROL

It is not necessary to control weeds over the entire area for maximum growth of walnut trees. Treating spots or strips is cheaper than complete control and reduces the chances of erosion. Even on very gentle slopes, erosion can become severe where there is complete weed control over the entire plantation.

The spot diameter or strip width need not be wider than 4 feet for the first 2 years and 6 feet for the third and fourth years. In studies in southern Illinois and Indiana, there were few differences among spot sizes after 2 years. During the third and later years there appears to be some

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[1] *This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.*

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

[2] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

advantage to increasing the size of the weed control spot beyond 4 feet in diameter (fig. 2). The trees in the 4-, 6-, and 8-foot diameter treatments grew larger than those in the control and 2-foot spots. This and other studies suggest that as we continue weed control beyond the first few years the width of the weed control strip should be increased for maximum growth.

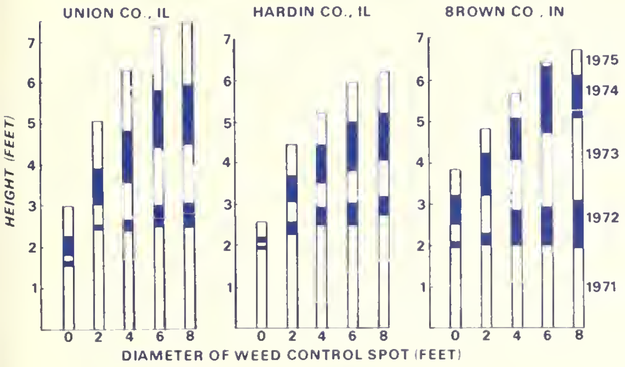

Figure 2.--*During the third and later years, height growth of walnut trees can be increased by controlling weeds in spots greater than 4 feet in diameter.*

In another experiment in southern Illinois, we controlled weeds for the first 7 years with chemicals (simazine + dalapon + 2,4-D amine) in strips 4 to 20 feet wide, plus a control. No weed control was done during the eighth year. For the first 4 years, there was no gain in height made by spraying in strips wider than 4 feet. Then during the last 4 years, the trees in the wider strips grew taller and larger in diameter than those in the narrow strips (fig. 3).

Whether or not to spray spots larger or strips wider than 4 feet is uncertain at this time. For spraying spots in a plantation with a 12- by 12-foot spacing, and using simazine at 5 pounds per acre, costing $3.50/lb, the cost of the chemical per acre would be as follows:

Spot diameter (feet)	*Cost of simazine/acre*
4	$ 1.53
6	3.43
8	6.10
10	9.54
12	13.73

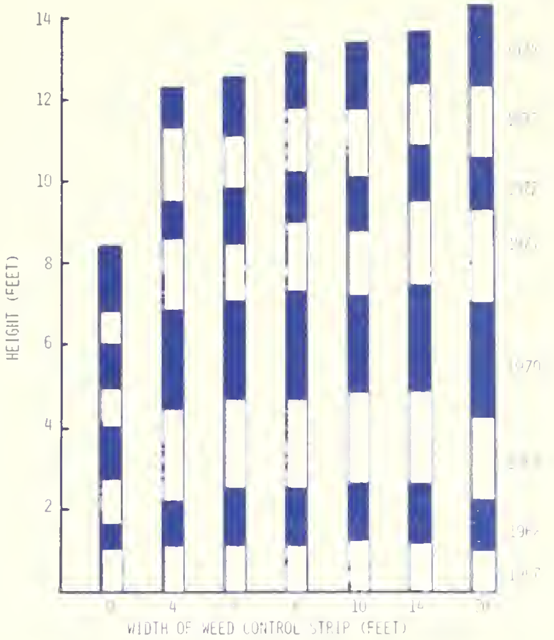

Figure 3.--*In an experiment in southern Illinois, trees with weed control in strips wider than 4 feet grew larger than those in narrower strips.*

We feel that if spraying is continued for more than 2 years, spot size should be increased to 6 to 8 feet in diameter. The additional cost of materials would be minor compared to the expected return. To go from 4- to 8-foot spots would mean an additional cost of less than $5/acre for chemicals plus a small amount for additional labor. The additional chemical cost compounded for 40 years at 10 percent will amount to about $225, but probably less than the increased value due to the additional weed control.

1, 2, 3 OR MORE YEARS OF CONTROL

Weeds should be controlled for at least 3 years in black walnut plantations for maximum growth. In experiments in Indiana and Iowa, we compared three weed control treatments (simazine, atrazine, and cultivation) for 1, 2, and 3 years. In both States, tree growth was greater when weeds were controlled for 3 years than for 2, and for 2 years than for 1 (fig. 4). The differences in growth due to treatment varied by State and may be partially explained by the intensity of the cultivation received. In Iowa no weeds were allowed to grow in the cultivated plots,

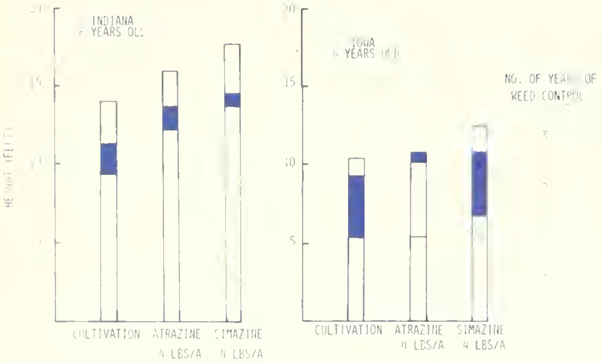

Figure 4.--*In two plantations, walnut growth was generally greater when weeds were controlled for 3 years than for 2, and for 2 years than for 1.*

while in Indiana the plots were not cultivated until the weeds were quite dense.

By controlling weeds in wide strips or spots during the fourth and later years, we believe that we will get faster tree growth. Yet, the answer to the question of whether or not it is worth the extra cost is not clear. Costs for chemical weed control probably will not exceed $25/acre at current prices. To get a 10 percent return on the $25 over the next 40 years, we need to receive an increase of $1,131/acre due to the additional weed control. It is questionable if weed control beyond 3 years is an economically sound practice. From the biological standpoint, it seems reasonable that we should continue weed control until the crown is large enough to shade out some of the competing weeds. On good sites and at a 10- by 10-foot spacing, crowns will begin overlapping at about age 5. Weed control should be continued for at least 3 years, but not longer than when crowns begin to close and shade out competing weeds.

DISCUSSION

People plant walnut trees for many different reasons, and the weed control practice that is best for one grower may not be suitable for another. For some, mowing may increase the value simply by making it easier to walk through the plantation, while for others this may not be important. Other interacting factors that influence decisions regarding weed control include spacing, interplanting, kinds of weeds present, and site quality. In addition, all weed control is not alike. Two years of excellent control may benefit survival and growth more than 3 years of moderate control. Although weed control practices described in this paper refer to planting on old fields, the principles are the same for cut-over forest land (Krajicek 1975). Control of herbs, grasses, and brush for several years provides for maximum growth of walnut trees.

One of the most important things you can do to increase growth of walnut trees during the first few years is to control weeds. Without weed control, plantations are likely to fail. Yet weed control is neither a cure-all nor a substitute for other management operations. By combining weed control with proper seed source selection, site selection, pruning, thinning, and pest management, maximum production in walnut plantations will be obtained.

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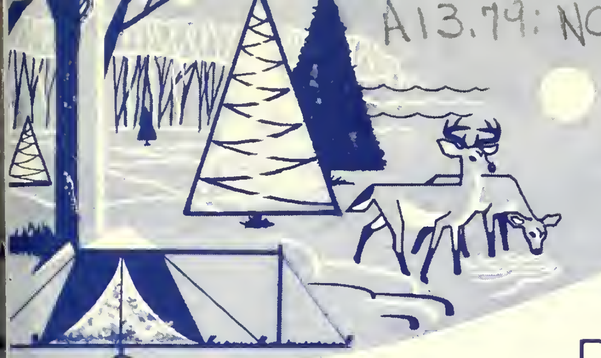

USDA FOREST SERVICE

RESEARCH NOTE NC-204

RTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101
1976

SOIL CONDITIONS AFFECT GROWTH OF HARDWOODS IN SHELTERBELTS[1]

Willard H. Carmean, *Principal Soil Scientist*

ABSTRACT.--Large growth differences were found for hardwoods in shelterbelts on three contrasting soils of western Minnesota. Five years after planting, height growth was outstanding for green ash and Russian olive planted on a moderately fine-textured, somewhat poorly drained soil. Growth was much poorer on coarse-textured or shallow soils. Size of planting stock was not related to growth of trees after planting.

OXFORD: 266: 181.32:176.1(776). KEY WORDS: tree growth, stock size.

Shelterbelts are used in the central plains for protecting fields and homesteads (Read 1964, Stoeckeler 1970). But tree growth in shelterbelt areas, as well as in forested regions, differs greatly depending upon the soil and climate where trees are planted. Thus, selecting tree species for shelterbelt plantings requires information about their adaptability to local soil and climatic conditions. Our studies in western Minnesota reveal large differences in growth for trees planted on soils widely different in texture, depth, and internal drainage.

THE STUDY AREA

Shelterbelt plantings were made in 1968 on the following three contrasting soils in Swift County, Minnesota:

(1) *Renshaw sandy loam* (Udic Haploboroll, fine-loamy over sandy or sandy-sheletal, mixed). This excessively drained soil has a shallow sandy loam surface soil overlying calcareous outwashed glacial sand and gravel. Topography is level and this soil is considered very droughty.

(2) *Buse loam* (Udorthentic Haploboroll, fine-loamy, mixed). This well drained soil has a very dark-colored loam surface soil overlying calcareous loam and clay loam glacial till. Mottling is evident in the subsoil at about 40 inches indicating moderate permeability. Topography is a knob on a rolling landscape, and surface soils are shallow on the steeper slopes because of past erosion.

(3) *Colvin silty clay loam* (Typic Calciaquoll, fine-silty, frigid). This somewhat poorly drained calcareous soil has developed from glacial lacustrine deposits. Topography is level, internal drainage is slow, and the subsoil is mottled and very calcareous at shallow depths.

Annual rainfall averages about 22 inches per year. The Renshaw area is 15 miles west of the other two areas, and thus may have lower rainfall and greater evapotranspiration.

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[1] *A cooperative study with the Minnesota Division of Lands and Forestry. We thank State personnel who provided the seedlings and the planting areas and who assisted with planting, cultivation, and tree measurements.*

METHODS

Three species commonly used in shelterbelts were planted in each of the three areas: (1) 3-0 green ash (*Fraxinus pennsylvanica* Marsh); (2) 2-0 Russian olive (*Elaeagnus angustifolia* L.); and (3) 3-0 Siberian peashrub (*Caragana arborescens* Lam.).

Trees were planted 2 feet apart in rows 15 feet apart. On each area, 24 plots were used for each of the three species--a plot was a portion of a row containing 9 to 18 trees. Three stock sizes were used for each species, and each stock size was replicated in eight plots in a completely randomized statistical design (table 1).

Table 1.--*Tree species and the size of seedlings planted in each of the three soil areas*
(In inches)

Stock size	Tree species: Siberian peashrub (3-0): Average height	Siberian peashrub (3-0): Stem caliper[1]	Russian olive (2-0): Average height	Russian olive (2-0): Stem caliper[1]	Green ash (3-0): Average height	Green ash (3-0): Stem caliper[1]
Large	15.1	0.29-0.35	23.8	0.35+	24.3	0.35-0.42
Medium	12.4	0.20-0.26	16.8	0.23-0.35	17.1	0.23-0.29
Small	9.5	0.10-0.17	9.8	0.10-0.23	9.5	0.10-0.17

[1] Stem diameter measured 1 inch above the root collar.

Each planting area was plowed and disked in the fall of 1967, and planting was done in May 1968 using a machine planter. All trees were checked to ensure proper planting. Weeds were controlled by cultivation and hand weeding during the first three growing seasons, but only occasional cultivation was done in the fourth and fifth growing seasons.

RESULTS

Survival

Survival of Siberian peashrub and green ash was excellent on all soils regardless of stock size (table 2). Large Russian olive also had excellent survival on all soils, but survival was usually poorer for medium- and small-sized Russian olive. This generally excellent survival probably was due to: (1) favorable weather conditions (cloudy and rainy) during planting; (2) checking to ensure proper planting; and (3) controlling weeds. Most of the mortality resulted from accidental uprooting or burying of the smaller seedlings when they were cultivated during the first and second growing seasons. For Russian olive, uprooting or burying was particularly severe for small- and medium-sized seedlings and, in the Renshaw area, survival of Russian olive also was reduced by flooding in 1969.

Size of Planting Stock

Size of planting stock was significantly related to annual height growth in only a few cases, and few consistent trends were evident. For the three species on each soil area, most large-, medium-, and small-sized seedlings grew similarly in

Table 2.--*Five-year survival on the three soil areas by tree species and seedling stock size*
(In percent[1])

Soil series	and stock size [2]	Tree species: Siberian peashrub	Russian olive	Green ash
Renshaw	large	88	81	97
	medium	96	[3]62	98
	small	93	[3]30	94
Buse	large	94	81	88
	medium	94	50	80
	small	72	24	88
Colvin	large	94	96	98
	medium	92	90	98
	small	88	68	92

[1] For each species the survival percents not connected by the same line are significantly different (5-percent level) as determined by the Newman-Keuls (Hartley modification) multiple range test.

[2] See table 1 for stock height and caliper.

[3] Survival of medium- and small-sized seedlings was reduced by flooding in 1969.

height for each of the 5 years following planting; most seedlings that were tall at the time of planting were taller by about the same amount after five growing seasons.

Soil Area

For each of the three species on each soil area, we averaged annual height growth for all 24 plots because few significant growth differences were evident due to seedling stock size. Then we compared both total and annual height growth and found that growth of two species differed greatly on the three soils (fig. 1). Siberian peashrub is a slow-growing shrub, and we found similar growth on the three soils. But growth for both Russian olive and green ash was outstanding on the moderately fine-textured Colvin soil. After 5 years, total height of Russian olive and green ash planted on the Colvin soil averaged 12.3 and 9.6 feet, respectively. In contrast, Russian olive and green ash grew very slowly on the coarse-textured Renshaw soil, and after 5 years total height averaged only 3.3 and 2.7 feet, respectively. Green ash was 22 percent taller on the medium-textured, shallow Buse soil than on the coarse-textured Renshaw soil. Russian olive, however, was only slightly taller on the Buse than on the Renshaw soil after 5 years.

CONCLUSIONS

For the first 5 years after planting, we found similar growth for large-, medium-, and small-sized seedlings. Hence, we conclude that seedling stock size was not closely related to growth of trees planted in our three shelterbelt areas. These results contrast with other studies that show stock size is related to growth of shelterbelt trees (George and Frank 1973). There are two possible reasons for this difference. First, our seedlings were carefully cultivated for the first 3 years after planting, thus early competition from grasses and weeds was controlled. Possibly, stock size would be more closely related to growth and survival where grass and weeds overtop and compete with small-sized seedlings. Second, none of our seedlings had a stem caliper less than 0.10 inch; close to the minimum caliper recommended for hardwoods (Limstrom 1963, Stoeckeler 1937, Stoeckeler and Jones 1957, Williams and Hanks In press). Poorer growth might have been observed if we had also included a very small seedling size class.

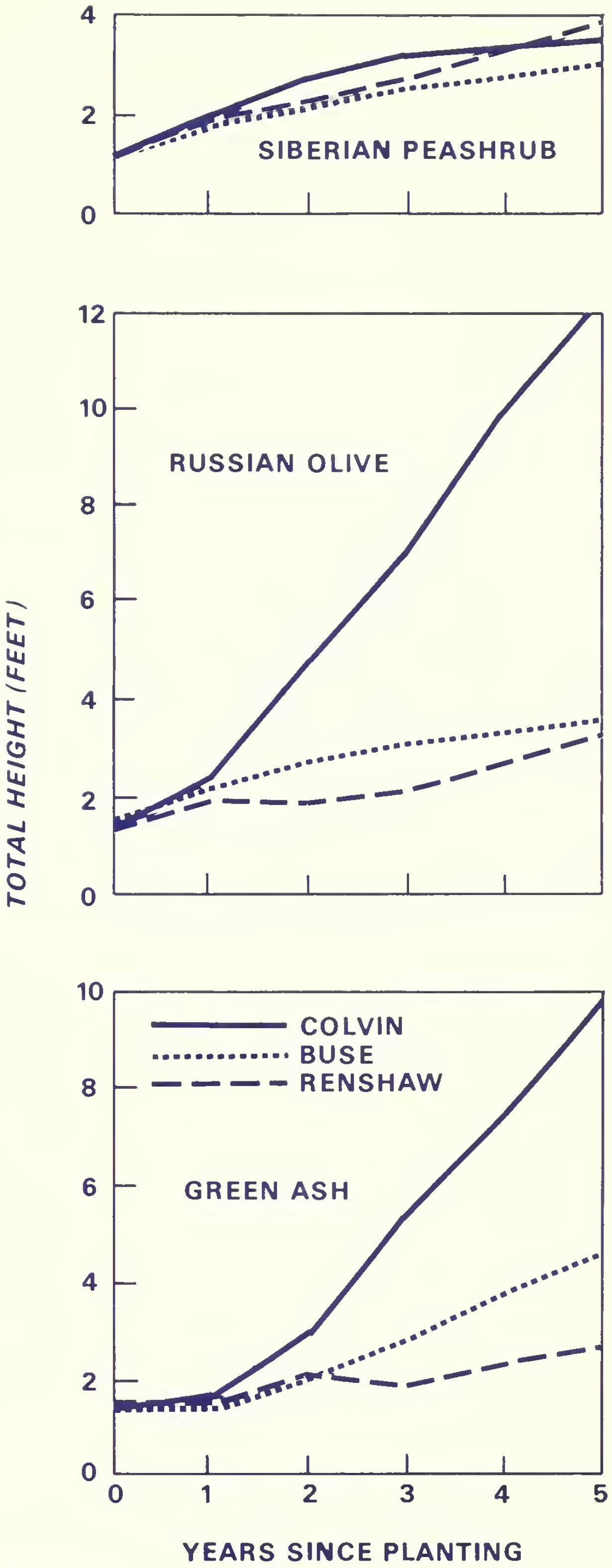

Figure 1.--*Average height growth for Siberian peashrub, Russian olive, and green ash planted on three contrasting soils of western Minnesota.*

Even though we did not observe any growth differences related to stock size, we conclude that large-sized seedlings are still preferable for shelterbelt planting. Large seedlings are easier to see, and thus are less likely to be uprooted or buried during cultivation. Also the greater initial height of large seedlings help them outgrow grass and weed competition sooner so less cultivation would be required for seedlings that are large at the time of planting.

The major finding of our study is that growth differs greatly on soils contrasting greatly in texture and drainage. Outstanding growth occurred on Colvin--an imperfectly drained silty clay loam soil. Poor growth occurred on Renshaw--a droughty, excessively drained sandy loam soil. Tree growth was only a little better on the Buse loam than on the Renshaw sandy loam even though the Buse loam is somewhat finer in texture than the Renshaw soil. However, the Buse soil is located on a fairly steep knob, and soil is shallow because of past erosion.

We can conclude from this study that trees planted in shelterbelts, as well as agricultural crops, have markedly different growth depending upon the kind of soil where they are planted. Hardwoods planted in deep, imperfectly drained, fine-textured soils of western Minnesota, will grow well. Those planted in shallow, coarse-textured soils, however, will grow slowly. Western Minnesota has a great variety of soils in addition to those of this study. Additional site studies are needed so that we can predict how well various shelterbelt tree species will grow when planted on different soils.

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USDA FOREST SERVICE

RESEARCH NOTE NC-205

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101
1976

SNOWMELT RUNOFF FROM PLANTED CONIFERS IN SOUTHWESTERN WISCONSIN

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and
David N. Tolsted, *Associate Forest Research Technician*
Forest Watershed Laboratory
La Crosse, Wisconsin

ABSTRACT.--Snowmelt overland flow was measured for one season from 10-year-old plantations of red pine, Norway spruce, European larch, and from old field control plots, on both north and south slopes. Pine and spruce plots produced more runoff than larch and old field plots; and south slope plots produced more runoff than north slope plots.

OXFORD: 116.2:116.21:174.7(775).
KEY WORDS: soil frost; infiltration.

Snowmelt runoff from frozen ground is the primary cause of spring floods in southwestern Wisconsin's unglaciated region. Natural deciduous forests rarely contribute, probably because of discontinuous or more permeable frost in the forest.[1] However, because coniferous forests insulate the ground better than deciduous forests, they may retain frost in the spring longer than open land, and thus produce more runoff from melting snow than open land.[2] [3] If this is true, extensive planting of conifers could worsen floods in the region. This note reports on a study conducted to determine if planted conifer stands produce more snowmelt runoff than natural deciduous forests.

METHODS

The study was conducted on the Coulee Experimental Forest near La Crosse, Wisconsin on plantations established specifically for the purpose. Three species were studied: red pine (*Pinus resinosa* Ait.), Norway spruce (*Picea abies* L. Karst.), and European larch (*Larix decidua* Mill.). The trees were planted in 1964 and 1965 at a spacing of 2 by 2 m on 0.2 h plots. The three species were planted in four blocks, two each on opposite north- and south-facing slopes of 15 to 20 percent. Each block consisted of a 500-tree plot of each species and an unplanted control plot of the same size. The study area had been an alfalfa meadow or old field. The trees were hand-planted in scalps to avoid the influence of planting furrows on overland flow. The soil is an eroded loessal silt loam of the Fayette series (valley phase).

Overland flow from 4-by 8-m runoff subplots made of redwood borders and catchment troughs was monitored during snowmelt in 1975. The runoff water was piped to collecting tanks. One runoff subplot was centered in each planted and control plot (16 in all). Water caught in the troughs and tanks was kept from freezing by electric heat tapes. The tanks were measured and then emptied six times during the snowmelt period.

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[1] *Richard S. Sartz, Willie R. Curtis, and David N. Tolsted. Hydrology of small watersheds in Wisconsin's Driftless Area. (Manuscript in process for publication.)*

[2] *Alfred Ray Harris. Infiltration rate as affected by soil freezing under three cover types. Soil Sci. Soc. Am. Proc. 36:489-492. 1972.*

[3] *Richard S. Sartz. Influence of land use on time of soil freezing and thawing in the Northeast. J. For. 55:716-718. 1957.*

Snow and frost depth were measured at three points 5 m apart on each plot at the beginning of the runoff period. Measuring points on planted plots were midway between rows of trees. Frost depth was measured by modified Gondahl frost depth gages.[4]

By 1975, the 10th year after planting, the pine and spruce were 3 to 4 m tall, and the larch were about 5 m tall. The larch canopy was closed, and the pine and spruce canopies were almost closed. The soil was almost completely covered with needles, mosses, and dead herbaceous growth on all plots, but the heaviest cover was formed by matted grass on the unplanted control plots.

RESULTS AND DISCUSSION

At the beginning of the 1975 snowmelt period the average depth of the snowpack was 30 cm on south slope plots and 50 cm on north slope plots. Corresponding water equivalents were about 9 and 15 cm, based on snow density data from elsewhere on the experimental forest. The snowpack started melting about the middle of March. Most south slope plots were bare by April 7, but north slope plots still had a continuous snow cover--up to 40 cm deep in spots. The last snowmelt runoff was measured on April 16, at which time small patches of snow still remained on north-facing plots. Snow depth and rate of melt on individual plots varied with aspect, which ranged from 31° E to 43° W on south aspects, and from 52° E to 37° W on north aspects.

Pine and spruce plots produced much more runoff than larch and unplanted plots, and south slope plots produced more than north slope plots. Total snowmelt runoff from March 18 to April 16 was as follows:

	South-slope plot	*North-slope plot*
	(In cm)	
Pine	2.9[5]	2.8
Spruce	4.0	2.4
Larch	1.2	0.1
Unplanted	1.3	0.3

Although the amount of runoff varied widely between replicates, runoff from the pine and spruce and the larch and unplanted were different (table 1). Expressed as a percent of the water content of the snowpack, runoff from south slope plots ranged from 14 to 42 percent, and from north slope plots, from 0.5 to 20 percent. Even with much more snow on the ground, north slope plots produced less runoff.

Table 1.--*Snowmelt runoff on individual plots, March 18 to April 16, 1975*
(In centimeters)

Plot	Pine	Spruce	Larch	Unplanted
		SOUTH		
1	[1] 3.46	[1] 3.42	1.32	1.02
2	2.24	[1] 4.62	1.18	1.60
Mean	[1] 2.85	[1] 4.02	1.25	1.31
		NORTH		
1	2.12	0.39	0.06	0.23
2	[1] 3.48	[1] 4.40	.08	.38
Mean	[1] 2.80	[1] 2.40	.07	.30

[1] Estimated. Runoff tanks overflowed.

Most of the runoff from both slopes occurred during the period from March 18 to 24. However, the proportion measured on the first and last days of record was different on the two slopes (table 2).

Table 2.--*Early and late runoff from pine and spruce plots*[1]
(In percent of total)

Date	South slope		North slope	
measured	Pine	Spruce	Pine	Spruce
March 18	20	26	9	5
April 16	10	3	27	17

[1] Means of two plots.

Frost incidence and depth as measured did not fully explain runoff differences. Frost was found at all three points only on one pine and one open plot; and none of the three sampling points was frozen on four of the eight spruce or pine plots. However, the measured frost values (taken at points midway between trees) probably did not reflect actual frost conditions under the canopies of the pines and spruces. Uneven distribution of snow caused by irregular shading and by interception and subsequent canopy dumping could have caused runoff differences between the pine and spruce plots, and the larch and open plots. Accumulation of ice on the soil surface from canopy drip could also explain the differences.[2]

The results of this study support Harris' conclusion that planting pine and spruce can increase snowmelt runoff in the unglaciated area. They also show that where flood prevention is an important consideration in tree planting programs, larch should be favored over pine or spruce.

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[4] *Alfred Ray Harris. Direct reading frost gage is reliable, inexpensive. USDA For. Serv. Res. Note NC-89, 2 p. North Cent. For. Exp. Stn., St. Paul, Minn. 1970.*

[5] *Values are means of two plots.*

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USDA FOREST SERVICE

RESEARCH NOTE NC-206

ORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108

THE EFFECT OF FOUR HERBICIDES ON THE SURVIVAL AND GROWTH OF NINE HARDWOOD SPECIES

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ABSTRACT.--To learn more about the tolerance of hardwoods to herbicides, the survival and growth of nine hardwood species were compared in plots either cultivated or treated with various herbicides applied at different rates, on prepared and unprepared ground, and before and after planting. Black walnut and white oak were very tolerant to all herbicides tested but American sycamore and European alder were highly susceptible to herbicide damage by all chemicals tested except dichlobenil.

OXFORD: 414.4:176.1. KEY WORDS: simazine, atrazine, amitrole, dichlobenil.

Many hardwood plantations fail in their early years because of heavy weed competition. Weeds can be controlled by cultivation, but the need for frequent cultivation and topographic limitations have restricted the use of mechanical control. The development of herbicides has made it feasible to control weeds in forest plantings at relatively low cost; chemical control is also less restricted by topography. However, herbicides may not be used in tree plantations unless such use is specified on the container label and is not limited by a State or federal regulation.[1]

Information about the tolerance or susceptibility of various newly planted hardwood species to herbicides has been limited. To control weeds in mixed-species plantations we must know if the same chemicals and rates can be used safely for all species in the mixture. A recent study shows great differences in first-year survival and growth among nine hardwood species treated with four weed control chemicals at different rates.

METHODS

The study was established on the Shawnee National Forest in southern Illinois. The soil is Haymond silt loam, a well drained soil of the floodplain. It is slightly acid to neutral, moderately permeable, and has moderately high natural fertility.

Stratified black walnut (*Juglans nigra* L.) seed and 1-year-old seedlings of nine

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[1] *This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.*

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

hardwood species, including walnut, were used in the study. The other species were white ash (*Fraxinus americana* L.), white oak (*Quercus alba* L.), sweetgum (*Liquidambar styraciflua* L.), black locust (*Robinia pseudoacacia* L.), American sycamore (*Platanus occidentalis* L.), river birch (*Betula nigra* L.), yellow-poplar (*Liriodendron tulipifera* L.), and European alder (*Alnus glutinosa* L.).

Four weed-control chemicals were tried alone or in combination--(1) dichlobenil alone, (2) atrazine-simazine (1:1), and (3) amitrole-simazine (1:3)--and at three different rates (table 1). Dichlobenil was applied before planting only; the atrazine-simazine and amitrole-simazine mixtures were applied before and after planting. Site preparation and tree planting were done in April.

Table 1.--*Weed control treatment*

Treatment	Rate (lbs/A)[1]	Weed cover June	Weed cover September	Weed height September
		Percent	*Percent*	*Feet*
Cultivation (control)	-	55	4	-
Dichlobenil (b)[3]	4	11	98	4
Dichlobenil (b)	6	10	92	3
Dichlobenil (b)	8	1	82	3
Atrazine-simazine (bp)[4]	1 + 1	12	100	3
Atrszine-simazine (bp)	2 + 2	10	84	2
Atrazine-simazine (bp)	3 + 3	6	70	2
Atrazine-simazine (ap)[5]	1 + 1	10	92	4
Atrazine-simazine (ap)	2 + 2	6	78	2
Atrazine-simazine (ap)	3 + 3	12	51[2]	2[2]
Amitrole-simazine (bn)[6]	0.5 + 1.5	25	89	3
Amitrole-simazine (bn)	1 + 3	16	84	3
Amitrole-simazine (bn)	1.5 + 4.5	15	84	2
Amitrole-simazine (an)	0.5 + 1.5	25	98	3
Amitrole-simazine (an)	1 + 3	20	88	2
Amitrole-simazine (an)	1.5 + 4.5	16	95	2

[1] Active ingredients (pounds per acre).

[2] Average of three plots. One contained 100 percent Johnsongrass 10 feet tall.

[3] b = before planting.

[4] p = plowed.

[5] a = after planting.

[6] n = not plowed.

The study area was an unimproved pasture that contained the native grasses plus scattered trumpet-creeper (*Campsis radicans* L.). Plots treated with dichlobenil and atrazine-simazine were prepared by plowing with a rotary tiller before the herbicides were applied. Plots treated with amitrole-simazine were not plowed before chemical treatment. The dichlobenil granules were broadcast, then lightly incorporated into the prepared soil. The wettable powder formulations of atrazine and simazine and the soluble powder formulation of amitrole were mixed with water and broadcast-sprayed on the surface. When herbicides were applied after planting, no effort was made to keep the spray off the dormant seedlings.

The 16 weed-control treatments were randomized in a complete block design that contained 4 blocks. Each treatment plot contained 10 rows of 10 trees or seed spots (one nut per spot) per row. A seedling of each species and a walnut seed were randomly assigned within each row. Thus, 40 seeds and 40 trees of each species were planted in each of the 16 weed-control treatments.

Spacing was 2 feet between and within rows.

Roots of all seedlings were pruned to 8 inches. Although seedling size varied among species, variation within a species was small. White oak and European alder, with top heights of 0.5 and 0.6 foot, respectively, were shortest. The tallest were river birch (1.5 feet) and American sycamore (1.4 feet). The other species' average heights ranged from 0.8 foot to 1.0 foot.

RESULTS

The only treatment that completely controlled the weeds and grasses was cultivation. Herbicides controlled the competing vegetation in early summer, but their effectiveness had diminished by late September (table 1). Predominant among the late germinating competition found on the plots in the fall were giant foxtail (*Setaria faberia* Herrm.) and fall panicum (*Panicum dichotomiflorum* Michx.). All other major weeds observed were the perennials: gray goldenrod (*Solidago nemoralis* Ait.), trumpet-creeper, horsenettle (*Solanum carolinense* L.), and yellow nutgrass (*Cyperus esculentis* L.). Johnsongrass (*Sorghum halepense* L.) had invaded on a small portion of the area.

The effects of the various herbicide treatments on the survival and growth of individual species are discussed below.

Black walnut seedlings.--Neither survival nor growth was adversely affected by any of the weed control chemicals (table 2). This supports the findings of Erdmann (1967) who found that black walnut seedlings were not damaged by either simazine or atrazine. He did, however, caution that atrazine should not be applied on sandy soils because it is leached more rapidly and to greater depths than simazine. In a greenhouse study, Wichman and Byrnes (1971) showed that black walnut can tolerate as much as 1.00 ppm of simazine and is more tolerant of simazine than of atrazine or diuron. In a field

Table 2.--*Mean survival percents and 1-year height growth, by treatments and species*

Species	Cultivated	Plowed									Unplowed					
		Dichlobenil lbs/A			Atrazine plus simazine						Amitrole plus simazine					
					Before planting lbs/A			After planting lbs/A			Before planting lbs/A			After planting lbs/A		
		4	6	8	1+1	2+2	3+3	1+1	2+2	3+3	0.5+1.5	1+3	1.5+4.5	0.5+1.5	1+3	1.5+4.
SURVIVAL (PERCENT)																
Black walnut seedlings	100	95	100	92	95	100	98	100	100	100	100	100	100	100	98	100
Black walnut seed	62	48	48	42	60	68	50	62	55	40	35	48	50	45	68	45
River birch	100	90	88	58	82	62	48	92	[illegible]	42	100	92	82	100	100	88
Yellow-poplar	92	88	90	62	98	88	72	100	95	68	98	98	92	98	90	80
White oak	85	82	88	70	100	98	92	92	95	98	98	98	100	98	92	95
Sweetgum	100	100	92	98	98	88	92	100	100	95	98	95	98	100	98	95
American sycamore	100	95	82	88	[illegible]	[illegible]	10	[illegible]	12	10	75	45	28	75	12	15
European alder	88	90	82	88	[illegible]	18	15	8	2	0	75	50	25	65	30	18
Black locust	90	95	95	90	82	28	22	90	52	18	100	82	68	95	88	72
White ash	93	83	77	87	83	73	40	97	53	33	93	93	77	100	97	73
HEIGHT GROWTH (FEET)																
Black walnut seedlings	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.4
Black walnut seed	1.2	0.9	0.9	0.9	1.0	1.1	1.0	[illegible]	1.0	1.0	0.8	1.0	1.1	1.1	1.0	1.1
River birch	3.3	1.8	1.7	2.2	[illegible]	1.8	1.5	[illegible]	2.2	[illegible]	2.4	2.2	2.2	2.4	2.1	2.5
Yellow-poplar	1.7	0.5	0.3	[illegible]	0.9	0.9	0.5	0.9	0.8	[illegible]	0.6	1.0	0.9	0.8	0.6	1.0
White oak	0.4	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.2	0.3	0.2	0.3
Sweetgum	1.5	0.8	0.8	0.8	1.2	1.0	1.0	1.4	1.2	0.6	1.1	1.2	0.8	1.0	0.6	1.1
American sycamore	3.7	1.6	1.5	1.8	1.3	0.7	0.2	1.0	0.5	0.3	1.1	1.0	1.2	1.2	0.4	1.0
European alder	2.8	2.0	1.2	1.7	1.5	1.0	0.3	1.6	0.4	--	2.3	1.8	1.6	2.3	1.3	2.3
Black locust	7.2	4.4	3.9	3.6	4.1	4.3	1.9	4.8	3.8	1.7	4.4	4.3	4.2	4.7	4.2	3.4
White ash	2.1	0.8	0.4	0.8	0.6	[illegible]	0.3	0.7	[illegible]	0.3	1.0	0.8	0.7	1.1	0.6	0.3

study, Roth (1971) observed slight damage to walnut seedlings from an 8 pounds-per-acre rate of simazine, while an 8 pounds-per-acre rate of atrazine caused severe damage. Black walnut seedlings normally grow little the first growing season after planting, so the poor height growth was not attributed to the weed control treatments.

Black walnut seeds.--Seed germination was poor but survival differences among treatments were not great (table 2). In a more recent study we found damage and mortality to germinating walnut seed when an atrazine-simazine mixture (2+2 pounds) was used.

River birch.--River birch was damaged by herbicide mixtures containing 2 pounds or more of atrazine (table 2). However, river birch seems tolerant of simazine, especially at low rates. Survival of seedlings treated with atrazine-simazine ranged from 92 to 42 percent, but when amitrole was the other chemical mixed with simazine, survival ranged from 100 to 82 percent. Cultivated trees were twice as tall as those treated with the highest rates of atrazine-simazine.

Yellow-poplar.--Survival of yellow-poplar decreased as the rate of herbicide was increased, regardless of the chemical used (table 2). However, survival was 80 percent or more except when the highest rates of atrazine-simazine were used; simazine was also a part of the amitrole-simazine mixture, so it appears that atrazine is responsible for poor survival. Height growth of the cultivated trees was about double that of trees in herbicide-treated plots. These results for simazine and atrazine support the findings of Erdmann (1967). However, in their greenhouse study, Wichman and Byrnes (1971) found that yellow-poplar was very susceptible to damage by atrazine and only moderately tolerant of simazine.

White oak.--White oak appears to be tolerant of the chemicals at the rates used (table 2). Survival tended to be poorer when dichlobenil was used. Height growth, characteristically poor the first growing season, was poor for all treatments.

Sweetgum.--Sweetgum was tolerant of all chemicals, rates of application, and methods of application used. There were, however, small differences in height growth among the treatments.

Sycamore.--Survival of cultivated sycamore was 100 percent but 75 percent or less for all chemical treatments except dichlobenil (table 2). The extremely high mortality resulting from the chemical treatments other than dichlobenil shows the need for great caution when herbicides are tried. Height growth of cultivated sycamore was more than twice that of sycamore in any herbicide treatment.

European alder.--The survival of European alder was similar to that of sycamore: poor for all herbicides except dichlobenil (table 2). Survival of European alder was decreased more by atrazine-simazine applied after planting than to the same chemicals applied before planting. Height growth of cultivated trees was best, but growth of some herbicide-treated trees was almost as good.

Black locust.--Survival of black locust was poor, 22 and 18 percent, when the atrazine-simazine mixture was applied at the highest rates (table 2). Survival was 90 percent or more in the dichlobenil plots. In plots treated with the amitrole-simazine mixture, survival was 82 percent or more for all but the highest rates. So, again, the more easily leached atrazine seems responsible for excessive mortality. Height growth for all treatments, except the two highest rates of atrazine-simazine, was good, but growth in the cultivated plots was far superior.

White ash.--Survival of white ash treated with dichlobenil was not correlated with rate. Survival was poor in plots treated with the 2+2 and 3+3 rates of the atrazine-simazine mixture and best for the two lower rates of amitrole-simazine (table 2). As noticed for other species, atrazine appears to be the harmful chemical. Although only 2.1 feet, height growth for the cultivation treatment was about double that for the best herbicide treatment and as much as seven times that of the poorest.

DISCUSSION AND CONCLUSIONS

The lowest of the three herbicide rates used for each herbicide treatment was too low for adequate weed control. The highest of the three rates normally would be excessive. Under certain conditions, such as high temperature and dry soil, dichlobenil may volatilize, limiting effective weed control to about 2 months, thus allowing weed invasion for much of the growing season.

Many plant species are susceptible to chemical damage when very young, but are usually more tolerant of the same chemicals during the second or third growing seasons. Therefore, some of the species damaged by the herbicide treatments used in this study may show greater tolerance if the herbicide is applied after the first growing season. However, if herbicides are not used until the second year, weeds should be controlled by cultivation the first year.

Some species are much more susceptible to herbicide damage than others. Neither black walnut nor sweetgum survival was affected by any of the herbicide treatments and only the highest rate of dichlobenil killed white oak. Survival of sycamore and European alder was decreased substantially by all herbicide treatments except dichlobenil. Survival of black locust, white ash, and river birch was poorest when mixtures containing atrazine were used.

Cultivation produced better height growth for most species than any of the herbicide treatments. Neither the growth of black walnut nor white oak was affected, but first-year growth of these two species is characteristically poor. Cultivated yellow-poplar, sycamore, black locust, and white ash grew much better than their chemically treated counterparts. Mixtures containing atrazine were especially detrimental to growth of river birch, sycamore, and European alder; sweetgum seems sensitive to dichlobenil.

With the exception of the poor survival of European alder when the atrazine-simazine mixture was applied after planting, it made no difference whether herbicides were applied before or after planting. Erdmann (1967), although testing other species, stated that atrazine should be applied before planting to prevent injury.

Each species was tolerant of at least one of the herbicides tested. Cultivated trees grew faster than herbicide-treated trees the first growing season, but cultivation is expensive. These results indicate, however, that for maximum growth some species should be cultivated the first year, then compatible herbicides used the second and third years.

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Research Note NC-207

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108

1976

SEWAGE EFFLUENT SPRAY INCREASES DIAMETER GROWTH OF JACK PINE

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ABSTRACT.--Sewage effluent applied to jack pine in southwestern Wisconsin significantly increased diameter growth during the second year.

OXFORD: 237.41:561.21:U628.38:174.7 *Pinus banksiana*. KEY WORDS: irrigated, sprinklers, dominant, increase, growth.

Sewage effluent was applied to forest land to determine how such irrigation might affect the growth of jack pine (*Pinus banksiana*, Lamb.). This note reports the results.

METHODS

The study site was located at the Fort (formerly Camp) McCoy military reservation in southwestern Wisconsin. The trees treated were part of a 45-year-old jack pine forest of medium stocking growing on the fast-draining Sparta sand. Until the early 1930's this land had been farmed.

Two plots of about 0.44 acres were established. One was irrigated and the other was not. The irrigated plot was divided in half, one half receiving 2 inches of effluent per week and one half receiving 4 inches per week. Effluent was applied throughout the year (intermittent during winter months) with 36 impact sprinklers situated to give equal distribution over the plots.

Only dominant and codominant trees were measured--14 on the 2-inch plot, 15 on the 4-inch plot, and 27 on the nonirrigated control plot. The trees were measured at the beginning and end of the 1974 growing season and at the end of the 1975 growing season. The data were tested for statistical significance by analysis of variance.

Average diameters, taken at the beginning of the study, were 9.6 inches for the control plot, 9.2 inches for the 2-inch application plot, and 8.7 inches for the 4-inch application plot.

Growing season rainfall was about the same for the 2 years (19.13 inches in 1974 and 20.06 inches in 1975). Normal rainfall for this period is 20.35 inches.

RESULTS

Diameter growth was not significantly affected by either application of effluent the first year. However, in the second year (1975) diameter growth was significantly greater (1 percent level) on both irrigated plots than on the control plot (fig. 1). Tree diameter did not influence growth response. The marked increase in growth the second year of irrigation suggests that waste water disposal on jack pine areas may produce a worthwhile benefit in increased wood production.

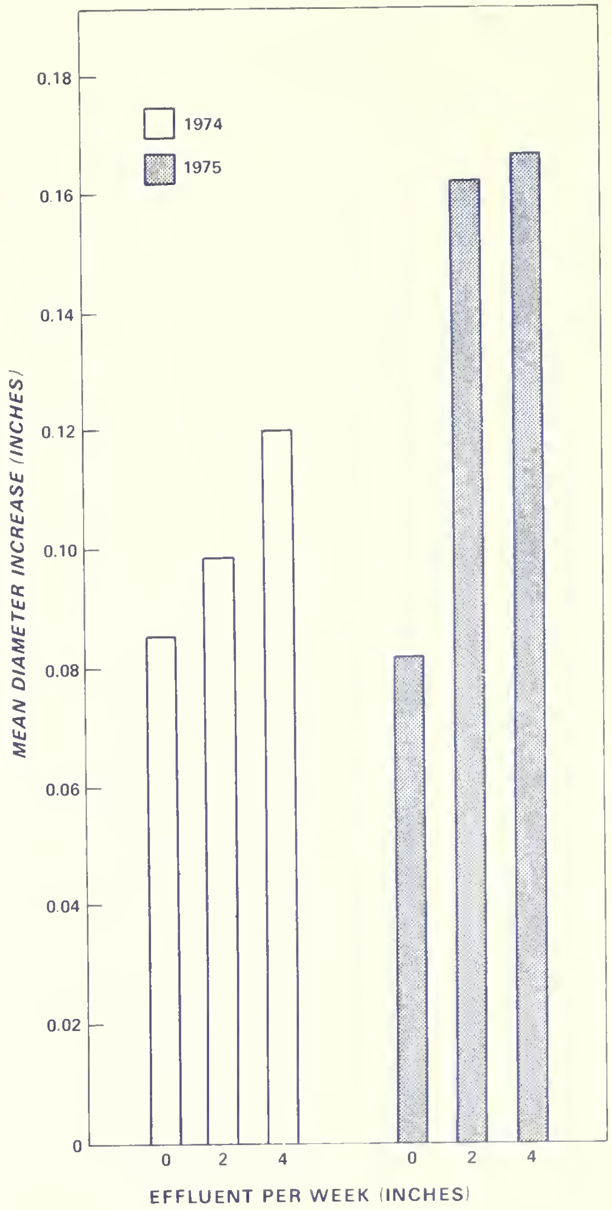

Figure 1.--*Effect of effluent on tree growth.*

U.S. Government Printing Office: 1976--669-553/156 Region No

USDA FOREST SERVICE

Research Note NC-208

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108

1976

AN EASY-TO-MAKE SHELTER FOR THE TRIPLE BEAM BALANCE USED AT FIRE WEATHER STATIONS

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and
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ABSTRACT.--Describes how to build a housing for the balance used to weigh fuel moisture sticks. The housing is easy to build, low-cost, and can be mounted on the supports of the standard cotton region shelter.

OXFORD: 431.2--015.7. KEY WORDS: fire-danger-rating, fuel moisture sticks.

The National Fire Danger Rating System requires fuel and weather measurements to determine forest fire potential.[1] One of these measurements is the weight of fuel moisture sticks usually made with the aid of a triple beam balance. Unfortunately the balance is often housed in the cotton region instrument shelter or kept in the observer's office in lieu of constructing the somewhat elaborate, recommended balance-shelter. These practices can lead to serious measurement errors.

To reduce the chance for error, we have devised an inexpensive (about $15) housing for the balance that is easy to build and can be mounted on the supports of the cotton region instrument shelter (fig. 1). This design eliminates an additional installation and removes one possible shade source for the fuel moisture sticks. This balance housing can be made from 5/8-inch exterior plywood or 3/4-inch lumber. It has a plexiglas window across the front to facilitate readings on windy days (fig. 1).

The shelter is 36 inches long, 8 inches wide, and 10 inches high (fig. 2). Construct as follows:

1. Cut all wood parts.
2. Paint parts with an oil base primer.
3. Seal the predrilled plexiglas window on the inside with caulking compound and then screw it in place with #6 by 1/2-inch round head wood screws.
4. Glue and nail the box together with galvanized six penny box nails.
5. Finish with white exterior enamel house paint.
6. Attach brass hinges and hasp.
7. Bolt to instrument shelter supports in level position, facing south 4 inches below floor of instrument shelter (fig. 1).

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[1] *J. E. Deeming, J. W. Lancaster, M. A. Fosberg, R. W. Furman, and M. J. Schroeder. 1972. The National Fire Danger Rating System. USDA For. Serv. Res. Pap. RM-84, 165 p. Rocky Mt. For. & Range Exp. Stn., Fort Collins, Colorado.*

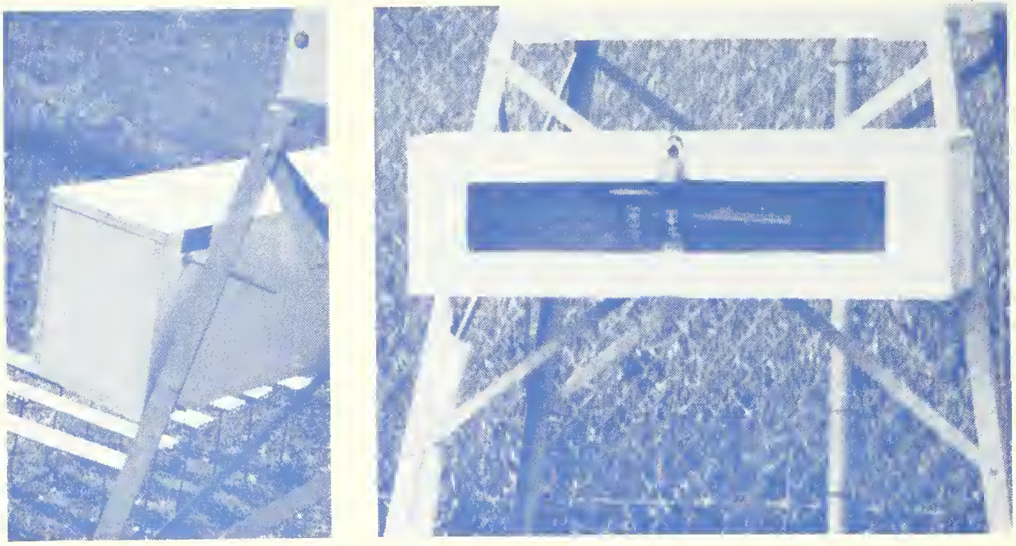

Figure 1.--*Mounting arrangement for balance shelter (left) and front view of balance shelter (right).*

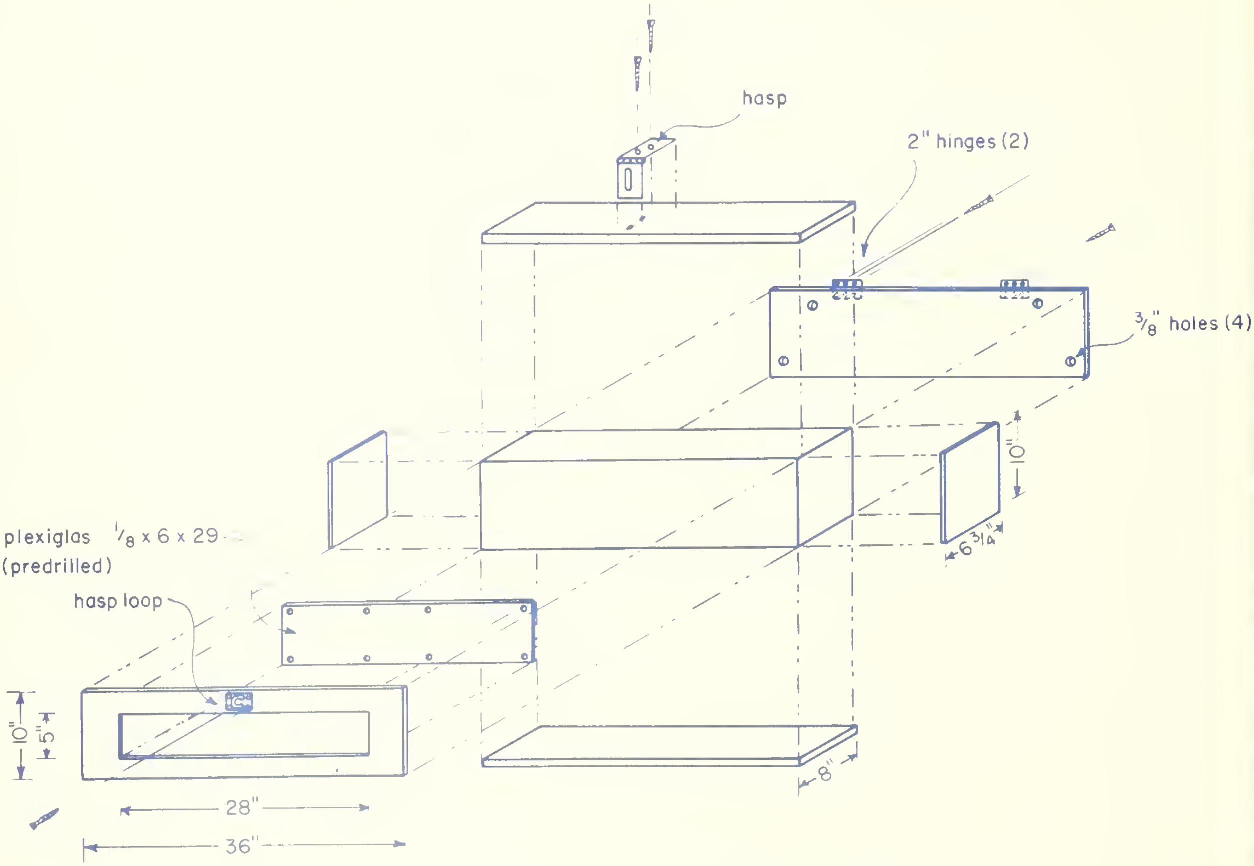

Figure 2.--*Diagram of shelter construction.*

U.S. Government Printing Office: 1976—669-586/158 Region No

Research Note NC-209

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108

1976

A BIRD AND BEE PROBLEM IN HOUSE SIDING

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3STRACT.--Plywood house siding made to imulate reverse board-and-batten design is ometimes attacked by woodpeckers because eaf-cutting bees, their prey, make nests 1 holes in the plywood core. The problem an be prevented by plugging the holes efore nesting occurs. If nesting does occur, 1e nest should be destroyed and then the oles plugged.

FORD: 845.4:845.58. KEY WORDS: wood-eckers, plywood siding, leaf-cutting bees, e nests.

Homeowners in wooded areas of southern chigan have been experiencing damage to 1e rustic plywood wood siding on their houses. oodpeckers had excavated at various places 1 their houses in search of prey, a egachilid bee, *Megachile relativa* Cresson,[1] 1at had taken up residence inside the siding ig. 1).

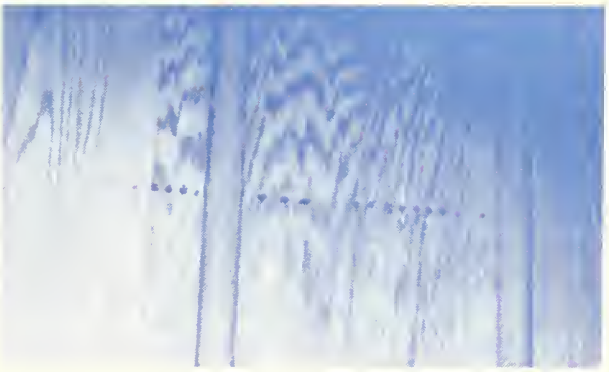

Figure 1.--*Holes in plywood siding caused by woodpeckers seeking megachilid bee larvae.*

All houses attacked were sided with dar or redwood exterior plywood constructed to simulate a reverse board-and-batten design. The design resembles 8 to 10 inch vertical rough-sawn boards, separated by spaces backed behind with batten boards. These spaces are actually grooves cut about half-way through the plywood, which may be 3/8 to 3/4 inch thick, depending upon the siding.

The woodpecker-bee problem arises because of factory plywood construction

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[1] *Specimens identified by R. L. Fischer, partment of Entomology Michigan State iversity, East Lansing, Michigan 48824.*

procedures used in making the reverse board-and-batten design. The core veneer, or inner layers, used for plywood construction are assembled from lower quality veneer pieces of various widths. During assembly of the plywood sheets, gaps or small voids inevitably occur from place to place between the core layers. The face and back veneer ordinarily cover these voids, but they are sometimes visible on the edges. The voids do not affect the strength or appearance of the plywood. However, when the grooves are cut for the reverse board-and-batten effect, the voids are exposed. Megachilid bees seek out such small cavities to build their nests and enlarge them, if necessary, for cell contruction. These cells, provided for the young bees, are lined and separated by circular pieces of leaf tissue. Six or more containing one larva each may be constructed in the cavity depending on its length. Thus, a nest may be 5 or 6 inches long.

Woodpeckers locate these nests and peck holes in the plywood to remove the larvae. The holes, up to 1/2 inch in diameter and 5 or 6 in a row at each attack, are jagged and contrast readily against the dark-stained wood.

This problem is probably rather common. Reverse board-and-batten plywood siding is popular and extensively used in wooded areas to provide a rustic look. *Megachile relativa* and woodpeckers both live in wooded areas and take advantage of this situation.

The problem can be prevented by sealing or plugging the exposed voids that appear in each of the grooves cut in veneer cores. This will eliminate the nesting sites. Sealing the voids at the factory could greatly increase the cost of the material, so the best method is for the on-site contractor or owner to check the plywood and plug or fill any holes present. These entrance holes must be filled before the bees build their nest. If the holes are plugged after the nest is made, the bees will chew their way out or the woodpeckers will seek out the larvae. The only recourse then is to destroy the nest with a long thin instrument, such as a stiff wire, before woodpeckers discover it. Holes already made by woodpeckers can be patched with an exterior patching compound stained to match the plywood finish. This is time consuming, however, and will show, so the preventive treatment is recommended.

USDA FOREST SERVICE

Research Note NC-210

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55108

1976

GROWTH OF RED PINE PLANTED ON A NORTHERN HARDWOOD SITE

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ABSTRACT.--A red pine conversion planting was established on a cutover northern hardwood site in 1929. Competing hardwoods were controlled on half the area by cleaning during the first 10 years after planting. After 46 growing seasons pine survival was 70 percent on the cleaned plot, and 25 percent on that not cleaned; mean annual increment was 2.37 cords (190 ft^3), and 0.91 cords (73 ft^3) per acre respectively. Merchantable volume of pine was 109 and 42 cords per acre. These data demonstrate the inability of red pine to compete with maple on medium textured soils, and illustrate the growth potential of the species if hardwood competition is controlled during plantation establishment. Results indicate that merchantable volume production on some well drained northern hardwood sites could be doubled by intensive management of red pine.

OXFORD: 562.21:815:174.7 *Pinus resinosa*.
KEY WORDS: red pine, species conversion, cleaning, hardwood competition, intensive silviculture, site quality.

In the Lake States, natural stands of red pine (*Pinus resinosa* Ait.) typically occur on dry, sandy soils (Braun 1950). The species occurs only rarely on heavier soils, probably because it cannot compete successfully with more aggressive species (USDA For. Serv. 1965). The inability of planted red pine to endure inadequate aeration encountered on poorly drained, heavy soils is well established (Stone *et al.* 1954, Dreisinger *et al.* 1956).

This paper documents the performance and competitive ability of red pine planted on a well drained northern hardwood site.

METHODS

Stand and Site

The plantation is located on the Upper Peninsula Experimental Forest near Marquette, Michigan, 10 miles (16 km) south of Lake Superior. The area was originally occupied by virgin northern hardwoods, chiefly hard maple (*Acer saccharum* Marsh.) averaging about 14,000 board feet per acre (35,000 per ha). The original forest was commercially clearcut in 1920. In 1928 the area was described as "a very open stand of sugar maple and brush."[1] There is no evidence that the area had been burned.

The soil is a Munising sandy-loam, a weakly developed spodosol (Alfic Fragiorthod) formed in well drained acid till of Valders age. Most of the roots occur in the upper 15 inches (38 cm) of soil; pH averages 4.8. A fragipan 6 to 16 inches (15 to 40 cm) thick occurs at a depth of about 18 inches (46 cm). Nutrients in the upper 10 inches (25 cm) of soil average approximately 0.12 percent total N, 35 lb/acre (40 kg/ha) P (Bray P_1 extractable), 90 lb/acre (100 kg/ha) K, 960 lb/acre (1,075 kg/ha) Ca, and 112 lb/acre (125 kg/ha) Mg (NH_4OAc extractable). This is a medium site

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[1] *Unpublished data on file at the Northern Hardwoods Laboratory, Marquette, Michigan.*

for growth of northern hardwoods: site index averages about 60 feet (18 m) at 50 years for sugar maple and 80 feet (24 m) for red pine.

Plantation Establishment

Concern over the lack of adequate hardwood regeneration following clearcutting of the old growth timber prompted a series of trials "to test the possibilities of underplanting and conversion plantings on cutover hardwood lands."[1] The objective of the underplanting and supplementary plantings was to develop fully stocked, conifer-hardwood stands. The aim of the red pine conversion planting was to develop a pure pine stand by cleaning as necessary to free the pine from competing hardwoods. Significantly, only the conversion planting with the planned cleaning treatments has shown any degree of success.

The red pine was planted in May 1929 at a spacing of about 7 by 8 feet (2.1 by 2.4 m) "on open hardwood land covered with brush, grass, weeds, and scattered young hardwoods"[1] (fig. 1). Planting stock was 2-1-2 transplants from the Higgins Lake Nursery in northern Lower Michigan. The plantation was first cleaned in August 1929. The subsequent records are fragmentary: as far as can be determined, the east half of the plantation was cleaned again the 3rd, 4th, and 6th years, and probably about the 10th year. The west half either was never cleaned, or was cleaned only the year it was planted.

At age 46 (from planting), diameter and merchantable height of all surviving pine were measured on a 0.1-acre (0.04 ha) plot in each half of the plantation (table 1).

RESULTS

First-year survival of planted seedlings was 99 percent and height growth averaged 7 inches (17.8 cm). After five growing seasons survival was 94 percent, total height ranged up to 7.2 feet (2.2 m) and averaged 4.1 feet (1.25 m). At 9 years the largest pines measured 14 feet (4.3 m) and averaged 8.8 feet (2.7 m) in height, but survival had dropped to about 80 percent.

Over the next 37 years, adjacent hardwoods, primarily sugar maple, completely

Figure 1.--*One of several experimental confier plantations established on cutover hardwood land on the Upper Peninsula Experimental Forest; September 1929.*

Table 1.--*Stand conditions and merchantable volume of red pine on a northern hardwood site, 46 years after planting (per acre)*

	Cleaned	Not cleaned
NUMBER OF TREES		
Red pine	540	190
Hardwoods	100	290
Total	640	480
MEAN DBH (INCHES)		
Red pine	10.0	10.4
Hardwoods	5.8	6.2
BASAL AREA (FT^2)		
Red pine	305	115
Hardwoods	20	83
Total	325	198
MERCHANTABLE VOLUME[1]		
Rough cords[2]	109	42
Cubic feet[3]	8,720	3,360
ANNUAL YIELD		
Rough cords	2.37	0.91
Cubic feet	190	73

[1] Bruno Lindfors, Munising Ranger District, Hiawatha National Forest, determined the merchantable volume of pine.

[2] Gross volume from composite volume table 6 (Gevorkiantz and Olson 1955).

[3] Net volume calculated at 80 cubic feet per rough cord.

replaced the planted pine on the south 33 feet (10 m) of the plantation, across both the cleaned and noncleaned portions. Hardwood encroachment also was severe along the west 20 feet (6 m) of the original planting. On the east side and along most of the north side of the plantation encroachment was negligible and pine survival was good. By 1974, 38 percent of the red pine in the cleaned half of the plantation were alive, but only 13 percent on the noncleaned portion. Based on the two sample plots located in the areas of highest pine stocking, survival averaged about 70 percent in the cleaned portion, and 25 percent in that not cleaned. The larger dominant pines averaged 79 feet (24 m) at age 46.

DISCUSSION

Early survival and growth were excellent for this region, probably due to a combination of site quality, careful planting, and use of large, vigorous planting stock. The transplants used in this study were older and presumably larger than the 3-0 red pine stock commonly used today. Unfortunately, no records are available on survival and growth after the 9th year. Apparently, most of the mortality occurred fairly early in the life of the stand because height growth of the surviving pines has exceeded that of the adjacent hardwoods for many years and there is little evidence of recent mortality on the plots (fig. 2).

Despite good early survival and growth, many of the pines could not compete with the encroaching hardwoods. Survival probably would have been greater with an additional cleaning at a later age, particularly along the south side of the planting where the hardwood encroachment was most severe. Even in the interior of the plantation where survival was 70 percent, the cleaned plot contains 100 maple stems per acre (250/ha) 2.0 inches (5.0 cm) dbh and larger, and an understory of maple saplings 5 to 10 feet (1.5 to 3.0 m) in height persists. The pine probably cannot be regenerated naturally; even if the maple were eliminated by thorough site preparation, the development of grass, brush, and herbaceous competition on this site would undoubtedly preclude the establishment of red pine from seed (fig. 1).

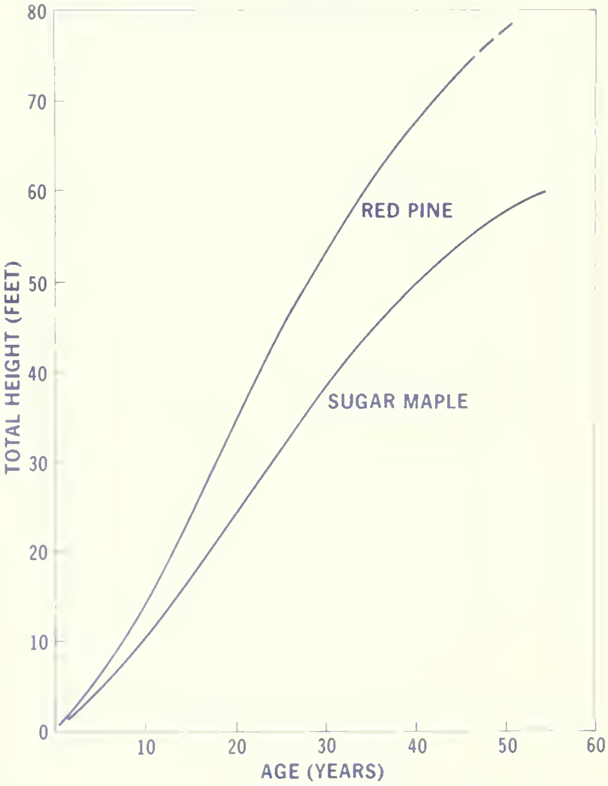

Figure 2.--*Height growth of red pine 46 years after planting on a northern hardwood site, and 54-year-old sugar maple in the adjacent stand. Both curves based on codominant trees; site index (50 years) is about 60 for maple and 80 for red pine.*

The poor survival in the noncleaned portion of the planting confirms the inability of red pine to compete with more aggressive species on medium textured soils (USDA For. Serv. 1965). Without the early cleanings, pine survival was only 13 percent over the entire area and 25 percent on the well stocked plot in the interior of the planting. Although the noncleaned plot contains more than 1½ times as many hardwoods as red pine, the pine has grown faster in both diameter and height than the hardwoods (table 1, fig. 2).

Volume growth of the red pine has been impressive, particularly on the cleaned plot. The mean annual increment of 2.37 cords per acre substantially exceeds published values for the species (Buckman 1962). In fact, growth of over 100 cords per acre in less than 50 years is high for any species in the Lake States (Horton and Bedell 1960, Wilde *et al.* 1965). The slightly lower average diameter of the pine on the cleaned plot reflects the excessively high stand density.

Mean annual growth on the cleaned plot has been 190 ft^3 per acre, more than 2½ times that on the noncleaned plot (table 1). A typical even-age northern hardwood stand nearby had a mean annual merchantable growth of 54 ft^3 per acre for 30 years after a commercial clearcut (Jacobs 1969). However, periodic annual growth from age 25 to 30 was 120 ft^3 per acre. Assuming that growth continues at this rate, at age 46 the hardwood stand will have a mean annual growth of 77 ft^3 per acre, about equal to that of the red pine on the noncleaned plot, but only about 40 percent of that on the cleaned plot.

This conversion planting has illustrated the inability of young red pine to compete with maple on a site where northern hardwoods are the climax vegetation. However, it also indicates the growth potential of red pine on an average, well drained northern hardwood site if maple competition is controlled during the first 10 years after planting.

These results indicate that the performance of red pine needs to be evaluated over a wider range of sites. In general, well stocked northern hardwood stands on medium and better sites contain many high quality stems and should be managed for high value products. However, many northern hardwood stands in the Lake States are below average in stocking, growth, and/or tree quality because of stand history, or occasionally, site quality. The species occupying a given site do not necessarily indicate the maximum yield, in volume or value, attainable on that site. Stevens and Wertz (1971) for example, estimated a potential 60 percent increase in sawtimber yield by coordinating species distribution with soil productivity in northern Wisconsin.

Although it is impossible to extrapolate from a small, nonreplicated study, these data indicate that volume production may be doubled by intensive management of red pine on some well drained northern hardwood sites. If these sites are utilized to produce high value softwood products like poles, piling, and saw logs, rather than poor quality hardwood products, the value yield will be more than doubled.

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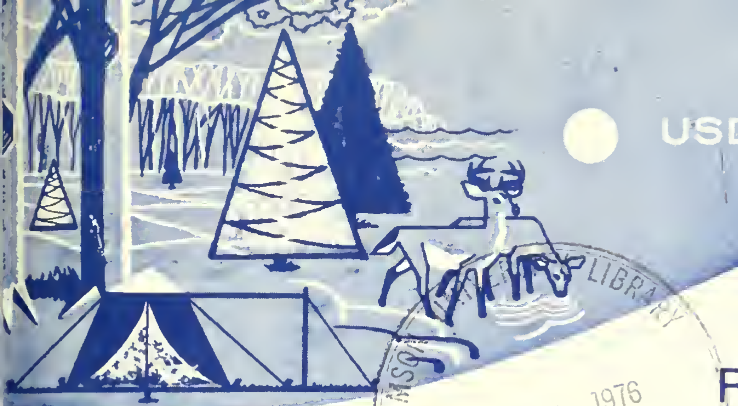

USDA FOREST SERVICE

Research Note NC-211

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE

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1976

PRELIMINARY BELT LIFE DATA FOR ABRASIVE PLANING OF PONDEROSA PINE

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ABSTRACT.--Initial observations indicate belt life may be longer and belt loading less at 0.080-inch than at 0.040-inch depth of cut with other machining variables held constant.

OXFORD: 823.1:829.13:174.7 *Pinus ponderosa*.
KEY WORDS: machining, sanding, surfacing, tool life.

Abrasive planing is widely used to avoid knife planing defects when surfacing wood. More than 1/4 inch of stock can be removed by this method, but generally depth of cut averages less than 1/16 inch for hardwoods at 30 to 40 feet per minute and much less than 1/32 inch for softwoods at 90 feet per minute. Proponents of abrasive planing claim economic advantages without sufficient unit cost data. Belt life data for specific combinations of feed rate and depth of cut need to be developed for specific belt speeds before the real cost of removing stock by abrasive planing can be determined.

We do not yet know where studies of depth of cut and feed rates for abrasive planing belt life should begin. So, a short study was undertaken to help establish the initial combinations. Preliminary data indicate that unique factors influence tool life relations for abrasive planer belts and that comprehensive belt life studies will be required to accurately estimate the unit cost for abrasive planing at specified feed rates and depths of cut within the ranges of current machinery.

METHODS

A sample of air-dry (12 percent average moisture content) nominal 2- by 4-inch ponderosa pine lumber was skip-dressed and then surfaced on both 4-inch faces to a uniform thickness so a uniform depth of cut could be maintained in the study. A resinous softwood was selected so that the belt life tests would go faster.

Three depths of cut (0.040, 0.080, and 0.120 inch) were applied to the lumber at a constant feed rate of 90 feet per minute and a nominal belt speed of 5,800 feet per minute. A new belt was used for each depth of cut, and the 4-inch-wide material was fed end-to-end until the belt failed.

RESULTS AND DISCUSSION

The 0.080-inch depth of cut resulted in the longest belt life:

Depth of cut (inches)	*Belt life* (feet)	*Total stock removal* (cubic feet)
0.040	18,689	20.8
.080	21,428	47.2
.120	7,187	24.0

Although the results are limited, the shorter belt life at the 0.040-inch depth of cut than at 0.080-inch depth of cut was suprising. Generally, belt life decreases as depth of cut or stock removal rate increases.

Two explanations are possible. First, the sample for the 0.040-inch depth of cut was at or near the lower tail of a belt life population and the sample for the 0.080-inch depth of cut was at or near the upper tail of a belt life population; and the two populations overlapped to some extent (fig. 1). Second, the belt from abrasive planing at 0.040-inch depth of cut was visibly more loaded with sanding particles than the other two belts (fig. 2). This may indicate that excessive belt loading reduces belt life for 0.040-inch depth of cut. Further, sample end points of belt life where the test results overlap could be misleading alone. Inspection of the belts is also required.

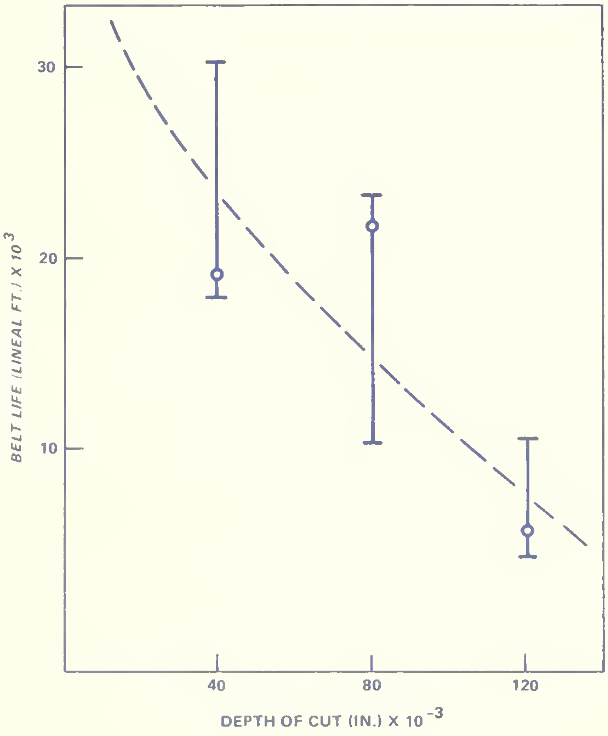

Figure 1.--*Possible relation of belt life to depth of cut if a single sample at 0.040-inch depth of cut were near the bottom of the population range and a single sample at 0.080-inch depth of cut were near the top of the population range for respective machining situations.*

The excessive loading of the belt at 0.040-inch depth of cut suggests a relation between sanding particle size and open space among the belt backing, grit, and workpiece when machining. Small particles from shallow depths of cut (approximately 0.015 inch or less) fit or are easily carried through the spaces formed by the belt backing, grit, and workpiece. At moderate depths of cut (such as 0.040 inch), the particles appear to be packed into the open spaces. At greater depths of cut (such as 0.080- and 0.120-inch) the sanding particl (chips) may be large enough to be forced ahead of the cutting tool (grit) and perhaps too large for the spaces. Thus, the large particles may create a wiping or cleaning action. Also, at the 0.120-inch depth of cut stresses and tool wear are much greater, thus reducing belt life.

High feed rates at slower belt speeds may prolong belt life. A long, thin particle could be "bunched up" to perhaps wipe or clean the belt similar to what happens with larger particles produced at depths of cut of 0.080-inch or greater. Another alternative would be to increase belt speed enough to approach a "zero" depth-of-cut condition. Actually, a wide selection of untried abrasive planing conditions may be as efficient or more efficient than present prescriptions.

Knots, because they cause instant power increases and, hence, stress increases, may have shortened belt life. The rapid stress increases would probably reduce belt life more at deeper cuts, such as at 0.080- and 0.120-inch, where the unit belt stress is higher initially. Thus, belt loading was apparently the major cause of short belt life at the 0.040-inch depth of cut.

Observations of commercial practice indicate the depth of cut for abrasive planing softwood lumber averages 0.010-inch with grit Nos. 24 and 36 at a feed rate of 90 feet per minute and belt speed at 5,800 feet per minute. Our preliminary tests indicate that abrasive planing at moderate depths of cut such as 0.040 inch may cause excessive belt loading and reduce belt life (fig. 3). The tests further indicate that heavy stock removal rates at depths of cut 0.080 or greater may reduce belt loading and prolong belt life. Thus, stock could probably be economically removed at other relative machining conditions. However, extensive tests will be required to determin the most efficient operating conditions for abrasive planing hardwoods and softwoods.

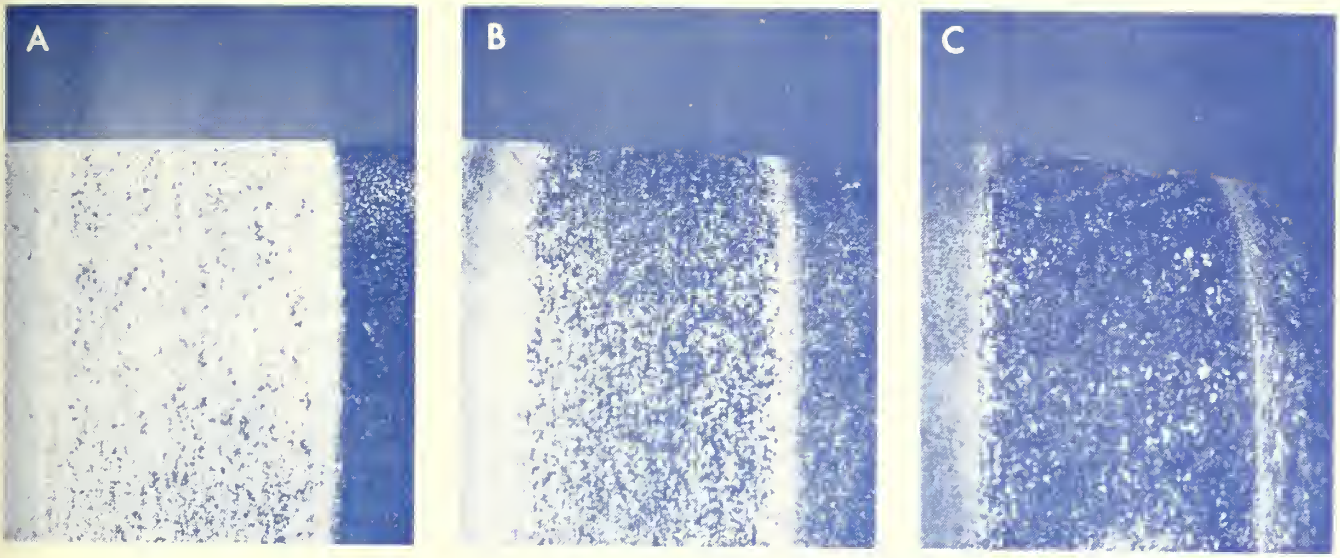

Figure 2.--*No. 36 grit belt condition after machining ponderosa pine at 90 feet per minute feed rate and 5,800 feet per minute belt speed: (A) 0.040-inch depth of cut; (B) 0.080-inch depth of cut; (C) 0.120-inch depth of cut.*

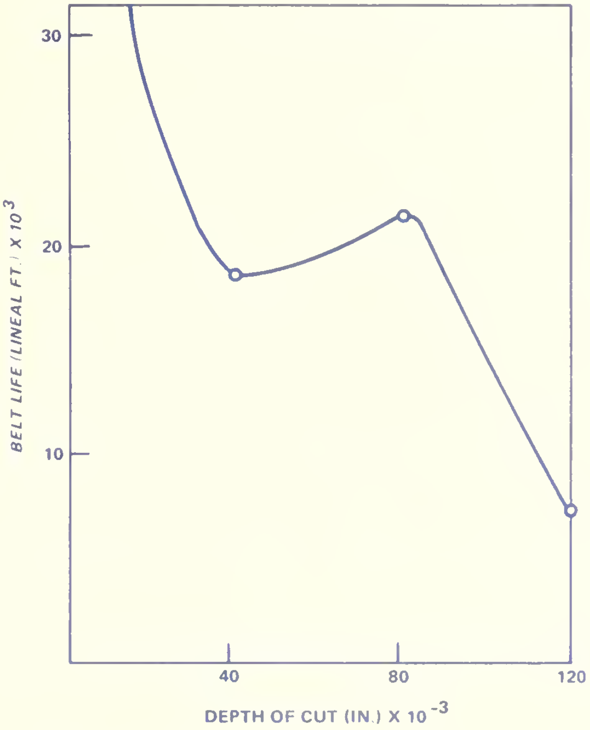

Figure 3.--*Possible relation of belt life to depth of cut if a relation between sanding dust particle size and belt loading exists.*

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USDA FOREST SERVICE

RESEARCH NOTE NC-212

1976

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

PULPWOOD PRODUCTION IN THE LAKE STATES BY COUNTY, 1975

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and Jerold T. Hahn, *Mensurationist*

ABSTRACT.--This 30th annual report shows 1975 pulpwood production by county and species group in Michigan, Minnesota, and Wisconsin. Production in these three Lake States fell to 4.1 million cords from 5.5 million cords in 1974.

OXFORD: 861.0(77):792. KEY WORDS: residue, Minnesota, Wisconsin, Michigan.

Pulpwood production in the Lake States plunged to 4.14 million cords in 1975 from 5.47 million cords in 1974 (table 1). Production dropped 562,000 cords in Michigan, 548,000 cords in Wisconsin, and 219,000 cords in Minnesota.

Most (92 percent) of the decline was in hardwood roundwood (including chips from roundwood). Half of the decrease was in aspen (669,000 cords). Other major declines were in maple (206,000 cords) and pine (116,000 cords).

About 89 out of every 100 cords were cut from roundwood (including chips from roundwood). The balance was derived from mill residue such as slabs, edgings, veneer cores, and chips from those materials.

Minnesota outproduced Michigan for the first time since 1958. However, Michigan's output was abnormally low because a major pulpmill was closed for several months while employees were on strike. In addition to the strike, a reduction in pulpwood inventories at some mills and weaker demand for paper and paperboard than in 1974 lowered Lake States pulpwood production in 1975.

Significant production declines occurred in Michigan's Upper Peninsula, northern and central Wisconsin, and northeastern Minnesota. Top-yielding counties were St. Louis, Koochiching, and Itasca in Minnesota; Oneida, Marinette, and Price in Wisconsin; and Iron, Menominee, and Delta in Michigan.

Pulpmills using Lake States timber in 1975 reported their pulpwood receipts by state, county, and species groups. Their cooperation is gratefully acknowledged. Thanks are also due the Michigan Department of Natural Resources for collecting the data from pulpmills in Michigan.

Table 1.--*Lake States pulpwood production by county and species, 1975*

(In hundred standard cords, roughwood basis)

MICHIGAN

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.	2/ RESIDUES
E. UPPER PENINSULA													
ALGER	194	123	2	5	23	x	3	10	4	x	12	12	
CHIPPEWA	172	53	12	24	7	3	2	50	4	x	8	9	
DELTA	582	106	46	121	44	1	4	205	12	1	21	21	
LUCE	318	150	28	42	12	1	2	29	11	x	24	19	
MACKINAC	137	37	5	17	11	1	3	31	7	x	13	12	
MENOMINEE	659	13	58	110	18	3	1	309	6	x	71	70	
SCHOOLCRAFT	348	108	33	38	45	2	5	51	12	x	28	26	
TOTAL	2680	590	184	357	160	11	20	685	56	1	177	169	270
W. UPPER PENINSULA													
BARAGA	396	19	9	10	51	1	1	237	10	1	45	12	
DICKINSON	479	19	27	40	10	6	1	350	7	x	13	6	
GOGEBIC	408	9	19	17	119	1	x	180	9	0	35	19	
HOUGHTON	105	9	6	16	23	x	x	32	4	x	13	2	
IRON	855	39	116	162	36	2	1	289	18	x	135	57	
KEWEENAW	14	0	6	6	2	0	0	0	0	0	0	0	
MARQUETTE	562	148	65	77	65	3	5	99	17	1	65	17	
ONTONAGON	410	6	2	7	37	x	1	190	14	4	109	36	
TOTAL	4010	249	250	335	343	13	9	1377	83	6	415	149	781
N. LOWER PENINSULA													
ALCONA	352	4	1	4	0	0	0	188	12	99	26	18	
ALPENA	129	2	2	7	0	0	0	64	7	13	18	16	
BENZIE	126	0	0	0	0	0	0	70	8	14	28	6	
CHEBOYGAN	245	28	3	7	0	0	0	142	26	1	20	18	
CLARE	189	29	0	0	0	0	0	113	7	21	16	3	
CRAWFORD	134	123	0	0	0	0	0	7	0	2	2	0	
EMMET	5	5	0	0	0	0	0	0	0	0	0	0	
GLADWIN	127	9	0	0	0	0	0	80	8	14	11	5	
GRAND TRAVERSE	66	8	0	0	0	0	0	33	5	12	7	1	
IOSCO	172	146	0	0	0	0	0	16	4	x	4	2	
ISABELLA	60	0	0	0	0	0	0	53	2	1	2	2	
KALKASKA	62	19	0	0	0	0	0	25	2	7	8	1	
LAKE	390	132	0	0	0	0	0	98	14	73	49	24	
LEELANAU	40	4	0	0	0	0	0	27	2	1	3	3	
MANISTEE	265	36	0	0	0	0	0	105	10	59	40	15	
MASON	123	9	0	0	0	0	0	52	4	16	32	10	
MECOSTA	147	25	0	0	0	0	0	92	6	7	9	8	
MIDLAND	5	0	0	0	0	0	0	5	0	0	0	0	
MISSAUKEE	118	7	0	0	0	0	0	80	7	11	9	4	
MONTMORENCY	464	142	4	10	0	0	0	226	10	38	17	17	
NEWAYGO	256	43	0	0	0	0	0	81	13	49	36	34	
OCEANA	72	22	0	0	0	0	0	35	2	11	1	1	
OGEMAW	106	69	0	0	0	0	0	24	1	7	4	1	
OSCEOLA	236	26	0	0	0	0	0	123	14	22	26	25	
OSCODA	536	159	x	1	0	0	0	254	21	63	26	12	
OTSEGO	35	25	0	0	0	0	0	6	x	2	2	0	
PRESQUE ISLE	274	76	7	15	0	0	0	114	29	1	19	13	
ROSCOMMON	181	67	0	0	0	0	0	80	3	27	3	1	
WEXFORD	316	214	0	0	0	0	0	85	5	7	4	1	
TOTAL	5568	1429	17	44	0	0	0	2278	222	578	422	241	337
S. LOWER PENINSULA													
ALLEGAN	10	3	0	0	0	0	0	4	x	3	x	x	
CASS	4	3	0	0	0	0	0	1	0	x	x	0	
GRATIOT	4	3	0	0	0	0	0	1	x	x	x	x	
IONIA	3	3	0	0	0	0	0	0	0	0	0	0	
KALAMAZOO	1	0	0	0	0	0	0	x	x	x	x	1	
KENT	20	19	0	0	0	0	0	x	x	1	x	x	
MONTCALM	28	7	0	0	0	0	0	7	x	5	4	5	
MUSKEGON	40	38	0	0	0	0	0	x	x	2	x	x	
OTTAWA	6	6	0	0	0	0	0	0	0	0	0	0	
TOTAL	548	82	0	0	0	0	0	13	0	11	4	6	432
STATE TOTAL	12806	2350	451	736	503	24	29	4353	361	596	1018	565	1820

(CONTINUED ON NEXT PAGE)

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1975.
2/ COUNTY FIGURES ARE NOT AVAILABLE.
x=LESS THAN 50 CORDS.

MINNESOTA

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.	2/ RESIDUES
NORTHERN ASPEN-BIRCH													
CARLTON	243	24	3	5	0	3	0	173	31	4	X	0	
COOK	297	39	84	15	0	0	0	159	0	0	0	0	
KOOCHICHING	2923	169	757	396	0	235	0	1262	29	7	X	68	
LAKE	742	220	247	120	0	1	0	134	20	0	0	0	
ST.LOUIS	3403	713	438	228	0	68	0	1842	77	0	X	37	
TOTAL	8069	1165	1529	764	0	307	0	3570	157	11	0	105	461
NORTHERN PINE													
AITKIN	501	13	15	7	0	41	0	345	25	55	0	0	
BECKER	18	9	0	0	0	1	0	8	0	0	0	0	
BELTRAMI	935	121	87	128	0	50	0	488	60	0	1	X	
CASS	487	162	10	25	0	10	0	250	29	0	X	1	
CLEARWATER	272	68	43	16	0	67	0	68	10	0	X	X	
CROW WING	154	51	0	0	0	3	0	92	5	3	0	0	
HUBBARD	440	92	5	3	0	10	0	316	14	0	0	0	
ITASCA	1157	89	161	261	0	53	0	565	26	0	X	2	
LAKE OF THE WOODS	286	24	114	6	0	3	0	132	0	0	0	7	
MAHNOMEN	27	12	X	0	0	2	0	8	5	0	0	0	
ROSEAU	252	100	57	3	0	11	0	76	5	0	0	X	
WADENA	64	46	0	0	0	0	0	14	4	0	0	0	
TOTAL	5138	787	492	449	0	251	0	2362	183	58	1	10	545
CENTRAL HARDWOOD													
BENTON	1	0	0	0	0	0	0	1	0	0	0	0	
KANABEC	18	0	0	0	0	0	0	9	2	7	0	0	
MILLE LACS	89	0	0	0	0	1	0	70	4	14	0	0	
MORRISON	83	11	0	0	0	0	0	63	2	7	0	0	
OTTERTAIL	6	6	0	0	0	0	0	0	0	0	0	0	
PINE	101	12	0	0	0	X	0	82	7	0	0	0	
TODD	6	6	0	0	0	0	0	0	0	0	0	0	
TOTAL	369	35	0	0	0	1	0	225	15	28	0	0	65
PRAIRIE													
POLK	5	0	0	0	0	5	0	0	0	0	0	0	
TOTAL	10	0	0	0	0	5	0	0	0	0	0	0	5
STATE TOTAL	13586	1987	2021	1213	0	564	0	6157	355	97	1	115	1076

(CONTINUED ON NEXT PAGE)

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1975.
2/ COUNTY FIGURES ARE NOT AVAILABLE.
X=LESS THAN 50 CORDS.

WISCONSIN

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEMLOCK	TAMARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.	2/ RESIDUES
NORTHEASTERN													
FLORENCE	401	18	17	30	10	x	x	290	6	1	19	10	
FOREST	817	53	26	129	75	2	1	378	22	2	81	48	
LANGLADE	468	16	7	32	11	3	0	246	18	4	74	57	
LINCOLN	668	19	8	37	13	5	0	325	51	18	96	96	
MARINETTE	917	71	22	103	30	2	2	589	52	6	24	16	
OCONTO	245	31	7	15	6	x	x	184	x	x	1	1	
ONEIDA	1001	123	61	182	17	5	x	397	84	40	62	30	
SHAWANO 3/	284	13	x	1	92	0	0	71	2	1	11	93	
VILAS	883	118	34	110	50	1	0	384	93	18	65	10	
TOTAL	6440	462	182	639	304	18	3	2864	328	90	433	361	756
NORTHWESTERN													
ASHLAND	548	81	23	99	21	2	0	208	39	7	42	26	
BARRON	5	2	x	0	0	0	0	0	x	1	1	1	
BAYFIELD	726	88	6	39	13	0	0	458	74	11	23	14	
BURNETT	201	157	x	0	0	1	0	43	x	0	0	0	
DOUGLAS	359	133	1	3	1	0	0	186	32	x	2	1	
IRON	680	4	6	32	27	0	0	526	33	6	23	23	
POLK	21	21	0	0	0	0	0	0	0	0	0	0	
PRICE	894	34	12	74	20	6	0	447	94	23	93	91	
RUSK	170	1	0	1	1	x	0	79	19	8	29	32	
SAWYER	493	30	14	50	7	1	0	196	69	21	60	45	
TAYLOR	585	12	2	28	37	5	0	224	63	16	102	96	
WASHBURN	504	78	2	7	0	0	0	394	13	3	4	3	
TOTAL	5524	641	66	333	127	15	0	2761	436	96	379	332	338
CENTRAL													
ADAMS	345	300	0	0	0	0	0	1	2	31	4	7	
CHIPPEWA	160	7	x	1	1	2	0	65	18	4	31	31	
CLARK	178	40	1	1	x	0	0	20	10	45	28	33	
EAU CLAIRE	67	66	0	0	0	0	0	1	0	0	0	0	
JACKSON	164	143	0	0	0	0	0	3	2	10	3	3	
JUNEAU	195	148	1	0	0	x	0	4	2	26	4	10	
MARATHON	332	15	1	6	21	x	0	80	16	51	67	75	
MARQUETTE	56	27	0	0	0	1	0	x	2	15	4	7	
MONROE	64	53	0	0	0	0	0	1	x	8	1	1	
PORTAGE	162	64	x	x	2	1	0	29	4	30	12	20	
WAUPACA	53	17	x	x	x	x	0	24	1	5	2	4	
WAUSHARA	71	62	0	0	x	0	0	1	x	5	1	2	
WOOD	444	280	x	0	1	x	0	22	9	68	23	41	
TOTAL	2576	1222	3	8	25	4	0	251	66	298	180	234	285
SOUTHWESTERN													
BUFFALO	0	0	0	0	0	0	0	x	0	0	0	0	
CRAWFORD	21	0	0	0	0	0	0	x	x	5	8	8	
DUNN	9	9	0	0	0	0	0	0	0	0	0	0	
GRANT	2	0	0	0	0	0	0	x	x	x	1	1	
IOWA	0	0	0	0	0	0	0	x	0	0	0	0	
LACROSSE	4	4	0	0	0	0	0	0	0	0	0	0	
PEPIN	8	8	0	0	0	0	0	0	0	0	0	0	
RICHLAND	1	1	0	0	0	0	0	0	0	0	0	0	
SAUK	2	2	0	0	0	0	0	0	0	0	0	0	
TREMPEALEAU	0	x	0	0	0	0	0	0	0	0	0	0	
TOTAL	323	24	0	0	0	0	0	0	0	5	9	9	276
SOUTHEASTERN													
BROWN	3	2	0	0	x	0	0	1	0	0	0	0	
COLUMBIA	24	19	0	0	0	0	0	0	x	3	1	1	
DANE	4	3	0	0	0	0	0	0	0	0	0	1	
GREEN	8	8	0	0	0	0	0	0	0	0	0	0	
GREEN LAKE	8	6	0	0	0	0	0	0	x	0	1	1	
KEWAUNEE	0	0	0	0	0	0	0	x	0	0	0	0	
MANITOWOC	0	0	0	0	0	0	0	x	0	0	0	0	
MILWAUKEE	4	0	0	0	0	0	0	0	0	0	0	4	
OUTAGAMIE	1	1	0	0	0	0	0	x	0	0	0	0	
ROCK	3	3	0	0	0	0	0	0	0	0	0	0	
WAUKESHA	9	9	0	0	0	0	0	0	0	0	0	0	
TOTAL	189	51	0	0	0	0	0	1	0	3	2	7	125
STATE TOTAL	15052	2400	251	980	456	37	3	5877	830	492	1003	943	1780

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1975.
2/ COUNTY FIGURES ARE NOT AVAILABLE.
3/ INCLUDES MENOMINEE COUNTY.
x=LESS THAN 50 CORDS.

Research Note NC-213

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S.DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55108

1976

EFFECT OF SUGAR MAPLE ROOT EXUDATE ON SEEDLINGS OF NORTHERN CONIFER SPECIES

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Northern Hardwoods Laboratory
Marquette, Michigan

ABSTRACT.--It has previously been shown that a root exudate of sugar maple reduces the growth of yellow birch. A laboratory test indicated that the growth of northern conifers is also reduced in sugar maple root exudate. Allelopathy may play an important role in survival of species on sites where sugar maple is abundant.

OXFORD: 181.41:161.35:181.36:176.1(*Acer saccharum*). KEY WORDS: allelopathy, *Acer saccharum* Marsh., *Betula alleghaniensis* Britton.

It has been previously shown that sugar maple seedlings are capable of inhibiting growth of yellow birch seedlings (Tubbs 1973) by means other than normal competition. When sugar maple leaves are mature, exudates from the growing roots reduce the growth of the roots of yellow birch. This is followed in turn by a reduction in the growth of birch stems. In nature, this limits the survival of yellow birch in northern hardwood stands.

Sugar maple ultimately invades many plant communities, both natural and planted. The purpose of the present experiment was to determine if some northern conifers, especially those with easily germinated seeds, are affected as yellow birch is.

METHODS

Dormant sugar maple seedlings were lifted from stands at the Upper Peninsula Experimental Forest. Dormancy was broken by cold treatment and the seedlings were potted and grown in a greenhouse until the first leaves were fully expanded. Actively growing roots were then allowed to soak in distilled water for 48 hours in the dark at 41°F (5°C).

Four-tenths of a milliliter of the leachate was deposited on small steel planchets and evaporated to dryness.

Uniformly sized newly germinated seedlings[1] of black spruce (*Picea mariana* (Mill.) B.S.P.), tamarack (*Larix laricina* (DuRoi) K. Koch), jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* (Moench) Voss), northern white-cedar (*Thuja occidentalis* L.), and yellow birch (*Betula alleghaniensis* Britton) were measured and placed on the planchets. Three milliliters of distilled water were added to each planchet (concentration of dry matter about 4×10^{-4} g/ml). The planchets were covered with plastic wrap and placed in covered glass dishes in the dark. Each dish contained all the species tested plus controls containing a seedling of each species to which only distilled water had been added. Each species was replicated eight times and there were four controls for each species.

The seedlings were allowed to grow 24 hours and were then remeasured. Comparisons

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[1] *Thanks are due to Wesley Lehmann of the Michigan Department of Natural Resources for the seed used in this experiment.*

between controls and seedlings treated with maple root exudate were tested statistically by a "t" test.

RESULTS

All of the species were repressed when growing in the maple root exudate. Northern white-cedar growth was highly variable both in water and exudate so that the differences in growth was not statistically significant. Tamarack was the most sensitive to the exudate; yellow birch and black spruce were least sensitive (table 1).

Table 1.--*Growth of newly germinated seedlings in sugar maple root exudate compared to growth in distilled water*

Species	Treatment		Growth of treated seedlings as a percent of control
	Sugar maple exudate	Distilled water	
	mm	*mm*	*Percent*
Tamarack	0.7	3.3	21 *
White spruce	.4	1.0	40 *
Jack pine	.6	1.3	46 *
Black spruce	1.7	3.2	53 *
Northern white-cedar	.9	1.8	50 NS
Yellow birch	.9	1.4	64 *

* Significantly different from control at 5 percent level or better.
NS Nonsignificant.

DISCUSSION

The inhibitory material in sugar maple exudate may be as important in determining what tree species will dominate after a disturbance in northern hardwood stands as condition of seedbed, seed production, and advance reproduction.

Most of the species in this test can grow very well on typical well drained sandy loam sugar maple sites, even though in nature they are usually confined to either excessively well drained soils (jack pine) or poorly drained soils (tamarack, black spruce, white spruce, northern white-cedar).

For them to do well, however, sugar maple seedlings and sprouts must be absent. For example, an unweeded red pine planting at the Upper Peninsula Experimental Forest died out while the weeded portion survived well and grew at a rate of over 2 cords per acre for 46 years.[2] Observations of small test plantings of jack pine, spruce, and tamarack on cleared sugar maple sites indicate that these species also grow well if growth is not impeded by competing sugar maple. Yellow birch seedling survival and growth is good where sugar maple has been eradicated but poor where sugar maple has not been eliminated from the stand (Tubbs and Metzger 1969).

Except for cedar, the species, tested here are thought to be relatively intolerant of shade, which helps explain why they do not commonly invade existing stands of tolerant sugar maple. But even when light conditions are good for intolerant species, such as after clearcutting, there are fewer individuals of these species in the new stand than there are of the predominating sugar maple (Metzger and Tubbs 1971).

The reason that sugar maple is such a strong competitor in these cases seems at least partly due to its growth-inhibiting root exudate. Further field tests are needed with northern conifers to determine how important this inhibiting effect is in natural stands.

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[2] *Unpublished data on file at the Northern Hardwoods Laboratory, Marquette, Michigan.*

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U. S. FOREST SERVICE

RESEARCH NOTE NC-214

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55108

HYPOXYLON CANKER OF ASPEN ASSOCIATED WITH SAPERDA INORNATA GALLS

1976

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Michael E. Ostry, *Forestry Technician*
North Central Forest Experiment Station

and Gerald W. Anderson, *formerly Principal Plant Pathologist*
North Central Forest Experiment Station
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ABSTRACT.--Preliminary findings from a study to gain information on the infection process and genetics of resistance of the Hypoxylon canker fungus (Hypoxylon mammatum) on aspen (Populus tremuloides) indicate that the poplar-gall Saperda (Saperda inornata) may be involved. This paper describes the types of wounds made by the insect and how these and resulting Hypoxylon infections in the study plantation resemble the observed pattern of infections in the field.

OXFORD: 443:416.13. KEY WORDS: Populus tremuloides, poplar-gall Saperda, Hypoxylon mammatum, oviposition wounds.

Hypoxylon canker, caused by Hypoxylon mammatum Wahl. Mill., causes annual losses of more than 1 million cords of quaking aspen (Populus tremuloides Michx.) in Minnesota, Wisconsin, and Michigan (Anderson 1964). The means by which the fungus infects the tree is unknown and remains one of the major obstacles to the possible control of this disease.

In an attempt to gain information on the infection process and the genetical control of host resistance to this disease, three plantations consisting of aspen from controlled crosses have been established. These crosses involved parent trees that were cankered and noncankered and were selected over the geographic range of aspen in Minnesota. Beginning in 1966, crosses were made each spring and approximately 15 progenies plus the parents, established by root cuttings, were planted at 3 locations: Rosemount and Pike Bay, Minnesota, and Langlade, Wisconsin. The results of the work at Rosemount, Minnesota, are reported here.

The plantation consists of 574 trees resulting from 41 different crosses. The trees were planted at a 10- by 10-foot spacing and now range in height from 4 to 25 feet. The nearest wild aspen stands are 0.5 and 2.3 miles from the plantation and only the latter stand contained some trees infected by H. mammatum. The plantation trees were observed each month throughout the growing season. So far, 13 Hypoxylon cankers have been positively identified. A Hypoxylon canker is considered "positive" when hyphal pegs releasing conidia or stroma-producing ascospores are found on a canker. All cankers were the result of natural infection and no artificial inoculation or wounding of any kind has been attempted.

All but one of the cankers was associated with an insect gall caused by Saperda inornata = (S. concolor). Manion (1975) also reported Hypoxylon cankers associated with this insect in New York. In several cases, hyphal pegs of the Hypoxylon fungus formed on the small branch near the gall. However, in most cases, the fungus produced spores after it had grown from the site of the gall down the branch and into the main stem of the tree.

The poplar-gall Saperda lays eggs in aspen branches usually less than 3/4 inch in diameter. Typical Cerambycid exit holes were noted on many galls. The branch is weakened at the site of the gall and is easily broken by the wind. The gall results from the deposition of eggs by the adult beetle and the subsequent development of the insect in the aspen branch. Shield- or u-shaped ovipositing scars are characteristic of this beetle. In the Rosemount plantation adult beetles emerged the first week of June, 1976, and at the same time hyphal pegs were being formed by the Hypoxylon fungus. The S. inornata infestation was first noted in August, 1973, on 1- to 3-year-old trees. These insect galls were the result of egg-laying activity the previous year.

Sixty additional "Hypoxylon-like cankers have begun at the insect galls and have as yet not produced spores typical of the Hypoxylon canker fungus. These cankers are similar to those reported by Nord and Knight (1972) which were also associated with S. inornata on aspen in Michigan. Several cankers have been noted resembling "Nectria" or "Ceratocystis" type cankers of aspen and these also appear to have begun in branch galls of this same insect.

The percentage of trees with positive Hypoxylon cankers is 2.26 and compares with infection data of aspen in natural stands. Many of the "Hypoxylon-like" branch cankers apparently will not migrate to the main stem as the branch often becomes too dry for fungus growth.

Since these observations were made on trees at the Rosemount, Minnesota, plantation, Hypoxylon cankers that appear to have started in S. inornata galls have been found on wild aspen trees in other areas of the State and also at the Langlade, Wisconsin, plantation.

The "typical Hypoxylon canker" with a central dead branch stub is a symptom familiar to foresters and researchers who have studied this disease. Also, it has been noted that, in general, the older the tree the higher the canker is on the main stem (Day and Strong 1959). Infection has long been suspected to have involved in some way the branch stub associated with most cankers.

Evidence from this study indicates that Hypoxylon infection can take place in insect galls on small branches or on main stems of small trees. The fungus grows down the branch and into the main stems and the branch is broken off at the gall resulting in the dead branch stub. While there are probably other means of infection, the one reported here associated with the S. inornata gall fits the pattern of Hypoxylon canker on aspen so commonly observed in Minnesota, Wisconsin, and Michigan.

Much remains to be learned about the infection process and the role of vectors in this insect-fungus-host relation. Also there are indications of insect resistance among the various aspen crosses. This type of resistance will be valuable in attempts to obtain insect and disease resistant aspen.

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USDA FOREST SERVICE

Research Note NC-215

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108
1976

THE IMPACT OF PULPWOOD RAIL FREIGHT COSTS ON THE MINNESOTA-WISCONSIN PULPWOOD MARKET

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ABSTRACT.--Transportation costs affect the marketing and utilization of pulpwood. Their impact on the procurement and utilization of pulpwood often prove difficult to measure because deriving an average annual measure of the transportation cost is difficult. This note, by means of a simple index method for measuring regional inter-State pulpwood rail freight costs, illustrates that the cost for shipping pulpwood from Minnesota to Wisconsin by rail more than doubled between 1946 and 1958. In 1959 rates declined slightly and remained stable before escalating in the late 1960's and early 1970's to more than three times the 1946 rate. Rail rates were estimated to have a significant impact on shipments of pulpwood from Minnesota to Wisconsin mills, and Wisconsin mill utilization of both softwood and hardwood pulpwood.

OXFORD: 783:717. KEY WORDS: pulpwood marketing, pulpwood freight rate index.

Because pulpwood is a bulky raw material with a low value-weight ratio, rail freight costs often account for a major portion of the total delivered cost of pulpwood to a mill. Even small changes in freight costs can affect mode of transportation, size and location of procurement areas, and kind of material used at the mill. So, measuring transportation costs is important to the industry as well as to economists attempting to analyze the behavior of pulpwood markets.

Unfortunately, it is difficult to derive an average annual measure of the cost of transportation. So we devised a simple index for measuring regional pulpwood rail freight costs and applied it to the Minnesota-to-Wisconsin inter-State pulpwood rail transportation cost trend. This enabled us to evaluate the influence of rail rates on the behavior of the Minnesota-Wisconsin pulpwood market.

The index is most useful when applied directly to regions where there is inter-State pulpwood traffic, i.e., where tariffs are governed by the Interstate Commerce Commission. Adjustments or changes in inter-State tariff schedules are nearly always percentage changes that apply across-the-board for all origin-destination points. This is not always the case with intra-State tariffs, where individual mills may negotiate rate changes with the railroads on pulpwood shipped over specific routes. Thus, in regions where intra-State rail shipments are common, the inter-State index may represent only an indication of the real cost relation.

CALCULATING THE INDEX

To calculate the index, first select a major pulpwood loading concentration point and pulpmill destination between which there are inter-State pulpwood shipments. Then obtain freight rate tariffs and their effective dates from the railroad moving pulpwood along the route. Next, multiply each tariff rate by the number of months it was in effect during a specific year, add the products together, and divide by 12 to get an average tariff for each year. Finally, assuming the first year's tariff to be 100 percent, calculate the indexes for the subsequent years as percentage deviations from this "base" year.

APPLYING THE INDEX TO MINNESOTA-WISCONSIN INTERSTATE PULPWOOD FREIGHT TARIFFS

Using the above procedure, we derived an index of inter-State pulpwood rail freight costs for Minnesota-to-Wisconsin shipments for the period 1946 to 1975 (fig. 1). It shows that the cost of shipping pulpwood by rail from Minnesota to Wisconsin more than doubled between 1946 and 1958. At that point changes in the tariff schedule were negotiated industry-wide and in 1959 the rates declined. Throughout most of the 1960's the rates remained stable before rapidly escalating in the late 1960's and early 1970's to more than three times the 1946 rate. Although published prices for pulpwood increased gradually throughout the major portion of the period (until the mid 1970's), transportation costs have represented an increasing share of the total cost of pulpwood to the mill.

Within both the Minnesota and Wisconsin roundwood pulpwood markets utilization of hardwood pulpwood has gained at the expense of softwood pulpwood since World War II. For example, the utilization of hardwood roundwood increased about 4-1/2 percent annually in both Minnesota and Wisconsin. Softwood roundwood utilization, on the other hand, decreased about 0.2 percent annually in Minnesota and 2.2 percent annually in Wisconsin.

Historically, Minnesota has been a primary pulpwood supplier for Wisconsin mills, and most of the shipments have been by rail in the last quarter century. However, pulpwood shipments from Minnesota to Wisconsin have decreased from approximately 400,000 cords during the early part of the period to just under 200,000 cords in 1973. The decrease in shipments in terms of total Minnesota production is even greater (fig. 2)

How are these trends related to pulpwood rail freight costs? In a recent study of the 1946 to 1969 period[1], many Minnesota and Wisconsin pulp and paper mill officials cited changing transportation costs as a major reason for the increased importance

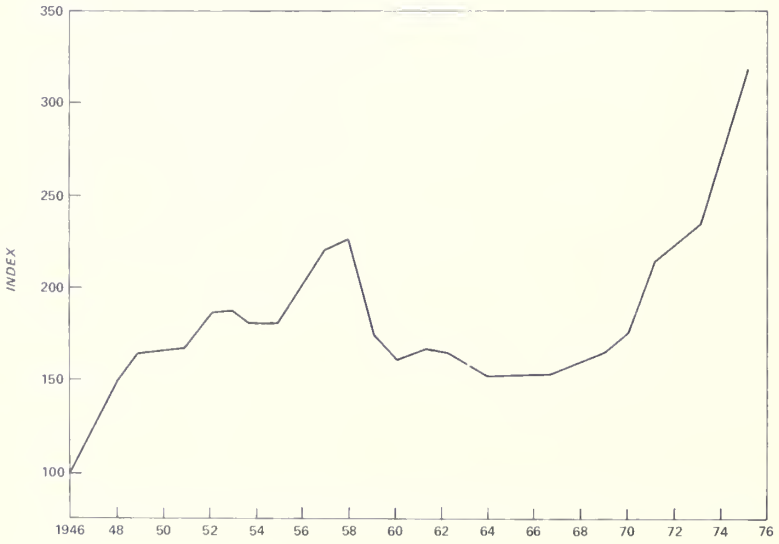

Figure 1.--*Minnesota to Wisconsin inter-State roundwood pulpwood freight rate index, 1946 to 1975.*

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[1] *Lothner, David C. 1974. The Minnesota and Wisconsin pulpwood markets: and econometric study of past changes and the future outlook for forest resource planning. 215 p. Unpubl. Ph.D. Diss., Univ. Minn.*

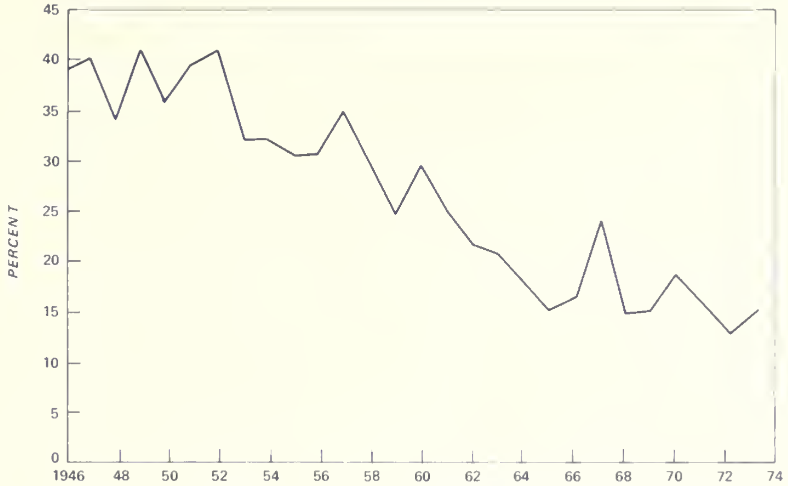

Figure 2.--*The percent of Minnesota-produced roundwood pulpwood shipped to Wisconsin, 1946 to 1973.*

of hardwood pulpwood, shifts in procurement areas, and the use of increased amounts of softwood *wood pulp* from outside the region. It was implied that mills often obtain more competitive rates on wood pulp from farther distances (outside the Lakes States region) than on pulpwood nearer the pulp mills.

A model of the Minnesota-Wisconsin pulpwood market was developed in which the rail freight index was one of several variables analyzed.

Increased rail rates, as indicated by the index, reduced Minnesota shipments of pulpwood to Wisconsin mills: For every 1 percent increase in freight costs, Minnesota shipments of pulpwood to Wisconsin decreased by 0.75 percent, all other things remaining constant. Rail rate increases also decreased roundwood softwood utilization while increasing roundwood hardwood utilization by Wisconsin mills: for every 1 percent increase in freight costs the utilization of softwood roundwood pulpwood by Wisconsin's pulp mills decreased by 0.22 percent, all other things remaining constant, and the utilization of hardwood roundwood pulpwood by Wisconsin pulpmills increased by 1.07 percent.

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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE — U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55108

1976

STEAMING CHIPS FACILITATES BARK REMOVAL

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ABSTRACT.--Whole tree chipping is a productive and economical harvesting system. The resultant product, however, is barky chips. This paper outlines a promising method for removing the bark particles from whole tree chips.

OXFORD: 821:825.71. KEY WORDS: barking, whole tree chipping.

Logging residues in the United States total more than 3.5 billion cubic feet annually. Recovery of this valuable fiber could supply more than half our annual pulpwood requirements. These residues have not been utilized because of the high cost of harvesting by conventional logging methods and the lack of effective and economical methods for removing enough bark to make them suitable for pulping.

In general, the bark on most residues cannot be removed with conventional debarking methods. Most of the residues can, however, be chipped at reasonable cost if they can be concentrated at a central woods landing economically. We undertook some research to provide a means of removing bark after chipping.

We have published several articles on methods for removing bark from wood chips. This paper deals with a complementary process developed to increase the bark removal efficiency of the chip compression process (Arola and Erickson 1974). The improvement includes steaming the unbarked chip mass before the compression treatment followed by a light mechanical attrition and screening.

STUDY VARIABLES

The main variables considered for the chip debarking study were species, season chipped, steam pressure, and steaming time. Observations during testing indicated that we should also consider variation in bark removal and wood loss due to compression roll surfacing (smooth and knurled) and bark removal in each size class of chips.

In addition to steaming before debarking, we also submitted the output chips to a light mechanical attrition to break the bark remaining with the chips into fines. Mechanical attrition is beneficial because the bark remaining after compression is very friable and is readily subject to further breakdown. The selective breakdown in bark size allowed additional bark to be removed by screening. There are many attrition methods, so we decided to begin a new study dealing only with attrition methods. A separate report has been published on the results of that study (Mattson 1974).

Three major northern pulpwood species were tested; aspen (*Populus tremuloides*), sugar maple (*Acer saccharum*), and jack pine (*Pinus banksiana*).

Bark removal is affected by season of the year trees are cut and chipped: it is easier to debark during the growing season than during the dormant season. The efficiency of bark removal from chips also varies within season. So, over a 2-1/2-year period tests were made during several dormant and growing season months (table 1).

Table 1.--*Cutting and chipping month schedule for bark removal tests*

Month	Aspen	Jack pine	Sugar maple
January	X		
February	X	X	X
March	X	X	
April	X		
May			X
June	X	X	X
July	X	X	
August	X	X	X
September	X	X	X
October	X		X
November	X	X	
December	X		X

TEST PROCEDURE

All material was cut in Baraga County and chipped at Michigan Technological University's Ford Forestry Center near L'Anse, Michigan. The chipping was performed with a Morbark Chip Pac.[1]

After chipping, the sample material was brought to the Forest Engineering Laboratory in Houghton, Michigan. The barky chips were then screened using a Sweco Classifier[1] to remove fines (-3/16 inch) and oversized chips (+1-1/8 inch). The fines and overs were discarded. (In a mill situation the oversized material could be rechipped and recycled over the screens but they were discarded in these tests because a rechipper was not available.)

Next, the chips were steamed. Steam pressures and steaming times tried were 2 to 14 lb/in.^{2}g and 1 to 10 minutes, respectively. Then chip mass was run through the compression debarker. Finally, the material was screened again to remove the waste and classify the chips by size.

RESULTS

Steaming the chips improved bark removal but adversely affected wood loss for all three species, but expecially for aspen and sugar maple (tables 2 and 3).

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[1] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Table 2.--*Residual bark factor*[1] *for varying steam times and pressure compared to unsteamed for three northern species in growing and dormant seasons*

Species and steam time	Tests	Growing season			Tests	Dormant season		
		Steam pressure				Steam pressure		
		2	8	14		2	8	14
	No.	- - - -*Lb/in.*^{2}*g* - - - - -			*No.*	- - - - *Lb/in.*^{2}*g* - - - -		
Aspen								
1 min.	6	0.24	0.23	0.18	14	0.54	0.47	0.41
5 min.	6	.25	.21	.18	13	.51	.42	.34
10 min.	6	.23	.18	.18	14	.48	.39	.33
Unsteamed	16		.51		15		.71	
Sugar maple								
1 min.	6	.42	.44	.40	6	.54	.53	.45
5 min.	6	.38	.46	.39	6	.54	.48	.42
10 min.	6	.45	.41	.40	6	.54	.41	.44
Unsteamed	4		.50		4		.64	
Jack pine								
1 min.	6	.25	.25	.26	5	.37	.36	.32
5 min.	6	.24	.24	.26	5	.35	.27	.28
10 min.	6	.25	.26	.26	5	.35	.30	.28
Unsteamed	7		.29		6		.52	

[1] Use of residual bark factor--assume 10 percent input bark. Predict output bark by multiplying 10 percent times residual bark factor.

Table 3.--*Expected wood loss (percent) during compression debarking of wood chips at varying steam pressures and time vs. unsteamed chips*

Species and steam time	Tests	Growing season Steam pressure 2	 8	 14	Tests	Dormant season Steam pressure 2	 8	 14
	No.		*Lb/in.^{2}g*		*No.*		*Lb/in.^{2}g*	
Aspen								
1 min.	6	4.3	4.1	4.7	14	4.3	3.7	4.2
5 min.	6	3.8	4.8	5.0	13	4.1	3.9	4.1
10 min.	6	3.6	4.5	4.8	14	4.3	4.1	4.2
Unsteamed	16		2.8		15		3.1	
Sugar maple								
1 min.	6	7.7	8.4	8.8	6	3.9	4.6	4.2
5 min.	6	7.8	7.8	8.8	6	4.0	4.0	4.4
10 min.	6	8.7	8.8	8.6	6	4.1	3.8	4.7
Unsteamed	4		5.8		4		2.4	
Jack pine								
1 min.	6	7.8	7.4	7.2	5	8.2	9.5	9.0
5 min.	6	7.4	6.8	7.0	5	10.4	10.2	10.9
10 min.	6	6.9	7.8	7.4	5	9.7	10.5	10.8
Unsteamed	6		7.0		6		9.4	

Increased steam pressure seemed to improve bark removal in dormant wood, so we made further tests at higher pressures. Separate bark removal tests at 10 lb/in.^{2}g and 30 lb/in.^{2}g were compared with tests run without steam treatment. The bark removal was significantly better as steam pressure increased (fig. 1).

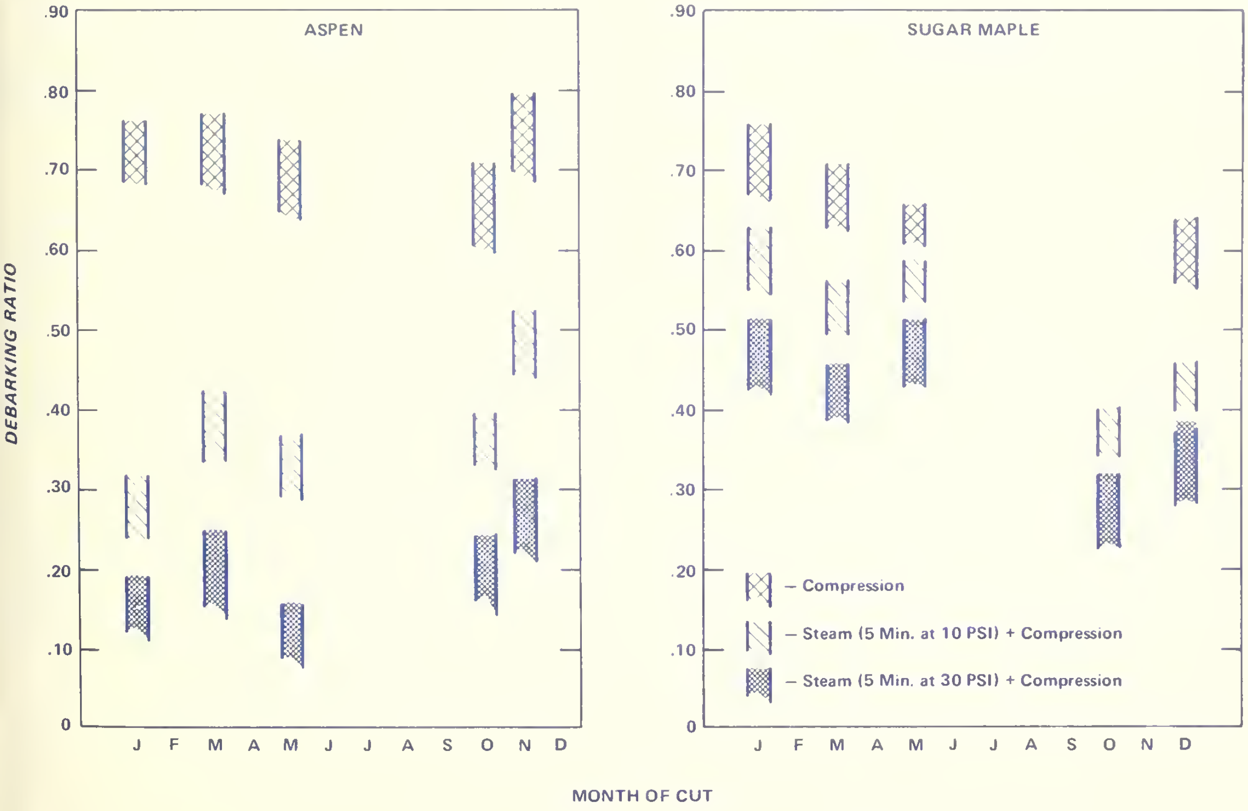

Figure 1.--*The effect of chip steaming to improve bark removal with the compression debarking process.*

Minimizing wood loss is important in any barking system, so an analysis was made of the wood loss along with the bark removal from the two different rolls--smooth and knurled. The knurled roll was used to ensure that the wood chips would be pulled through the nip spacing. It was found that the bark removal was nearly the same from both rolls while the wood loss in most cases was significantly greater from the knurled roll (table 4).

For all species the bark content in fractions exceeding a 3/8-inch round hole screen was very low (1 to 3 percent). The chips passing a 3/8-inch screen and held on a 3/16-inch screen (about 10 to 15 percent of the output) contained a considerable amount of bark. This 3/16-inch chip fraction can either be scalped for use as fuel or furnish for other lower grade fiber products, or processed further to remove more bark.

Table 4.--*Bark removal and wood loss by roll surface*
(In percent)

Species	Growing season				Dormant season			
	Smooth roll		Knurled roll		Smooth roll		Knurled roll	
	Bark removed	Wood loss	Bark removed	Wood loss	Bark removed	Wood loss	Bark removed	Wood loss
Aspen	49	33	51	67	55	52	45	48
Sugar maple	42	5	58	95	47	28	53	72
Jack pine	53	39	47	61	61	43	59	57

In view of these results, we decided to use two smooth rolls instead of one smooth and one knurled roll for future laboratory and pilot plant testing. To overcome feeding problems that can occur with some species, two smooth rolls with clearing slots machined the width of the roll have been tested with good results.

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☆ U.S. Government Printing Office: 1976—766-144/22 Region No. 6

RESEARCH NOTE NC-217

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108
1977

TIMBER VOLUME IN IOWA COUNTIES

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ABSTRACT.--The second forest inventory of Iowa shows timber volume reaching more than 1 billion cubic feet in 1974. Hardwoods make up 99 percent of this total.

OXFORD: 612(777). KEY WORDS: growing stock, sawtimber, hardwoods, softwoods.

Iowa's 1.5 million acres of commercial forest land supported more than 1 billion cubic feet in growing-stock trees in 1974. Included in the total volume of growing stock are 3.5 billion board feet of saw log material.

In addition, volume in live rough and rotten trees (nongrowing stock) is 308 million cubic feet.

Hardwoods completely dominate in Iowa, making up 99 percent of the total growing-stock volume. The oaks, led by white oak and northern red oak, make up almost 40 percent of the total. Other common species groups and their volumes are:

	Million cubic feet
Oaks	403
Maples	148
Elms	95
Cottonwood	92

The State is divided into three geographical units--two in the east and one in the west. The northeastern and southeastern forest survey units contain the major concentrations of timber in the State (fig. 1). The three counties with the most growing-stock in the State are Allamakee, Clayton, and Jackson (table 1), all bordering the Mississippi River.

The sampling error of volume for the survey was ± 3.96 percent for 1,055 million cubic feet of growing stock in the State. The survey was conducted by the North Central Forest Experiment Station and the Iowa Conservation Commission.

Table 1.--*Net volume of growing stock, sawtimber, and rough and rotten trees on commercial forest land by county, Iowa, 1974*

Survey Unit and county	Growing stock[1]	Sawtimber[2]	Rough and rotten[3]
	Thousand cubic feet	*Thousand board feet*[4]	*Thousand cubic feet*
Northeastern:			
Allamakee	85,128	283,378	28,269
Benton	11,170	37,602	4,268
Black Hawk	6,589	21,055	3,263
Bremer	10,695	37,506	3,778
Buchanan	7,383	23,745	2,990
Butler	5,683	19,557	2,642
Cedar	11,046	36,787	4,237
Chickasaw	6,083	20,654	2,117
Clayton	67,421	230,933	23,129
Clinton	17,187	56,678	7,467
Delaware	13,548	45,508	4,616
Dubuque	27,861	91,541	9,932
Fayette	21,968	74,766	7,245
Floyd	4,799	16,081	1,906
Grundy	379	1,169	188
Howard	5,094	17,285	1,676
Jackson	42,770	141,002	15,737
Johnson	15,075	51,854	5,582
Jones	20,337	66,261	7,745
Linn	21,343	69,850	8,379
Mitchell	3,821	13,692	1,288
Scott	7,292	24,284	3,136
Tama	14,875	50,692	5,579
Winneshiek	32,460	108,284	10,715
Total	460,007	1,540,164	165,884
Southeastern:			
Appanoose	16,092	50,925	4,219
Boone	13,170	44,573	2,940
Clarke	12,793	37,171	3,651
Dallas	13,277	44,109	2,926
Davis	16,707	52,222	4,390
Decatur	16,664	50,691	4,814
Des Moines	18,156	59,100	4,301
Guthrie	17,990	59,823	4,013
Hamilton	4,344	14,578	1,050
Hardin	6,412	20,846	1,464
Henry	13,606	41,337	3,519
Iowa	14,799	50,811	3,146
Jasper	8,819	30,483	1,936
Jefferson	12,166	39,385	2,917
Keokuk	12,227	40,642	2,628
Lee	32,950	101,413	8,127
Louisa	19,984	70,708	4,052
Lucas	19,873	62,011	4,883
Madison	16,529	52,500	4,314
Mahaska	12,637	43,064	2,648
Marion	10,945	34,993	2,992
Marshall	6,739	23,790	1,326
Monroe	22,009	68,379	5,579
Muscatine	14,633	49,747	3,164
Polk	7,525	26,300	1,849
Poweshiek	5,346	18,060	1,197
Story	4,151	14,058	874
Van Buren	22,760	71,624	6,036
Wapello	16,327	53,133	3,789
Warren	15,597	51,645	3,828
Washington	13,760	45,317	3,040
Wayne	9,830	31,234	2,436
Webster	12,920	42,888	2,845
Total	461,737	1,497,560	110,893

(Table 1 continued on next page)

(Table 1 continued)

Survey Unit and county	Growing stock[1]	Sawtimber[2]	Rough and rotten[3]
	Thousand cubic feet	*Thousand board feet*[4]	*Thousand cubic feet*
Western:			
Adair	3,304	10,242	844
Adams	4,975	17,765	1,072
Audubon	541	1,601	165
Buena Vista	1,103	3,220	258
Calhoun	640	3,020	77
Carroll	634	2,770	81
Cass	1,636	6,039	393
Cerro Gordo	602	2,368	60
Cherokee	2,342	7,789	593
Clay	2,521	9,176	527
Crawford	2,445	7,381	601
Dickinson	111	211	66
Emmet	1,441	5,443	339
Franklin	2,320	9,224	403
Fremont	7,231	23,025	1,838
Greene	4,619	17,756	887
Hancock	211	542	86
Harrison	15,936	50,579	3,982
Humboldt	1,607	5,742	307
Ida	531	2,470	42
Kossuth	2,480	10,403	372
Lyon	1,118	4,017	224
Mills	7,331	24,308	1,773
Monona	12,006	37,022	3,170
Montgomery	3,007	10,970	620
O'Brien	911	3,776	168
Osceola	89	327	23
Page	4,438	14,591	1,005
Palo Alto	1,159	4,236	215
Plymouth	3,150	10,935	716
Pocahontas	436	1,035	105
Potawattamie	7,716	25,554	1,849
Ringgold	8,180	26,588	2,023
Sac	1,025	4,117	219
Shelby	1,231	4,806	254
Sioux	723	3,149	102
Taylor	5,718	19,164	1,381
Union	7,304	23,263	1,782
Winnebago	67	120	23
Woodbury	7,690	25,277	1,857
Worth	593	1,858	175
Wright	1,804	6,813	384
Total	132,926	448,692	31,061
State total	1,054,670	3,486,416	307,838

[1] The volume of sound wood in the bole of growing-stock trees 5.0 inches d.b.h. and larger, from a 1-foot stump to a minimum of 4.0-inch top diameter outside bark, or to the point where the central stem breaks into limbs. Growing-stock volumes are shown in cubic feet.

[2] Net volume of the saw log portion of live sawtimber trees (softwoods 9.0 inches d.b.h. and larger and hardwoods 11.0 inches d.b.h. and larger) from stump to a minimum 7 inches top diameter outside bark for softwoods and 9 inches for hardwoods.

[3] Net volume of live trees 5.0 inches d.b.h. and larger that do not contain at least one merchantable 12-foot saw log or two noncontiguous 8-foot or longer saw logs, now or prospectively, because of roughness and poor form or because of rot (that is, when more than 50 percent of the cull volume of the tree is rotten).

[4] International 1/4-inch rule.

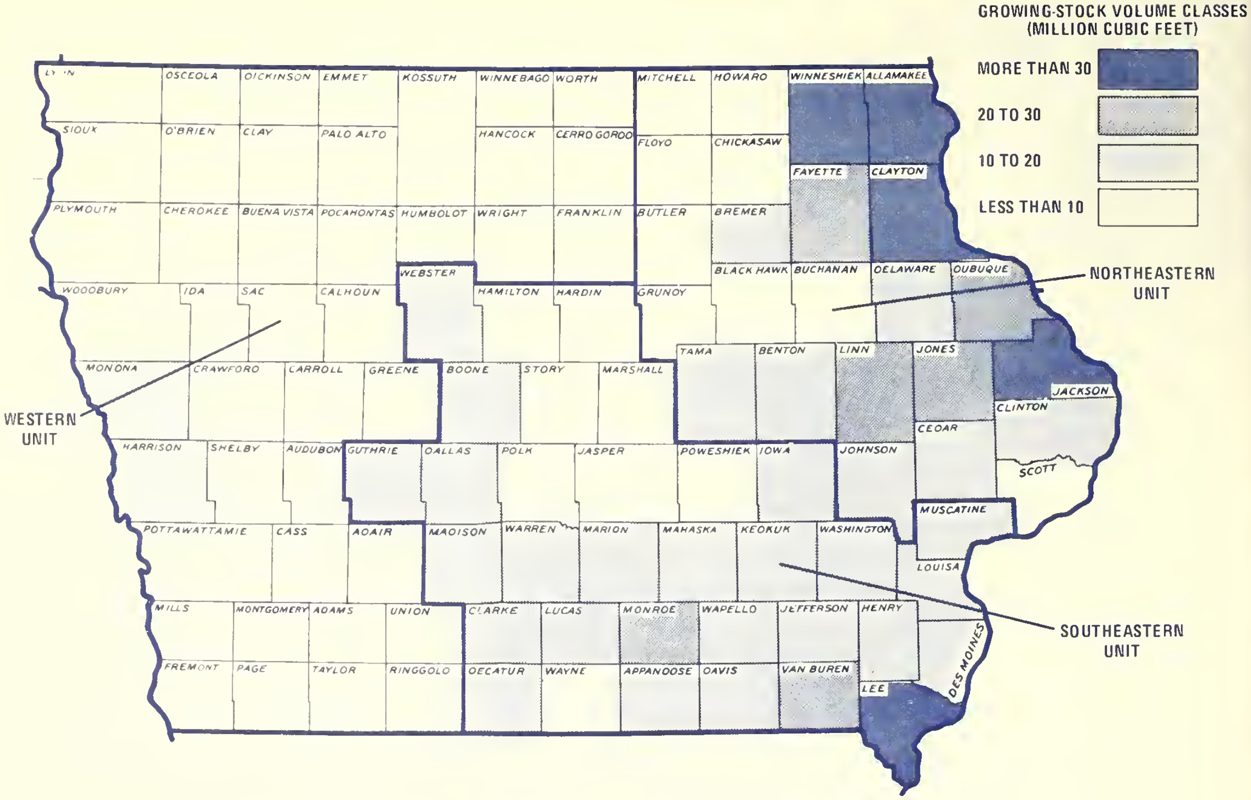

Figure 1.--*Growing-stock volume in Iowa counties, 1974.*

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USDA FOREST SERVICE

RESEARCH NOTE NC-218

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55108
1977

TALL FESCUE RESPONSE TO FIRE

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ABSTRACT.--Application of fire to tall fescue stands in the Ozarks caused significant changes in forage yields, seedstalk numbers, and stand composition.

OXFORD: 268.4:268.5(778). KEY WORDS: grass, grasslands, range management, pasture management, prescribed burning.

Converting tree and brush stands to tall fescue (*Festuca arundinaceae* Schreb.) grassland is common practice in the Ozarks (Crawford and Bjugstad 1967), but, maintenance of the grassland is hampered by invasion of woody plants. Fire has been used as a followup treatment to suppress top growth of woody plants in tall grass prairie (Kucera *et al.* 1963). Fire has also been used on native grassland to reduce competition from woody vegetation (Dalrymple 1969) and competition from undesirable bluegrass invasion (McMurphy and Anderson 1965). But the effect of fire on tall fescue in the Ozarks has not been investigated. So we designed a study to measure the response of tall fescue forage yields, seedstalk numbers, and stand composition to season of burning.

METHODS

A uniform tall fescue stand located on the Mark Twain grazing allotment on the Ava Ranger District of the Mark Twain National Forest in Missouri was subjected to four different burning times (four applications) and a no-burn control. The burning times were: late winter (February) before dormancy of the vegetation was terminated; early spring (April) immediately after dormancy was terminated; midsummer (August) during the period when tall fescue is inactive; and late fall (November) just before the herbaceous vegetation becomes dormant. Dormancy here refers to the time when fescue is not actively growing because this species tends to remain green yearlong. A control plot was mowed each time burning was done, so that burned and unburned stands could be compared. The burning times were selected to realistically represent management: they coincided with periods when both damage to the herbaceous vegetation and the time required for regrowth and return to grazing would be minimal.

Fire temperature was estimated by means of a graded series of thermal sensors (Probasco *et al.* 1976) to determine the temperatures associated with burning fescue stands and to find out if the temperature generated was above the minimum lethal threshold for woody vegetation. Byram (1958) reported that killing temperatures are time dependent. However, short-duration temperatures in the range of 60° C to 65.6° C usually kill vegetation. Data were collected at 2.5 cm (1 inch) below the soil surface, at the soil surface, and at 5 cm (2 inches), 15 cm (6 inches), and 61 cm (24 inches) above the soil surface. The respective temperatures for the graded sensors at each collection point were 37.8, 65.6, 149, and 232° C.

Forage yields were measured by the double-sampling technique (Wilm *et al.* 1944). Twenty 4.8 ft^2 quadrat samples were taken on each plot during June and October of the year following the burning.

RESULTS AND DISCUSSION

The fire was consistently more intense at the midrange height, 5 cm to 15 cm (table 1). Intensity varied at the upper and lower heights; greater intensity was attained at the lower heights early in the year and at the upper heights late in the year. The sensors set 2.5 cm below the soil surface were unaffected by the heat.

Table 1.--*Thermal sensors responding to heat treatment (a total of 40 tubes was possible at each point)*
(In percent)

Sensor heights (cm above soil)	Sensor temperature (°C) 37.8	65.6	149	232
LATE WINTER				
0	93	88	75	48
5	100	100	93	78
15	100	100	93	60
61	98	53	5	0
EARLY SPRING				
0	100	95	73	43
5	100	98	80	63
15	100	100	80	63
61	100	73	5	3
MIDSUMMER				
0	68	53	25	5
5	100	95	83	60
15	100	95	95	78
61	100	100	90	45
LATE FALL				
0	85	85	30	13
5	100	98	90	55
15	98	98	90	73
61	100	100	60	13

There were no significant differences in forage yields among the four treatments. However, tall fescue yields did differ significantly between burning treatments applied during the dormant or inactive growing period and those applied during active growing periods. Dormant burning did not reduce yield: yield averaged 3,083 lb/acre, which compares favorably to the 2,893 lb/acre produced on the unburned plots. However, burning during active growth significantly reduced production to 2,529 lb/acre.

Tall fescue seedstalk numbers were stimulated by the midsummer burn: numbers per square foot ranged from 8 for the early spring burn to 31 for the midsummer burn. Ehrenreich (1959) reported that similar treatments stimulates seed production of native grasses in Iowa.

Red clover (*Trifolium pratense* L.) was a rather insignificant component in the grass stand before the burns but increased substantially in plots burned in late winter or early spring (table 2).

After 1 year of study it appears that when burning only for tall fescue stand maintenance, fire should be applied during a dormant or inactive period, either late winter or midsummer. For renovating a red

Table 2.--*Tall fescue and red clover production and density related to burning treatment*

Burning season	Tall fescue		Red clover	
	Lb/acre	*Seedstalks/ft*^{2}	*Lb/acre*	*Plants/ft*^{2}
Late winter	[2]2,856a	[1]20f	[1]183d	8d
Early spring	2,406a	8g	187d	11d
Midsummer	3,312a	31h	1e	1e
Late fall	2,651a	22f	3e	1e
No burn	2,893a	16i	2e	1e
Active growth period $\frac{\text{(ES+LF)}}{2}$	[3]2,529			
Inactive growth period $\frac{\text{(Lw+Ms)}}{2}$	[3]3,083			

[1] Means followed by the same letter were not significantly different at the 0.05 level, Duncan's New Multiple Range Test.

[2] Letters denote no significant differences at 0.10 level based on standard analysis of variance techniques.

[3] Active growth period yields vs. inactive growth period yields were significantly different at the 0.10 level based on standard analysis of variance techniques.

clover stand, burn in either late winter or early spring. When considering both tall fescue and red clover, burn in late winter. When interested in tall fescue seed production, burn in midsummer.

Finally, a few precautions about the use of fire. Fire is an efficient and economical management tool, but its use calls for thorough planning and organization. Local fire authorities must be notified. Weather information, before, during, and immediately after the burn should be obtained. Adequate education as to the proper use and behavior of fire is also important to the success of any prescribed burn.

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RESEARCH NOTE NC-219

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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1977

WILDFIRE EFFECTS ON AN OAK-HICKORY FOREST IN SOUTHEAST MISSOURI

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ABSTRACT.--Plant community development was observed for 10 years after a fire had top-killed most trees in a southeastern Missouri oak-hickory forest stand. The forest was re-established by sprouts. Production of herbaceous plants and other potential wildlife food was abundant for 4 years before decreasing to a stable preburn condition.

OXFORD: 435.1:434(778). KEY WORDS: plant succession, forest fire effects, wildlife food production, fire ecology.

Many of the wildfires that occur in the North Central States burn oak-hickory forests. The amount of damage depends on the age and composition of the forest, the season of the burn, and the intensity of the fire. Sometimes only the ground vegetation or just the tops of the trees are killed, but other times the entire tree is killed. How a plant community responds after a fire would be useful knowledge for land managers to help them decide what action to take regarding salvaging timber, improving the stand, and providing food and habitat for wildlife. To find out how a stand did respond, the 10-year effects of a late spring fire on an oak-hickory community were studied.

THE STUDY

The fire occurred May 7, 1966, in Iron County, Missouri, in a fully stocked stand of predominantly large saplings. The dominant stand was a 23-year-old white oak-red oak-hickory stand (stand type 52 as described by the Society of American Foresters (1954)), which had developed following a fire in 1943. The soil was a Clarksville cherty silt loam (Miller 1976)[1] with a site index of 70 for black oak (Schnur 1937). The slope averaged about 15 percent and had an easterly aspect. The fire top-killed almost all trees, but left a few 23-year-old survivors and some older trees that had also survived the earlier fire.

Four plot point centers, three in the burned and one in the adjacent unburned area, were selected as representative of the area burned. Four sub-plots were located 7.9 m in cardinal directions from each plot center. The following information was gathered from each of the 16 sub-plots: (1) trees 1.5 cm dbh and larger that were intercepted using a 10-factor prism were tallied; (2) trees 30.5 cm or taller within a 4.6-m radius were tallied (height of only the tallest stem per single root system was measured, except after the 10th growing season when all heights were tallied); and (3) the annual production of trees, shrubs, vines, grasses, and forbs to a height of 1.5 m was estimated within 1.9 m^2. Annual

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[1] *Miller, M. R. 1976. Personal communication, Missouri National Forests.*

production for woody plants included the foliage and new stems or branches $\leq$ 1.27 cm in diameter; current growth on old stems or branches was not included.

Moisture content was determined gravimetrically at 85 C. The green weight estimates were converted to ovendry.

Tree tallies were made 1, 2, 5, and 10 growing seasons after the 1966 fire, and production tallies were made 1, 2, 3, 4, 5, and 10 growing seasons after the fire. Estimates were made after major growth was completed--between mid-August and mid-October. The tree community was evaluated using the basic factors of frequency, density, and dominance--evaluation factors used by Curtis and McIntosh (1951).

RESULTS

Trees

The 1966 fire reduced the stand to 64 living stems and 1.1 m^2 of basal area per hectare. The surviving trees ranged from 10 to 46 cm dbh. Just before the 1966 fire, 79 percent of the stand was oaks and hickories (table 1). Surviving trees were almost all oaks.

The new tree stems developed primarily as basal sprouts of the top-killed trees. After the first growing season about 29,500 tree stems from 5,600 plants were growing per hectare. After 10 growing seasons the ratio had decreased from 5.3 stems per plant found the first year to 1.6 stems per plant. Height of the tallest stem for each plant for oaks, the major species, increased from 0.8 m after the first season to 2.9 m at the end of the fifth growing season. Following the 10th growing season when all stem heights were measured, heights for oaks averaged 6.3 m for the 8 cm dbh class, 5.9 m for the 5 cm class, 4.5 m for the 3 cm class, and 2.0 m for the less than 3 cm class. Oaks and hickories comprised 64 percent of the stand after 10 years (table 1).

Table 1.--*Composition of a southeast Missouri oak-hickory stand before and after fire*

BEFORE FIRE[1]

Species	Freq.[2]	Trees[3]	Basal Area[4]
		No./hectare	*m2/hectare*
Quercus alba	11	1451	6.2
Quercus velutina	10	539	6.0
Quercus coccinea	7	625	2.7
Carya spp.	3	514	.5
Sassafras albidum	1	378	.2
Cornus florida	1	378	.2
Juglans nigra	1	17	.5
Morus rubra	1	42	.2
Total	35	3944	16.5

10 GROWING SEASONS AFTER FIRE[5]

Species	Freq.[2]	Trees[3]	Basal area[4]
		No./hectare	*m2/hectare*
Quercus alba	11	2385	2.5
Quercus velutina	12	1078	1.4
Quercus coccinea	10	813	.6
Quercus imbricaria	3	37	.0
Carya spp.	11	737	.3
Sassafras albidum	12	976	.3
Cornus florida	9	660	.2
Morus rubra	8	304	.1
Nyssa sylvatica	6	242	.1
Rhamnus spp.	6	126	.1
Acer rubrum	3	153	.1
Prunus serotina	5	64	.0
Celtus occidentalis	2	52	.0
Ostrya virginiana	1	101	.1
Prunus americana	2	64	.0
Crataegus spp.	1	37	.0
Juglans nigra	1	12	.0
Diospyros virginiana	1	12	.0
Viburnam spp.	1	12	.0
Total	105	7865	5.8

[1] Tree tally based on 10-factor prism intercept of trees 1.5 cm d.b.h. and larger that were present before the May 7, 1966, fire for 12 sub-plots.

[2] Number of occurrences per 12 possible.

[3] Convert No./ha to No./acre by multiplying by 0.405.

[4] Convert m^2/ha to ft^2/acre by multiplying by 4.355

[5] Tree tally includes all trees 30.5 cm or taller but excludes fire-residual trees (survivors of the May 7, 1966, fire)--all within twelve 4.6-m radius sub-plots.

Tree browse production reached a peak during the 3rd growing season (table 2), decreased markedly by the 5th growing season, and decreased further by the 10th growing season. Dogwood generally accounted for about one-half or more of the tree browse on the unburned area, and reached one-half on the burned area the 10th growing season. Estimated production of all oak species declined following the third growing season. Unburned stand production averaged about 117 kg per hectare.

Shrubs and Vines

Rhus, primarily the dwarf sumac (*Rhus copallina*), were abundant on the burned area soon after the fire; it was not found on the unburned area. After the 10th

Table 2.--*Ovendry weight of potential wildlife food production in a southeast Missouri oak-hickory stand in a burned and in an adjacent unburned stand*[1]

(In kilograms per hectare)[2]

Vegetative material	Burned Stand Growing Seasons After Fire						Unburned Stand Growing Seasons After Fire					
	1	2	3	4	5	10	1	2	3	4	5	10
Trees	407	494	1297	850	252	92	47	79	212	113	123	124
Shrubs and vines	155	342	758	629	200	113	5	4	4	Trace	Trace	2
Total Browse	562	836	2055	1479	452	205	52	83	216	113	123	126
Grasses and sedges	118	281	287	147	27	24	3	4	7	2	Trace	1
Forbs	390	393	385	200	56	58	1	6	12	2	Trace	9
Total herbaceous	508	674	672	347	83	82	4	10	19	4	Trace	10
Total browse and herbaceous	1070	1510	2727	1826	535	287	56	93	235	117	123	136

[1] Includes the current season's growth of new branchwood, stems, foliage, and fruit within 1.5 m of the ground.

[2] Convert kg/ha to lb/acre by multiplying by 0.892.

growing season there were still 3,500 *Rhus* and 1,200 *Corylus* stems per hectare.

Shrubs and vines provided the most abundant browse by the third growing season (table 2). Production decreased markedly by the fifth growing season.

Grasses and Sedges

Grasses and sedges were most productive the second and third seasons (table 2). They had decreased markedly by the 5th season, but did not change again by the 10th season. Grasses and sedges were sparse on the unburned area.

Forbs

Only 20 of the 34 forb genera identified on the burned plots after the first growing season remained after the 5th growing season and only 19 remained after the 10th. Only seven genera were found on the unburned plot. The high production of annuals such as *Acalypha, Ambrosia, Cassia, Croton,* and *Erechtites* during the first 2 years quickly became negligible.

The production of perennials such as *Aster, Cimicifuga, Desmodium, Galium, Monarda, Potentilla, Solidago,* and *Strophostyles* was high through the fourth season. Some production of perennials continued through the 10th growing season, but the plants were generally small and poorly developed. Five genera of perennials--*Aster, Desmodium, Galium, Lespedeza,* and *Solidago*--were common on the unburned area.

Total forb production did not change the first three growing seasons (table 2). By the fifth season, production had greatly decreased but was stable.

Forb production was negligible on the unburned plot.

Deer and Turkey Food

Production of preferred deer and turkey foods were estimated on the basis of Murphy and Ehrenreich (1970). Peak production occurred the third season after fire for both of these game species foods (fig. 1). Production decreased sharply from the 3rd to the 5th season, and more slowly from the 5th to the 10th season. There was very little production of these preferred foods on the unburned area.

CONCLUSIONS

Top-killed trees of oak-hickory stands will usually re-establish themselves by sprouting. Thus, the major timber loss was 23 years of growth on the stand. To manage for optimum sawtimber volume and quality it would have been advisable to cut all residual trees because they tend to become large-crowned due to their dominant positions and produce low-quality sawtimber. They also suppress the new stand. But the scattered surviving trees are of special value for wildlife. Because these trees develop large crowns, they often

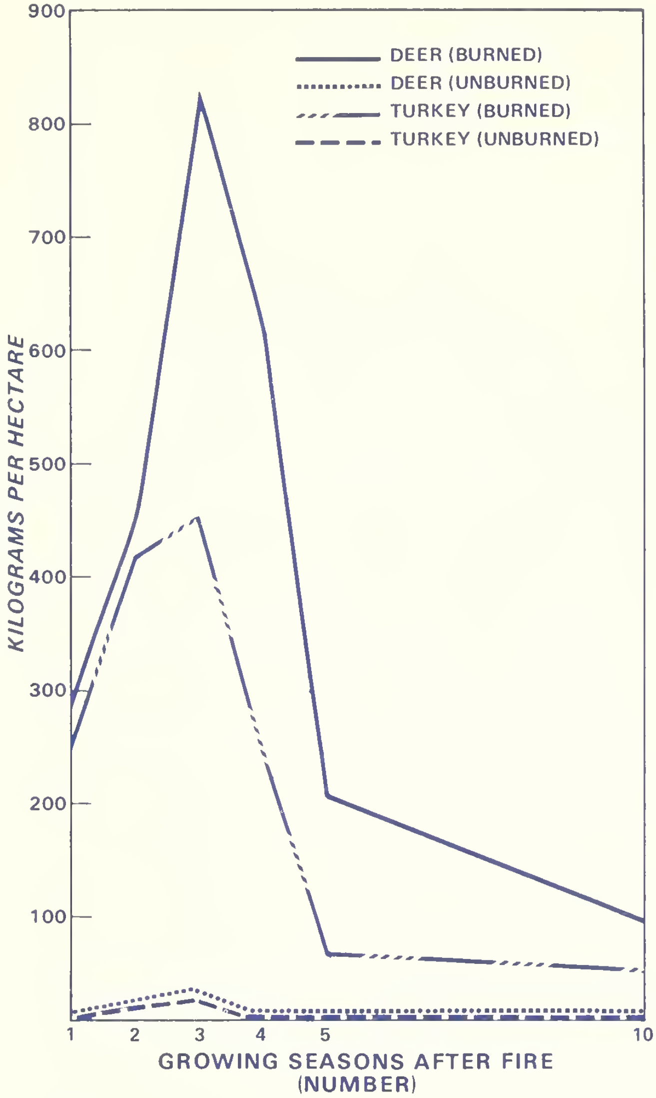

Figure 1.--*Estimated production of preferred deer and turkey food for a burned and for an unburned oak-hickory stand in southeast Missouri. (Based on preferred foods lists presented by Murphy and Ehrenreich (1970).)*

produce excellent nut crops. They are also potential den and nesting trees, provide different food, and lend esthetic diversity to the area.

Wildlife food was produced in large quantities for 4 years on the burned area. Thereafter, production greatly decreased, but it was still well above that on the unburned area.

Fire effects on an oak-hickory plant community should generally follow those observed in Iron County, Missouri. However, a similar fire may have different effects if the soil and site conditions, stand composition, age, or density are different. Whether effects of a fire in an oak-hickory stand are beneficial or destructive depends on the objectives and priorities of land management.

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INCREASING WHITE ASH SEED GERMINATION BY EMBRYO DISSECTION

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ABSTRACT.--Dissection of white ash embryos from the seed, coupled with cytokinin treatment, has been shown to enhance germination and seedling survival, as compared to whole seed stratification methods.

OXFORD: 161.6:176.1 *Fraxinus americana*.
KEY WORDS: zeatin, stratification, viability, yield, treatment.

A major barrier to the mass production of some forest trees is seed dormancy. Dormancy may be imposed by mechanisms ranging from impermeable seed coats to hormonal inhibitors (Leopold and Kriedemann 1975). Once the dormancy mechanism is known for a particular species, it can be circumvented, often by mimicking some environmental influence. In the laboratory, dormancy can often be broken with growth stimulants.

Seeds of white ash (*Fraxinus americana* L.) normally are dormant after imbibition (Mayer and Poljakoff-Mayber 1963). Sondheimer *et al.* (1968) demonstrated that dormant seeds of this species contain high concentrations of the potent germination inhibitor, abscisic acid (ABA), in both the embryo and endosperm. Stratification can break dormancy in white ash seeds, apparently both by reducing the ABA level (Sondheimer *et al.* 1968) and by stimulating the appearance of growth stimulators (Villiers and Wareing 1965), probably hormones, in the embryo. On the other hand Sondheimer and Galson (1966) and Tzou *et al.* (1973) have induced dormant ash embryos (not stratified) to germinate by treating them with hormones (especially gibberellins and cytokinins). However, at best only about 30 percent of the seeds can be induced to germinate by either of these methods (McBride and Dickson 1972).

We used this information to design a system for germinating large numbers of ash embryos. We found that removing the embryos from the seeds and treating them with growth hormones gives much higher germination rates than conventional seed handling techniques.

METHODS

Seed Viability

About 400 seeds were sliced longitudinally and placed in a 1 mg/ml solution of tetrazolium red in 0.1 M phosphate buffer, pH 7.0 for 6 hours. Viable embryos were stained red (Burstone 1962). Nearly 97 percent of the seeds were viable. Several imbibing techniques were employed (including a cold treatment) but no difference in apparent viability was found.

Embryo Germination

Preliminary germination tests were carried out with several hormones, to find the best germination stimulator. Embryos were treated with zeatin, kinetin, and gibberellic acid, at concentrations reported by Sondheimer and Galson (1966), and Tzou, *et al.* (1973) to be effective in promoting germination of white ash seeds. Test procedures was as follows.

Winged seeds showing no insect damage were collected from several trees. The seeds were soaked in water for 24 hours, removed from the wings, and soaked for an additional 48 hours. The embryos were carefully dissected from the endosperm. They were placed in petri dishes, on filter paper soaked with hormone solution prepared in 0.01 M potassium phosphate buffer, pH 6.0, 10 embryos per dish. The dishes were then kept either in a growth chamber with a 17-hour day, or in a greenhouse with continuous illumination provided by supplemental fluorescent lighting.

After 10 days the germination rate was determined, and germinated embryos were transplanted to sand in styrofoam cups, which were capped with petri dish covers to prevent dessication. The survival rate was recorded at 13 days and again at 30 days after the start of the experiment.

A major factor reducing viability in the embryos was damage inflicted during dissection. Damaged embryos rapidly become necrotic and failed to germinate.

Only zeatin proved effective in stimulating ash embryo germination (fig. 1). Based on this result, extensive tests were done on germination and survival rates of ash embryos with zeatin.

Stratification

Seed was planted in moist sand, placed in an incubator (68-78°F) for 30 days, transferred to a cooler (38°F) for 30 days, then allowed to germinate in an incubator for 60 days. Germination counts were made every two days.

RESULTS

The results (table 1) show that the embryo dissection technique can lead to much greater germination than can stratification methods. Comparing germination and survival rates of hormone-treated embryos with those for untreated embryos in the two growth conditions indicates that environment may influence germination rates. Under the conditions used, continuous light appeared to produce much the same effect as the zeatin treatment. Apparently the environment also interacts with the genome of the seedling. The zeatin-treated embryos of the tree #13 had a low survival rate in the greenhouse, but not in the growth room; while the situation is reversed for the seeds of tree #14.

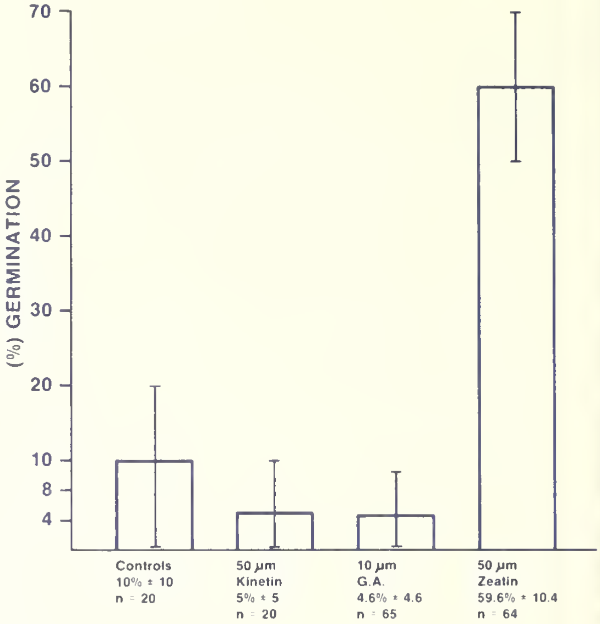

Figure 1.--*Results of preliminary germination tests with several hormones. Error bars are two standard deviations.*

At the end of the 30-day growth period in sand in styrofoam cups, all the surviving trees were well developed and growing vigorously. They had one to two sets of true leaves and extensive root systems. The overall length of the plants from the various treatments was not significantly different. The mean length was 62.3 mm (S.E. = 4.15). These trees could be transplanted to soil and raised to maturity.

DISCUSSION

The embryo dissection technique appears to be a valuable tool to circumvent the problems of germinating dormant ash seeds.

Table 1.--*Results of germination tests on zeatin treated (+Z) control (H_2O) embryos and whole seed stratification. The embryo method is based on 12 observations from 4 trees and 3 dishes. Stratification results are from 400 seeds per tree.*

(In percent)

Tree	Greenhouse				Growth Room				Stratification germination
	Germination		Survival		Germination		Survival		
	+Z	H_2O	+Z	H_2O	+Z	H_2O	+Z	H_2O	
2	100	100	97	97	100	70	100	70	24
7	100	67	100	67	100	20	100	20	12
13	97	93	77	93	100	73	100	73	39
14	100	97	100	93	97	70	77	70	72
Mean	99	89	93	87	99	58	94	58	37
$s_{\bar{x}}$	.8	7.6	5.6	6.9	.8	12.7	5.8	12.7	13

Survival rates above 90 percent are 2 to 3 times greater than obtained by stratifying and planting whole seeds.

This technique may be useful for selecting desired seedling phenotypes. Light and/or temperature conditions can be altered to select seedlings with increased chances of survival in particular natural conditions. In addition, the high rates of survival help to maximize yields when the number of seeds is limited, such as controlled crosses of particularly desirable seed parents.

In general, this technique provides a rapid and reliable method to obtain ash seedlings at a much higher yield than has been previously possible.

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SLUDGE-TREATED COAL MINE SPOILS INCREASE HEAVY METALS IN COVER CROPS

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ABSTRACT.--Four species of forage were grown in a greenhouse on acid strip mine spoil treated with municipal sewage sludge. Foliar levels of heavy metals exceeded those recommended for animal consumption. No plant toxicity symptoms were evident.

OXFORD: 114.449.8U628.36:114.26. KEY WORDS: cadmium, strip-mine, reclamation, forage, sewage.

Acid spoil banks resulting from strip-mining of coal pose a severe rehabilitation problem because of toxic concentrations of cations and droughty surface soils. Digested sewage sludge has been used as one means of creating a medium for establishing plant growth in Ohio, Pennsylvania, and Illinois. In Illinois, research has been conducted by the USDA Forest Service on the Palzo tract of the Shawnee National Forest near Crab Orchard, representative of about 4,900 ha of the highly acid spoil conditions in Illinois (Haynes and Klimstra 1975). Rehabilitation plans have been developed cooperatively with the Metropolitan Sanitary District of Greater Chicago to use liquid sludge on about 73 ha of nonvegetated land (Cunningham, R. *et al.* 1975).

Preliminary field studies of the ameliorating effects of sludge on acid mine spoil showed that lasting effects required at least 178 metric tons/ha for continued growth of test vegetation (Lejcher and Kunkle 1973). Greenhouse tests of higher dosage rates were begun in 1972 for evaluation of the chemical changes in percolating subsoil water (Cunningham, R. *et al.* 1975).

Tests of plant growth on agricultural soils that have received high dosages of sewage sludge indicate the need to maintain high pH values to reduce toxicity of metals on test plants. Suggested limits for total metal additions to soils, with a cation exchange capacity (CEC) greater than 15 m.e./100 g, are: Zinc 870 kg/ha, Copper 435 kg/ha, Cadmium 17 kg/ha (Sommers and Nelson 1976).

The use of sewage sludge for amelioration of phytotoxic conditions on acid spoils requires high dosages to alleviate acidity and reduce drought stresses, but is justified on highly acid spoil where the availability of micro-elements to plants might be expected to exceed plant tolerance limits.

COVER CROP TESTS

Greenhouse tests were conducted in 30.5 x 60.5 x 122 cm deep leaching chambers by the North Central Forest Experiment Station at Carbondale, Illinois. Dosages of 336 and 672 t/ha dry weight equivalent of sewage sludge were incorporated into the surface 12.5 cm of spoil to simulate field procedure. Lime was added at 0, 22.4, and 44.8 mt/ha rates with two replicate chambers for each treatment combination. Dosage rates of nutrients and metals in the sludge are listed below:

Sludge application rate t/ha	*336*	*672*
Element	Loading rate kg/ha	
N	7280	14560
P	6160	12320
K	1300	2600
Ca	11760	23520
Mg	4640	9280
S	4370	8740
Fe	18140	36270
Cu	250	500
Cr	1680	3360
Cd	70	140
Pb	770	1540
Ni	17	34
Zn	1144	2287

The sludge-treated chambers were leached with distilled water semi-monthly for 20 months. Percolating water was collected for analysis on a monthly basis. Results of analysis of this leachate are reported elsewhere (Cunningham, R. *et al.* 1975).

Four species of forage were planted at two planting dates in the leaching chambers according to the following schedule:

Species	*Date planted*	*Date harvested* 1	2	3
Rye (grain)	5/08/74	6/06/74		
Ky-31 Tall Fescue	6/10/74	1/02/75	3/31/75	6/3/75
Reed Canary Grass	5/08/74	7/22/74		
Sudan Grass	10/18/74	1/22/75	3/31/75	6/3/75

The 12 replicates of each sludge treatment were equally divided between the two species planted on each date. Three lime treatments were superimposed. The six chambers planted to rye were replanted to tall fescue after the rye was harvested. The chambers planted to reed canary grass were replanted to sudan grass. Three clippings from the second set of species were harvested on the dates shown.

Foliage was clipped about 2 cm above the soil surface. Root systems were pulled out, washed thoroughly with distilled water, and dried and weighed. Vegetation samples were dried to constant weight, weighed, and ground for analysis. Vegetative materials were analyzed at the Agronomy Lab, University of Illinois.

METHODS OF ANALYSIS OF PLANT TISSUE

Plant tissues were wet-ashed in Folin-Wu tubes using a 10 ml mixture of 5:1 HNO_3:$HClO_4$. The ashed samples were then analyzed for Ca, Mn, Zn, Cd, Cr, and Cu by atomic absorption with background correction for matrix effects. Total nitrogen analysis was done according to the procedure of Bremner (1965).

RESULTS

Application of sludge increased the cation exchange capacity of the soil (table 1). Peterson and Gschwind (1972) reported a CEC of Chicago sludge of 73 meq/100 g solids. pH values were increased by sludge applications. Reductions in acidity were measurable only to about 30 cm depths.

Table 1.--*Cation exchange capacity and pH of the spoil profile of the sludge-lime treatments*[1]

Spoil depth	Sludge application rates mt/ha 0	332	664
0-7.5 cm			
CEC	15-20 meq/100g	20-29	27-40
pH	2.5-3.0	5.0-5.6	5.5-5.7
7.5-15 cm			
CEC	16-17	20-23	23-27
pH	2.6-3.0	4.6-4.8	5.1-5.4
15-22.5 cm			
CEC	16-20	17	16-21
pH	2.7-2.8	2.6-3.1	3.3-4.3
22.5-30 cm			
CEC	14-17	15-17	15-18
pH	2.7-2.9	2.8-2.9	3.0-3.1

[1] Spindler, Dean R. 1976. Fate and effects of sewage sludge and lime on chemical characteristics of acid strip mine spoils. Unpublished M.S. thesis. Southern Illinois Univ., Carbondale, Illinois.

Concentrations of various nutrient elements are shown in table 2 for foliage and roots. Root systems extended to the depth of sludge incorporation, 12.5 cm. Root systems were generally higher in all trace metals except Mn than foliage. In general, higher dry matter production occurred on the 664 mt/ha treatment.

Sudan grass was a high accumulator of cadmium, especially at the high lime rates (table 3). Reed canary grass also accumulated cadmium at higher concentrations than

Table 2.--*Nutrient content of foliage and roots of forage crops grown on sludge amended spoils*

Species	Sludge level	Nutrient element concentration %				
	mt/ha	*Ca*	*Mg*	*K*	*P*	*N*
Rye foliage	332	0.79	0.71	2.65	0.67	3.70
	664	.82	.61	3.25	.58	4.23
Reed canary grass foliage	332	.54	.62	1.83	.37	2.87
	664	.65	.49	2.58	.41	2.77
Tall fescue foliage	332	.76	1.14	1.10	.60	2.77
	664	.90	.95	1.34	.57	3.39
Sudan grass foliage	332	.81	1.00	.77	.36	1.55
	664	.85	.71	1.05	.28	2.03
Rye roots	332	.39	.41	1.55	.63	2.92
	664	.39	.41	2.08	.65	3.12
Reed canary grass roots	332	.39	.28	.86	.54	2.13
	664	.40	.28	1.28	.61	2.15
Tall fescue roots	332	.67	.42	.43	.53	1.62
	664	.67	.45	.52	.63	1.91
Sudan grass roots	332	.45	.56	.34	.31	.87
	664	.49	.52	.40	.23	1.28
Average all spp. (foliage)	332	.72	.86	1.58	.50	2.72
	664	.80	.69	2.05	.46	3.27
Average all spp. (roots)	332	.47	.41	.79	.50	1.88
	664	.48	.41	1.07	.53	2.11

rye or fescue. Selection of these two forage crops for erosion control would also serve to retain metals on the site in the organic matter portion of the soil. Green manure management of sudan grass and reed canary grass would serve as an excellent method of holding cadmium in the surface soil to protect against leaching to ground water.

Zinc concentrations in foliage were consistantly reduced by higher lime rates. Cadmium concentrations showed no consistent relation to liming, except in sudan grass. The highest cadmium levels occurred at 332 mt/ha sludge treatment and 0 mt/ha lime rate. It is also interesting to note that uptake of cadmium by sudan grass, and to some extent by rye grass, always occurred at low sludge and lime treatment. This seems to indicate that the source of cadmium uptake is that which is indigenously present in the spoil materials. Laboratory analysis of spoils and roof shales from the area indicated the presence of sphalerite, a zinc sulfide ore, with cadmium sulfide as codeposits. This explains why uptake of zinc is always high at low lime and low sludge treatments.

Nitrogen levels in both foliage and roots were highest in the high (664 t/ha) sludge rate for each species.

Zinc and cadmium levels were comparable to those reported by Jones *et al.* (1975) on agricultural soils treated with sludge at similar rates. King and Morris (1972) found that liming reduced the concentrations of Mn, Cu, and Zn in rye foliage where natural soils were fertilized with high rates of sludge. On the acid spoils liming reduced Zn and Mn consistently but Cu was erratically affected. Yields tended to be reduced by high lime rates in soils treated with 664 mt/ha of sludge (significant from 0, 332). This is probably due to the catalytic effect of high pH on oxidation of pyrite which is resulted from higher rate of ferric (Fe III) formation (Singer 1970).

Repeated cropping by the same crop would be required to determine the trend in metal concentrations.

Table 3.--*Chemical composition and yield of foliage grown on sludge and lime amended spoil*

Species	Sludge rate	Lime rate	Yield	Mn	Zn	Cd	Cr	Cu	Cd/Zn
	t/ha	*t/ha*	*kg/ha*	- - -	- - -	- - - *ppm* - - -	- - -	- - -	%
Rye (annual)[1]	332	0	2383	223	554	6.4	9.0	12.0	1.2
		22.4	2489	171	424	6.6	15.5	17.5	1.5
		44.8	2391	169	244	3.5	4.5	21.5	1.5
	664	0	2950	186	358	4.9	4.5	12.0	1.4
		22.4	2692	168	292	3.9	4.0	10.5	1.3
		44.8	3290	173	210	3.1	4.0	10.0	1.5
Reed canary grass[1]	332	0	2428	308	710	3.1	6.5	15.5	0.4
		22.4	2325	303	602	5.5	8.0	17.5	0.9
		44.8	2729	248	449	5.3	5.0	14.5	1.2
	664	0	2342	273	686	7.1	7.5	17.5	1.0
		22.4	2532	310	591	6.8	6.0	15.0	1.1
		44.8	1993	218	572	6.5	7.0	14.0	1.1
Ky 31, tall fescue[2]	332	0	566	409	557	6.2	.83	15.6	1.1
		22.4	934	331	397	3.9	1.23	15.5	1.0
		44.8	1193	365	270	3.2	2.0	14.3	1.2
	664	0	1012	332	402	4.6	1.0	16.1	1.2
		22.4	1224	270	437	6.0	.93	11.1	1.4
		44.8	984	253	293	5.3	1.3	13.9	1.8
Sudan grass[2]	332	0	1124	370	787	18.4	.73	16.1	2.3
		22.4	1620	371	682	15.6	1.0	13.7	2.3
		44.8	2310	287	383	7.3	1.77	10.4	1.9
	664	0	2304	262	510	8.2	.83	14.8	1.6
		22.4	2330	250	423	9.6	1.2	11.9	2.3
		44.8	2290	185	362	8.5	1.13	11.0	2.3

[1] First crop on chamber.

[2] Second crop on chamber, mean of 3 clippings.

Leaching chambers not treated with sludge failed to produce any vegetative material for analysis. Lime treatments did not produce conditions amenable to growth of grasses without addition of sludge.

In selecting the best erosion control cover for the Palzo rehabilitation project, drought resistance must be considered as well as the factors discussed here. Rye offers the opportunity for dormant season cover as well as the lowest cadmium concentration in the foliage. A more drought-resistant species will be needed to maintain adequate ground cover during the summer months.

If a forage crop were to be selected for animal fodder on the basis of foliar cadmium concentration, rye would be the best choice although the levels are higher than those recommended for animal consumption (Melsted 1973). Although the two sludge rates were excessive in agricultural terms, crops did not show toxicity symptoms. If the use of the vegetation is to be limited to erosion control, reed canary grass offers the best trace element accumulation in the plant materials. Cadmium, zinc, and copper incorporated into plant tissues would be, at least temporarily, withheld from leaching to ground water or moving to streams by surface runoff.

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RESEARCH NOTE NC-222

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101
1977

JACK PINE AND ASPEN FOREST FLOORS IN NORTHEASTERN MINNESOTA

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ABSTRACT.--Chacteristics of upland forest floors under mature jack pine and aspen in northeastern Minnesota were investigated. These fuel measurements were needed as input for fire behavior prediction models--useful for fire management decisions. The forest floor weight averaged 33,955 kg/ha and depth averaged 7.1 cm. Bulk density averaged 17 kg/m^3 for the L (litter) layer, 45.7 kg/m^3 for the F (fermentation) layer, and 61.6 kg/m^3 for the H (humus) layer. The L layer was found to consist of 65 percent foliage, 31 percent wood and bark, 2 percent herbaceous vegetation, and 2 percent miscellaneous. No significant differences were found in weight, depth, or bulk density, except for the bulk density of the H layer, between the forest floors of jack pine and aspen.

OXFORD: 431.2(776) KEY WORDS: forest fuels, forest fire, fuel models.

Rothermel (1972) developed a fire behavior prediction model that is used for fire management decisions. To apply this model to the mature and overmature jack pine and aspen stands in the Boundary Waters Canoe Area (BWCA) of the Superior National Forest, it was necessary to determine the characteristics of the forest floor. Reported here are the weight, depth, and bulk density of the forest floor under these stands.

THE STUDY

Fifteen 0.2 hectare plots in mature jack pine and aspen stands were selected on the Kawishiwi Ranger District of the Superior National Forest in Lake County, Minnesota. These plots were representative of much of the area in the BWCA and showed no evidence of fire within the past 30 years. The stands were on gently rolling topography with shallow sandy loam soils and an occasional exposure of bedrock. Both the jack pine and the aspen stands were similar in age, basal area, and number of trees per hectare (Table 1). Field collections were made from late June through July 1976.

For each plot, 64 uniformly distributed, 12.7 cm diameter circular subsamples were selected to determine the estimated mean weight per hectare of forest floor materials. The estimated weights were determined from initial plots to be within 12 percent of the mean for the L layer, 13 percent of the mean for the F layer, and 17 percent of the mean for the H layer, all with 95 percent confidence limits. Similar material from all subsamples in a plot was then pooled for processing. All sample material was ovendried at 105 C. In addition, the H layer material was ashed in a muffle furnace at 590 C. The reported H layer weight is the loss by incineration. This procedure eliminated both mineral soil and ash from H layer weight. Cones, wood,

Table 1.--*Mean stand characteristics for mature jack pine and aspen forest cover types in northeastern Minnesota.*

Cover type[1]	Plots	Age		Basal area[2]		Trees ≥ 2.5 cm d.b.h.[3]	
		Years	Range	m^2/ha	Range	no/ha	Range
	No.						
Jack pine	9	83	70-105	18	14-24	680	282-1,406
Aspen	6	81	55-90	18	15-20	811	687-1,087
Combined: jack pine & aspen	15	82	55-105	18	14-24	731	282-1,406

[1] Cover types as described by Society of American Foresters (1954).
[2] Multiply m^2/ha by 4.356 to convert to ft^2/acre.
[3] Multiply no/ha by 0.405 to convert to no/acre.

and roots larger than 0.6 cm in diameter or thickness were excluded from the samples. Depth measurements were made at each of the 64 subsample points using the profile exposed by removing the forest floor material. Distinct separation of the forest floor layers was often difficult because there was a gradual rather than an abrupt transition. The most troublesome separation was between humus and mineral soil because a duff mull profile, that includes an A_1 horizon, was present occasionally. The top of the L layer was defined as the highest forest floor particle within 2.5 cm of the point where the profile was measured.

RESULTS

Total weight of forest floor in these stands averaged 33,955 kg/ha of which 2,937 kg/ha was litter (L) layer, 6,860 kg/ha was the fermentation (F) layer, and 24,158 kg/ha was the humus (H) layer. Forest floor total depth averaged 7.1 cm of which about one-fourth was litter. Bulk density averaged 17.0, 45.7, 61.6 kg/m^3 for the L, F, and H layers; respectively (Table 2).

By weight, the L layer contained 65 percent foliage (leaves and/or needles), 31 percent wood (twigs, bark), 2 percent herbaceous vegetation and 2 percent miscellaneous (small cones, flower parts, etc.).

Except for H layer bulk density, there were no significant differences (0.05 level) between the jack pine and aspen stands for weight, depth, or bulk density for any forest floor layer. Thus, all plots were combined. An average of 55 percent of H layer ovendry weight was subtracted as ash and soil.

Table 2.--*Forest floor weight, depth, and bulk density for mature jack pine and aspen forest cover types on shallow upland soils of northeastern Minnesota.*

Cover type[1]	Forest floor layer	Weight[2]		Depth[3]		Bulk density[4]	
		kg/ha	Standard error	cm	Standard error	kg/m^3	Standard error
Jack pine	L	3,031	278	1.7	0.06	18.2	1.67
	F	7,080	422	1.5	.09	48.2	1.85
	H	25,290	3,688	3.7	.38	66.6	3.14
	L+F+H	35,401	4,194	6.9	.50		
Aspen	L	2,794	238	1.8	.08	15.1	1.03
	F	6,532	572	1.6	.09	42.0	2.27
	H	22,460	3,762	4.1	.56	54.1	2.40
	L+F+H	31,786	4,510	7.5	.71		
Combined: Jack pine & aspen	L	2,937	189	1.7	.05	17.0	1.13
	F	6,860	336	1.5	.06	45.7	1.61
	H	24,158	2,612	3.9	.31	61.6	2.62
	L+F+H	33,955	3,026	7.1	.41		

[1] Cover types as described by Society of American Foresters (1954).
[2] All weights are ovendry; H layer weight is weight loss due to incineration; multiply kg/ha by 0.892 to convert to lb/acre.
[3] L layer depth measured from tip of highest leaf, needle, or twig; multiply cm by 0.393 to convert to in.
[4] Multiply kg/m^3 by 100 to convert to kg/ha/cm; multiply kg/m^3 by 0.062 to convert to lb/ft^3.

DISCUSSION

Normally a moisture gradient exists in the forest floor with moisture increasing with depth. This, together with increased bulk density, decreasing volatile content, and increasing ash and mineral content with depth, helps explain why forest floors resist complete consumption from fires. Even a high-intensity fire rarely consumes more than the L and F layers.

These weight estimates are for summer conditions. The L layer is the more responsive to seasonal changes; maximum amount is present after autumn leaf fall (Blow 1955, Loomis 1975) and minimum amount is present just before autumn leaf fall. The difference between maximum and minimum L layer forest floor weight would be approximately equal to annual litter production. Grigal and McColl (1975) reported total litter fall of 1,139 kg/ha/yr under northeastern Minnesota upland mature stands similar to those we studied but with a basal area of only 12.8 m^2/ha compared to the basal area of 18 m^2/ha of our plots. A general relation between annual litter production and latitude as presented by Bray and Gorham (1964) suggests that about 3,360 kg/ha/yr is produced. Litterfall was not measured in this study.

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USDA FOREST SERVICE

RESEARCH NOTE NC-223

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

PULPWOOD PRODUCTION IN THE LAKE STATES BY COUNTY, 1976

1977

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and Jerold T. Hahn, *Mensurationist*

ABSTRACT.--This 31st annual report shows 1976 pulpwood production by county and species group in Michigan, Minnesota, and Wisconsin. Production in these three Lake States climbed to 4.7 million cords from 4.1 million cords in 1975.

OXFORD: 861.0(77):792. KEY WORDS: residue, Minnesota, Wisconsin, Michigan.

Lake States pulpwood production rose to 4.69 million cords in 1976 from 4.14 million cords in 1975. Production increased 22 percent in Wisconsin to 1.84 million cords and 20 percent in Michigan to 1.54 million cords. Output in Minnesota fell 4 percent to 1.31 million cords.

Nine out of 10 cords were cut from roundwood, including chips from roundwood (table 1). The remainder was derived from mill residue such as slabs, edgings, veneer cores, and chips from those materials. Production from softwood and hardwood residue by State was:

State	*Softwood*	*Hardwood*
	Hundred standard cords	
Michigan	243	1641
Minnesota	335	658
Wisconsin	384	1291

All the increased output was from roundwood; use of Lake States wood residue for pulp fell slightly. Major increases from roundwood were in aspen (218,000 cords), elm (166,000 cords), birch (74,000 cords), pine (66,000 cords), and maple (61,000 cords). The continuing spread of Dutch Elm disease led to more than a 3-fold increase in elm harvesting for pulpwood; Wisconsin supplied 85 percent.

Increased harvesting occurred primarily in Michigan's Upper Peninsula and northern and central Wisconsin. Top-producing counties were St. Louis, Koochiching, and Itasca in Minnesota; Marinette, Oneida, and Price in Wisconsin; and Marquette Delta, and Iron in Michigan.

Pulpmills using Lake States timber in 1976 reported their pulpwood receipts by species groups and State and county of origin. Their cooperation is gratefully acknowledged. Thanks are also due the Michigan Department of Natural Resources for collecting the data from pulpmills in Michigan.

Table 1.--*Lake States pulpwood production from roundwood by county and species,*
(Hundred standard cords, roughwood basis)

MICHIGAN

UNIT[1] AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEMLOCK	TAMARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
E. UPPER PENINSULA												
ALGER	608	182	11	25	108	X	11	68	41	X	84	78
CHIPPEWA	384	199	30	37	30	X	2	52	6	X	15	13
DELTA	986	114	25	101	59	X	5	325	70	X	103	184
LUCE	467	191	38	71	56	X	5	23	21	X	31	31
MACKINAC	170	28	12	39	11	X	1	28	14	X	16	21
MENOMINEE	752	21	21	112	29	5	2	353	29	X	72	108
SCHOOLCRAFT	419	143	28	32	52	X	4	77	19	X	31	33
TOTAL	3786	878	165	417	345	5	30	926	200	X	352	468
W. UPPER PENINSULA												
BARAGA	274	39	7	7	41	X	2	126	9	1	30	12
DICKINSON	822	16	9	41	22	2	2	559	42	2	64	63
GOGEBIC	537	10	2	26	154	X	X	233	38	X	50	24
HOUGHTON	158	17	5	14	32	1	2	55	13	1	12	6
IRON	953	65	61	113	26	2	1	371	66	2	165	81
KEWEENAW	4	X	3	X	1	0	X	0	0	0	0	0
MARQUETTE	1123	274	51	98	132	1	15	242	88	3	160	59
ONTONAGON	404	10	2	8	34	X	2	168	37	1	98	44
TOTAL	4275	431	140	307	442	6	24	1754	293	10	579	289
N. LOWER PENINSULA												
ALCONA	414	26	X	2	X	0	0	225	13	109	24	15
ALPENA	170	6	3	7	X	0	0	101	9	9	25	10
ANTRIM	2	0	0	0	0	0	0	2	X	0	0	0
ARENAC	X	X	0	0	0	0	0	0	0	0	0	0
BENZIE	88	0	0	0	0	0	0	48	4	12	21	3
CHARLEVOIX	2	0	1	1	0	0	0	0	0	0	0	0
CHEBOYGAN	246	14	2	5	0	0	0	146	33	1	32	13
CLARE	212	13	0	0	0	0	0	154	4	26	13	2
CRAWFORD	232	168	0	0	0	0	0	21	2	32	7	2
EMMET	5	3	1	1	0	0	0	0	0	0	0	0
GLADWIN	53	0	0	0	0	0	0	38	2	7	5	1
GRAND TRAVERSE	96	29	0	0	0	0	0	44	4	10	6	3
IOSCO	174	143	0	0	0	0	0	16	4	2	8	1
ISABELLA	86	2	0	0	0	0	0	73	5	2	2	2
KALKASKA	95	38	0	0	0	0	0	29	4	11	11	2
LAKE	385	95	0	0	0	0	0	91	9	90	65	35
LEELANAU	42	X	0	0	0	0	0	12	X	12	13	5
MANISTEE	285	45	0	0	0	0	0	111	7	74	37	11
MASON	103	4	0	0	0	0	0	46	2	16	30	5
MECOSTA	221	48	0	0	0	0	0	103	8	38	13	11
MIDLAND	3	X	0	0	0	0	0	3	X	X	X	0
MISSAUKEE	88	14	0	0	0	0	0	51	3	6	11	3
MONTMORENCY	369	91	3	4	0	0	0	178	8	57	14	14
NEWAYGO	244	40	0	0	0	0	0	66	6	84	26	22
OCEANA	100	28	0	0	0	0	0	26	2	17	20	7
OGEMAW	37	4	0	0	0	0	0	22	2	6	3	X
OSCEOLA	165	21	0	0	0	0	0	83	5	23	18	15
OSCODA	387	114	X	X	0	0	0	179	15	51	20	8
OTSEGO	117	95	0	X	0	0	0	13	2	4	2	1
PRESQUE ISLE	265	48	4	8	0	0	0	137	36	3	19	10
ROSCOMMON	148	38	0	0	0	0	0	67	2	35	5	1
WEXFORD	433	273	0	0	0	0	0	76	1	44	34	5
TOTAL	5267	1400	14	28	X	0	0	2161	192	781	484	207
S. LOWER PENINSULA												
ALLEGAN	33	19	0	0	0	0	0	9	X	4	1	X
CASS	1	1	0	0	0	0	0	X	0	0	0	0
GRATIOT	9	X	0	0	0	0	0	9	X	X	X	0
KENT	34	13	0	0	0	0	0	17	X	2	1	1
MONTCALM	43	11	0	0	0	0	0	25	X	4	2	1
MUSKEGON	64	51	0	0	0	0	0	4	X	8	1	X
OTTAWA	9	9	0	0	0	0	0	0	0	0	0	0
TOTAL	193	104	0	0	0	0	0	64	X	18	5	2
STATE TOTAL	13521	2813	319	752	787	11	54	4905	685	809	1420	966

(CONTINUED ON NEXT PAGE)

[1] INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1976.
X=LESS THAN 50 CORDS.

MINNESOTA

UNIT 1/: AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
NORTHERN ASPEN-BIRCH												
CARLTON	379	42	2	20	0	5	0	267	43	0	X	0
COOK	382	48	102	39	0	0	0	193	0	0	0	0
KOOCHICHING	2507	194	644	153	0	153	0	1225	35	0	2	101
LAKE	791	210	218	85	0	1	0	241	36	0	0	0
ST.LOUIS	3026	546	328	138	0	34	0	1797	93	0	2	88
TOTAL	7085	1040	1294	435	0	193	0	3723	207	0	4	189
NORTHERN PINE												
AITKIN	357	13	17	11	0	34	0	246	18	9	4	5
BECKER	18	12	0	0	0	0	0	6	0	0	0	0
BELTRAMI	788	63	83	85	0	21	0	462	72	0	2	X
CASS	650	123	20	27	0	13	0	420	47	0	0	0
CLEARWATER	264	36	14	3	0	41	0	159	11	0	X	X
CROW WING	159	46	0	X	0	0	0	92	12	5	2	2
HUBBARD	372	93	4	3	0	11	0	236	25	0	0	0
ITASCA	1463	91	157	170	0	38	0	935	33	0	1	38
LAKE OF THE WOODS	219	46	105	1	0	4	0	63	0	0	0	X
MAHNOMEN	19	9	0	0	0	X	0	5	5	0	0	0
ROSEAU	201	54	61	X	0	5	0	76	5	0	0	X
WADENA	114	56	X	0	0	0	0	53	5	0	0	0
TOTAL	4624	642	461	300	0	167	0	2753	233	14	9	45
CENTRAL HARDWOOD												
BENTON	21	0	0	0	0	0	0	12	1	4	2	2
ISANTI	1	0	0	0	0	0	0	X	1	0	0	0
KANABEC	43	0	0	0	0	0	0	23	4	8	4	4
MILLE LACS	104	0	0	0	0	1	0	75	4	12	6	6
MORRISON	81	14	X	X	0	0	0	58	1	4	2	2
OTTERTAIL	4	4	0	0	0	0	0	0	0	0	0	0
PINE	109	13	0	1	0	0	0	85	10	0	0	0
TODD	7	7	X	0	0	0	0	0	0	0	0	0
TOTAL	370	38	X	1	0	1	0	253	21	28	14	14
PRAIRIE												
POLK	9	0	0	0	0	9	0	0	0	0	0	0
TOTAL	9	0	0	0	0	9	0	0	0	0	0	0
STATE TOTAL	12088	1720	1755	736	0	370	0	6729	461	42	27	248

(CONTINUED ON NEXT PAGE)

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1976.
X=LESS THAN 50 CORDS.

WISCONSIN

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
NORTHEASTERN												
FLORENCE	799	23	13	33	32	1	0	441	9	X	23	224
FOREST	877	37	34	135	44	3	0	362	50	X	101	111
LANGLADE	564	37	4	17	14	1	0	154	26	5	104	202
LINCOLN	871	24	13	26	22	5	0	397	51	16	79	238
MARINETTE	1255	106	16	79	18	2	X	873	92	X	30	39
OCONTO	319	69	2	12	4	1	0	212	12	1	4	2
ONEIDA	1169	111	45	201	16	7	0	463	147	17	99	63
SHAWANO 2/	375	15	X	1	82	X	0	170	10	X	31	66
VILAS	897	131	12	108	42	X	0	379	102	8	52	63
TOTAL	7126	553	139	612	274	20	X	3451	499	47	523	1008
NORTHWESTERN												
ASHLAND	758	76	15	91	23	1	0	346	51	4	79	72
BARRON	5	5	0	0	0	0	0	0	X	X	X	X
BAYFIELD	915	130	2	28	2	0	0	601	125	4	13	10
BURNETT	315	289	0	0	0	0	0	24	X	0	1	1
DOUGLAS	527	226	1	3	0	X	0	256	37	0	2	2
IRON	679	8	6	26	14	0	0	483	47	5	24	66
POLK	8	8	0	0	0	0	0	0	0	0	0	0
PRICE	986	14	8	55	17	5	0	443	102	10	95	237
RUSK	299	X	1	5	7	X	0	94	45	9	40	98
SAWYER	676	78	4	30	9	X	0	279	80	6	74	116
TAYLOR	523	7	4	16	20	2	0	174	52	10	77	161
WASHBURN	524	120	X	1	0	0	0	377	19	X	4	3
TOTAL	6215	961	41	255	92	8	0	3077	558	48	409	766
CENTRAL												
ADAMS	431	360	0	0	0	1	0	X	1	63	3	3
CHIPPEWA	295	5	0	X	2	2	0	88	35	65	50	48
CLARK	207	25	0	X	2	0	0	38	6	108	16	12
EAU CLAIRE	50	48	0	0	0	0	0	2	X	X	X	X
JACKSON	198	172	0	0	0	1	0	1	2	14	5	3
JUNEAU	238	175	0	0	0	X	0	6	2	44	6	5
MARATHON	869	30	6	19	57	X	0	93	20	26	102	516
MARQUETTE	59	21	X	0	0	0	0	X	2	2	15	19
MONROE	65	57	0	0	0	0	0	1	1	0	3	3
PORTAGE	173	84	X	X	1	0	0	19	1	52	7	9
WAUPACA	148	13	0	X	X	0	0	105	3	X	9	18
WAUSHARA	100	75	0	0	X	1	0	9	2	9	3	1
WOOD	364	173	X	0	2	X	0	24	5	131	14	15
TOTAL	3197	1238	6	19	64	5	0	386	80	514	233	652
SOUTHWESTERN												
BUFFALO	X	X	0	0	0	0	0	0	0	0	0	0
CRAWFORD	29	0	0	0	0	0	0	X	X	6	11	12
DUNN	15	15	0	0	0	0	0	0	0	0	0	0
GRANT	5	X	0	0	0	0	0	X	X	1	2	2
IOWA	1	1	0	0	0	0	0	0	0	0	0	0
LACROSSE	11	11	0	0	0	0	0	0	0	0	0	0
PEPIN	X	X	0	0	0	0	0	0	0	0	0	0
RICHLAND	1	1	0	0	0	0	0	0	0	0	0	0
SAUK	14	14	0	0	0	0	0	0	0	X	0	0
TREMPEALEAU	5	5	0	0	0	0	0	0	0	0	0	0
TOTAL	81	47	0	0	0	0	0	X	X	7	13	14
SOUTHEASTERN												
BROWN	2	2	0	0	0	0	0	X	0	0	0	0
COLUMBIA	24	11	0	0	0	0	0	0	1	8	2	2
DANE	3	3	0	0	0	0	0	0	0	0	0	0
DODGE	X	0	0	0	0	0	0	0	0	X	0	0
GREEN	11	11	0	0	0	0	0	0	0	0	0	0
GREEN LAKE	X	X	0	0	0	0	0	0	0	X	0	0
JEFFERSON	1	0	0	0	0	0	0	0	0	1	0	0
OUTAGAMIE	30	4	0	0	0	0	0	17	3	0	4	2
ROCK	9	9	0	0	0	0	0	0	0	0	0	0
WAUKESHA	23	23	0	0	0	0	0	0	0	0	0	0
TOTAL	103	63	0	0	0	0	0	17	4	9	6	4
STATE TOTAL	16722	2862	186	886	430	33	X	6931	1141	625	1184	2444

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1976.
2/ INCLUDES MENOMINEE COUNTY.
X=LESS THAN 50 CORDS.

RESEARCH NOTE NC- 224

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101
1977

RED PINE SEEDLING ESTABLISHMENT AFTER SHELTERWOOD-STRIP HARVESTING

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and **Alvin A. Alm**, *Associate Professor*
College of Forestry, University of Minnesota
Cloquet, Minnesota

ABSTRACT.—Shelterwood-strip harvesting in a mature red pine stand provided favorable growing conditions for red pine seedlings established by planting nursery stock, by planting 10-week-old to 1-year-old tubelings, and by direct seeding. How long the shelterwood-strips can be left standing before they seriously affect seedling development remains to be determined.

OXFORD: 221.223:232:174.7(77) *Pinus resinosa.*
KEY WORDS: regeneration, planting, seeding, tubelings, visual quality.

A shelterwood-strip harvesting method was tested in 1970 in a 100-year-old red pine (*Pinus resinosa* Ait.) stand on the Cutfoot Experimental Forest in north-central Minnesota (Benzie and Zasada 1972). The method was designed to harvest mature timber, prepare the site for regeneration, provide environmental conditions to favor tree growth, and maintain the visual quality of the landscape.

The shelterwood-strip method resulted in a pattern of clearcut strips 50 feet wide and uncut shelterwood-strips 16 feet wide (fig. 1). Some strips were oriented north-south and some east-west; all led to a common landing. Full-tree harvesting was used—trees were felled into the cut strips and skidding was confined to the cut strips. Limbing was done at the landing and the slash was piled and burned. Unmerchantable trees were cut, skidded, and burned with the slash to prepare the area for establishing a new red pine stand.

Figure 1. — *Shelterwood-strip harvesting in red pine provided good environmental conditions for seedling establishment.*

ESTABLISHING REGENERATION

During good seed years the trees left in the shelterwood-strips could supply up to a quarter of a million seeds per acre, but 1970 was a poor seed year and less than a thousand seeds per acre were produced. The 1-year-old conelets that would produce the 1971 seed crop were also poor. Therefore, 3-0 red pine seedlings, three age classes of red pine tubelings,[1] and untreated red pine seed were planted in the spring of 1971. At the time of planting the tubelings were 10 weeks, 16 weeks, and 1 year from date of seeding. The bare-root seedling stock was hand-planted without additional site preparation but tubeling and direct seeding planting sites were hand-scalped.

A row of nursery stock seedlings, tubelings, and a direct-seeded plot were established along each long edge and in the center of four north-south strips and four east-west strips. Each row had 10 nursery-grown seedlings, 10 tubeling seedlings from each of the 3 age classes, and 1 direct-seeded plot. This planting scheme resulted in a total of 240 nursery stock seedlings, 240 tubelings of each age class, and 24 seeded plots. Most of the seeded plots failed the first year and were reseeded the following spring.

SURVIVAL AND HEIGHT OF REGENERATION

Mean survival on the north-south strips was higher than on the east-west strips after 6 years, but the differences were not significant (table 1). Conversely, height growth was slightly greater on the east-west strips than on the north-south strips but again the differences were not significant.

Differences in survival and height by locations within the strips varied but generally survival was lower and height greater on portions of the strips that received longest exposure to midday sun. Survival was generally higher on the west edges of north-south strips and on the south edges of east-west strips. Height growth was generally greater on the north edge of east-west strips and on the east edge of north-south strips (table 2). The center plots had good height growth for both east-west and north-south strips.

Highest survival was obtained with 1-year-old tubelings. It was significantly higher than survival of the 3-0 nursery seedlings but not significantly higher than that of the 16-week-old tubelings. The survival of the 10-week-old tubelings was significantly lower than any of the other regeneration methods except direct seeding The differences in survival between tubeling age classes are similar to those previously found after three growing seasons (Alm 1974). The recommended 16-week mini mum cultural period for red pine tubelings is still valid after six growing seasons.

Direct seeding tree percent (number of surviving seedlings-per 100 viable seeds sown) was lower than th expected 5 to 10 percent.[2] So, under these condition about 39,000 seeds (approximately 3/4 pound) woul be required to establish 1,000 6-year-old seedlings pe acre.

The majority (62 to 68 percent) of the trees die during the first winter and the first two growing season

Table 1. — *Mean survival and height of red pine after 6 years by regeneration method and strip orientation*

Regeneration method	North-south strips: Survival	North-south strips: Height	East-west strips: Survival	East-west strips: Height
	percent	*feet*	*percent*	*feet*
3-0 seedlings	61	2.1	54	2.3
1-year tubelings	78	1.1	75	1.4
16-week tubelings	72	0.8	62	1.1
10-week tubelings	47	0.6	35	0.8
Direct seeding[1]	3	0.5	2	0.5

[1] Direct seeding survival is tree percent (seedlings per 100 live seeds sown). Seven plots in the north-south strip and eleven plots in the east-west strips had tree percents less than 3 the first year and were reseeded the spring of the second year.

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[1] *Seedlings were grown in 9/16-inch diameter, 3-inch long plastic tubes (Ontario tubes).*

[2] *Benzie, John W. 1965. Small plot direct seedin trials. Unpublished report on file at North Central Fore Experiment Station, Grand Rapids, Minnesota.*

Table 2. — *Mean survival and height of red pine after 6 years by regeneration method and location within strip*

Location	Regeneration method									
	3-0 seedlings		Tubelings						Direct seeding	
			1-year		16-week		10-week			
	Percent	*Feet*	*Percent*	*Feet*	*Percent*	*Feet*	*Percent*	*Feet*	*Percent*[2]	*Feet*
West Edge[1]	55	1.8	90	0.9	88	0.7	50	0.6	3	0.4
East Edge	70	2.2	80	1.0	72	1.0	48	.7	4	.4
South Edge	62	1.9	75	1.2	82	.8	38	.6	3	.4
North Edge	42	2.2	72	1.3	50	1.1	28	1.1	1	.4
Center	58	2.5	72	1.4	52	1.2	42	.6	4	.7
Mean[3]	58b	2.2e	78a	1.2f	69ab	1.0f	41c	.7g	3d	.5g

[1] East and west edges are on north-south strips, north and south edges are on east-west strips and the center plots include both strip directions.

[2] Direct seeding survival is tree percent (seedlings per 100 viable seeds sown).

[3] Means followed by the same letter do not differ significantly at the 0.01 level.

(1971-72). The major cause of death was smothering by leaves and other vegetation. Also, many seedlings were killed as a result of heavy deer activity in the cut strips.

Differences in height between regeneration methods were significant. As expected, the 3-0 seedlings were taller than all others. The next largest seedlings were the 1-year-old tubelings followed closely by those 16 weeks old. The 10-week-old tubelings and the direct-seeded seedlings were the smallest.

Red pine seedling establishment and early growth after harvesting by the shelterwood-strip method indicates generally favorable growing conditions within both north-south and east-west strips for all regeneration methods tested. Therefore use of the shelterwood-strip method need not be limited to a particular orientation of the strips. How long the shelterwood-strips can be left before they seriously affect seedling development remains to be determined.

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☆U. S. GOVERNMENT PRINTING OFFICE: 1978--767758/67 REGION NO. 6

USDA FOREST SERVICE

RESEARCH NOTE NC-225

IORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

1977

ROOT-CROWN RELATIONS OF YOUNG SUGAR MAPLE AND YELLOW BIRCH

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Marquette, Michigan

ABSTRACT.—Young forest-grown sugar maple and yellow birch (1 to 6 inches d.b.h.) crowns were mapped and roots excavated. Crown dimensions were compared. Sugar maple roots usually terminated within a few feet of the crown perimeter. Yellow birch roots frequently terminated well outside crown perimeters and roots of birch were more irregularly distributed than those of maple.

OXFORD: 181.62:181.36.
KEY WORDS: sugar maple, yellow birch, root distribution, crown dimension.

The trend toward more intensive culture of northern hardwoods has made it desirable to know more about root distribution of individual trees. Knowledge of root distribution can be used both in fertilizer application and in thinning. Also crown perimeter frequently is used to gauge thinning intensity and area of fertilizer application. This investigation sought to find a relation between crown perimeter and root extent and to also describe horizontal root distribution.

METHODS

During the summer of 1975, the roots of 18 randomly chosen sugar maple and 18 yellow birch, ranging from 0.85 to 5.97 inches d.b.h. were excavated from a fully stocked stand that originated from a clear-cut in 1963. Soils were sandy loam podsols with a cemented layer at about 2 feet. Following the general method of Hannah (1972) all large lateral roots were excavated for their full length and diagrammed; crown perimeters were measured and diagrammed on the same map. Root length was considered to be the straight line distance from the end of the root to the tree stem. Average root length was calculated from the four longest roots. The average crown radius was calculated using the radii at cardinal points. Trees were cut and total heights measured.

RESULTS

Root-crown-stem Size Relations

Most tree characteristics were closely related (table 1). Diameter breast height was well related to total height, average crown radius, and average root length. In turn, these characteristics are well related to each other. Crown radius was only slightly better related to the logarithm of d.b.h. than to d.b.h.; average yellow birch root length was better related to the logarithm of crown width than with actual data.

Small increases in stem diameter of both species were associated with disproportionately greater root lengths (fig. 1) in the smallest size classes; also small changes in crown radius of yellow birch were related to disproportionately large changes in root lengths (fig. 2). Average sugar maple root lengths and average crown radius were surprisingly close to a one-to-one ratio regardless of tree size. Average root lengths tend to exceed average crown widths in the smallest size classes (0.5 to 1.5 d.b.h.). Trees larger than 1.5 d.b.h. tended to have roots less than the average crown width. In general, the longest sugar maple roots were a few feet outside the perimeter.

Table 1. – *Coefficients of correlations between various characteristics of sugar maple and yellow birch sapling and poles*

Characteristics	Sugar maple				Yellow birch			
	Total height	Average crown radius	Longest root	Average root	Total height	Average crown radius	Longest root	Average root
D.b.h.	0.91	0.91	0.38	0.71	0.94	0.90	0.67	0.67
Log d.b.h.	--	.93	--	.80	--	.89	--	.85
Total height	--	.83	.40	.68	--	.69	.48	.74
Average crown	--	--	.51	.84	--	--	.69	.69
Longest crown	--	--	.76	--	--	--	.55	--
Average crown	--	--	--	--	--	--	--	.74

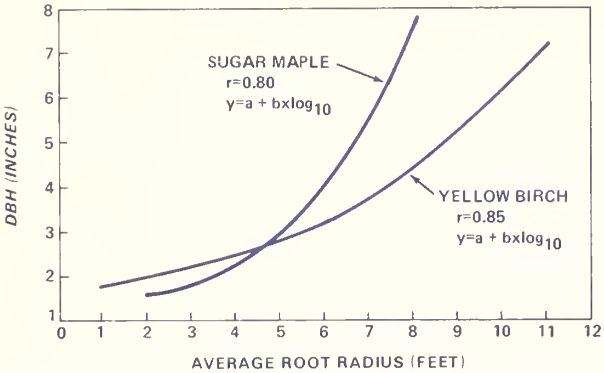

Figure 1. – *Average root length vs. diameter breast height for yellow birch and sugar maple.*

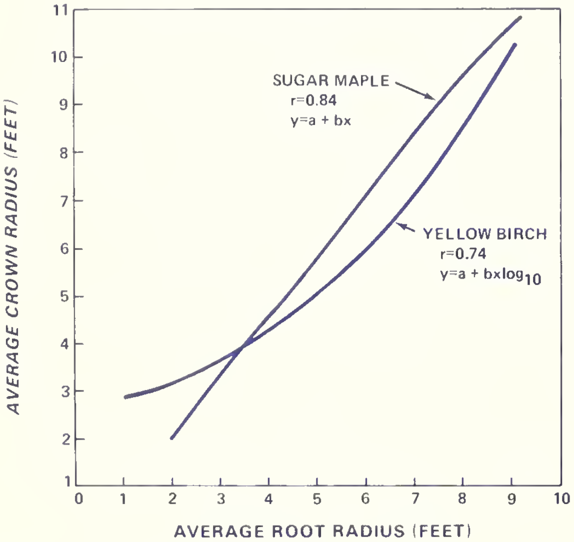

Figure 2. – *Yellow birch and sugar maple average root lengths vs. crown radius.*

For example, the data shows that the longest roots o trees with a 2.5- to 3-foot crown radius were about 4. feet in length.

The ratio of root length to crown radius in yello birch was generally less than 1:1 in the smallest siz classes (up to 2 inches d.b.h.), but about 1:1 in th larger size classes.

Root Distribution

Crown maps were divided into segments each equalli an 8th of a circle whose center was the tree ster Boundaries of the segments were compass directions (to NE, NE to E, etc.). The number of segments in whi roots fell were counted to provide an estimate distribution. Most yellow birch had short roots in segments, but no tree had long roots (2 feet or longer) all segments. Nine trees had roots in only 50 percent the segments. There seemed to be no relation betwe root distribution and other tree characteristics.

Twelve of the 15 birch had roots extending beyo the actual crown perimeter. Of these, three trees had examined roots terminating beyond the crown and ni trees had roots terminating both within and beyond t crown.

Fifteen of the 16 maple had one or more ro extending beyond the actual crown perimeter. In m cases these roots did not extend more than 2 or 3 f beyond the crown (in contrast to the birch whose ro occasionally grew 8 or 10 feet beyond). Seven maple inch in d.b.h. had 50 percent or fewer of the segme penetrated by roots. The larger trees had better dis buted root systems.

The vertical distribution of roots was not measured but variations from the typical were noted. Several birch and maple had sinker roots which grew straight down for some distance. One maple originated from a root sucker.

The actual distribution of the root mass in relation to the crown mass appeared to be much more variable in birch than in maple, as the previous data suggest. Maple crowns seemed to be more regular and roots were fairly evenly distributed (fig. 3). In contrast, birch crowns seemed quite irregular in shape and roots frequently were mostly on one side or other of the tree (fig. 4). Inspection of the maps of both species suggested that if the crown mass was off center from the stem, then the roots tended to fill in that part of the circle not occupied by the crown. This tendency is accentuated in leaning trees. The roots of leaning trees of both species always grew away from the direction of lean (and crown mass) as if to offset the imbalance created by the stem and crown (fig. 5).

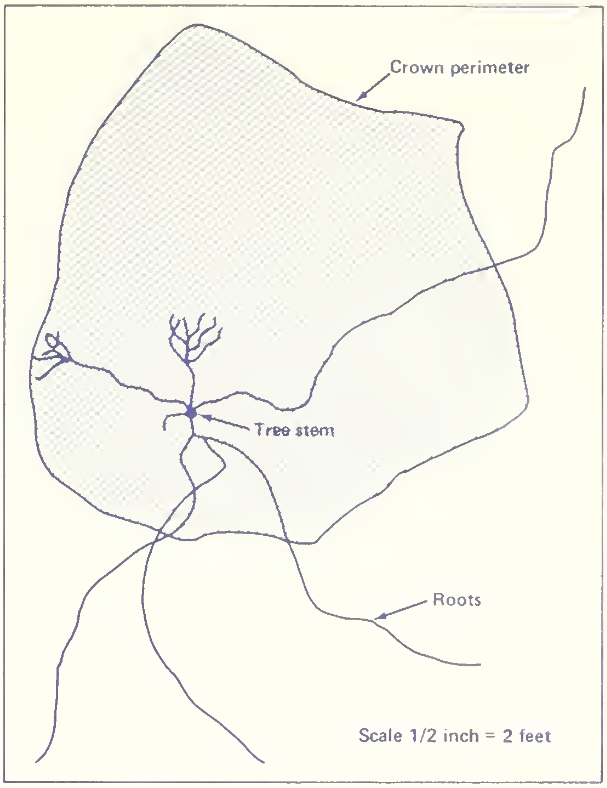

Figure 4. – *Yellow birch (5.3 inches d.b.h.) with irregular crown and root distribution.*

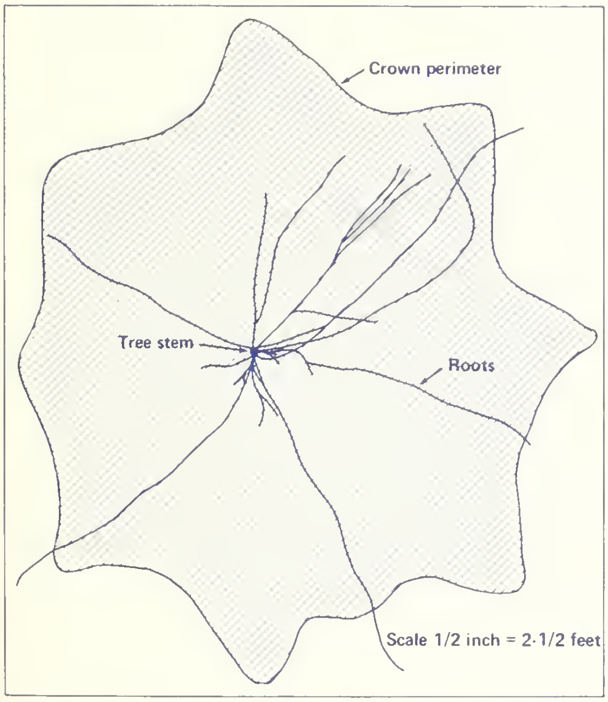

Figure 3. – *Sugar maple (4.3 inches d.b.h.) with regular crown shape and well-distributed root system.*

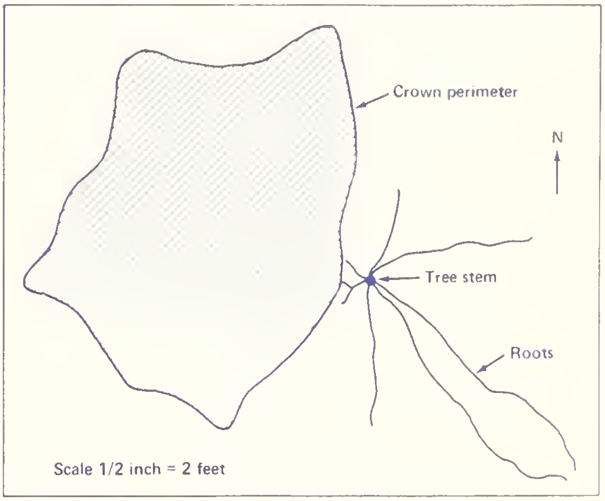

Figure 5. – *Yellow birch (1.4 inches d.b.h.) leaning toward west illustrating direction of root mass.*

DISCUSSION AND SUMMARY

Because these trees were growing in an unthinned stand and were chosen more or less randomly on the basis of diameter, most were probably suppressed to some degree. Generally, this reduction in photo-synthetic capability would result in relatively poor root growth; more open grown trees might not show the relations noted in this study. This possibility seems greatest with yellow birch; the smaller and more likely to be suppressed trees had roots which ended close to the crown perimeter, while trees more than 2 inches d.b.h. grew roots which on the average ended well beyond the crown perimeter.

Sugar maple roots in the seedling stage, on the other hand, do not respond to reduction in light (Logan 1965) and appeared to be less suppressed in this study than yellow birch. Maple roots seemed sparse under the smallest trees and this may be internally regulated or the result of some suppression.

In contrast to red pines (Day 1941, Stiehl 1970) whose roots are so widespread that individual tree thinning has little effect, forest grown yellow birch and sugar maple have fairly regular root distributions. Distribution is irregular enough however, that it is probably a significant cause of variation between trees in thinning studies, and warrants some caution in thinning and fertilization. Fertilizing done under the crown of a leaning tree may miss the roots entirely (fig. 5) and carefully weighed and evenly distributed fertilizer may be only partially effective because of irregular root distribution.

Measurements were not made of the influence of surrounding trees on root distribution. It seems noteworthy, however, that irregularities in crowns presumably caused by competitors were not necessarily copied by roots.

In summary, the average lengths of the main roots of yellow birch was greater than average crown length, especially in the smaller trees. The horizontal distribution of birch roots in relation to crowns was irregular and crowns were often irregularly shaped. Longest roots frequently were well outside crown perimeters.

Average sugar maple root area coincided closely to crown areas and longest roots frequently were within a few feet of the crown perimeter. The horizontal distribution of maple roots was fairly regular as were crowns.

Roots of both species were distributed away from the direction of lean of the tree.

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RESEARCH NOTE NC-226

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101
1977

BIOMASS ESTIMATION FOR SOME SHRUBS FROM NORTHEASTERN MINNESOTA

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ABSTRACT.--Biomass prediction equations were developed for 23 northeastern Minnesota shrub species. The allometric function was used to predict leaf, current annual woody twig, stem, and total woody biomass (dry grams), using stem diameter class estimated to the nearest 0.25 cm class at 15 cm above ground level as the independent variable.

OXFORD: 182.46:182.5(776). KEY WORDS: wildlife habitat, nonlinear regression analysis, allometric relations, dry weight, browse estimation.

A recent study (unpublished) to quantitatively describe a series of pine plantations in northeastern Minnesota as white-tailed deer and snowshoe hare habitat placed special emphasis on woody plants as potential browse. The descriptive information included shrub density and basal area. To estimate the browse represented by these data, equations were needed to determine the biomass of leaf and current annual woody-twig growth for each species. Reported here are the data collected and the resulting regression equations developed to produce the needed estimates. These equations should be useful to land managers, game managers, and other researchers who need to estimate biomass values for these species within the northern Lake States region.

For each of the major shrub species found in the plantations, stems spanning the size range were collected during the last half of August 1976. In the plantation study, shrub diameters had been determined to the nearest 0.25 cm at 15 cm above ground level. In sampling for the biomass estimation equations, we attempted to collect individuals from the lowest, highest, and middle size class for each species. Thus, if a species occurred in the study in size classes 1 (0 to 0.25 cm) through 7 (1.50 to 1.75 cm), we selected a minimum of three typical stems within each of three size classes spanning that range: for example, size class 1, 4 (0.75 to 1.00 cm), and 7. For shrubs with small diameters, such as Rosa blanda, we selected only stems within the lowest three size classes.

The stems were selected in the field, clipped at ground level, and taken to the laboratory where the leaves and current annual woody-twig growth were each separated from the remainder of the woody stem. Each component of each stem was bagged separately and dried at 70 C to constant weight. Each component was weighed to the nearest 0.01 gram immediately after removal from the oven.

Because of dry weather during the summer of 1976, some shrub stems had lost a portion of their leaves by late August. In those cases no leaf data were collected and the number of leaf biomass observations used in the leaf biomass regressions was reduced.

The independent variable, stem diameter size class; and each dependent variable-leaf, current annual woody-twig, stem, and total woody biomass were summarized for each species (table 1).

The numerical value used for stem diameter was the upper end of the diameter class range. Stems 0.50 to 0.75 cm diameter, for example, were considered to be 0.75 cm diameter in the data summary.

In earlier work estimating biomass of five shrub species from northeastern Minnesota, we found that shrub biomass data conformed to the allometric function as well as or better than they did to alternative functional relations (Ohmann, Grigal, and Brander 1976)[1].

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[1] *Ohmann, L. F., D. F. Grigal, and R. B. Brander. 1976. Biomass estimation for five shrubs from northeastern Minnesota. USDA For. Serv. Res. Pap. NC-133, 11 p. North Cent. For. Exp. Stn., St. Paul, MN 55108.*

Table 1.--*Dimensional data for*

	Acer rubrum	*Acer spicatum*	*Alnus crispa*	*Alnus rugosa*	*Amelanchier* spp.	*Betula papyrifera*	*Cornus rugosa*	*Corylus cornuta*	*Lonicera canadensis*	*Lonicera hirsuta*
Independent variable										
Stem diameter class (cm)										
Number of observations	10	27	26	15	27	10	9	43	9	13
Mean	1.17	1.17	1.14	.90	1.17	1.23	1.00	1.08	.75	.69
Standard deviation	.51	.52	.52	.53	.52	.55	.43	.53	.43	.27
Standard error	.16	.10	.10	.14	.10	.17	.14	.08	.14	.38
Range	.50-1.75	.50-1.75	.50-1.75	.50-1.75	.50-1.75	.50-1.75	.50-1.50	.50-1.75	.25-1.25	.25-1.00
Dependent variables										
Leaf biomass (dry grams)	---									
Number of observations		11	25	12	14	4	9	9	4	10
Mean		4.33	9.51	6.04	8.62	3.11	11.41	15.46	2.33	2.34
Standard deviation		11.79	9.18	8.64	6.75	4.33	10.35	15.75	1.52	2.86
Standard error		3.56	1.84	2.49	1.80	2.16	3.45	5.25	.76	.91
Range		.01-39.44	.07-27.00	.15-29.08	.05-19.95	.62-9.57	1.32-27.17	.11-36.21	.16-3.68	.18-9.29
Current annual twig (dry g)										
Number of observations	10	27	26	15	27	10	9	43	9	13
Mean	1.04	2.48	2.73	5.02	2.31	4.34	2.42	2.76	.97	1.15
Standard deviation	.72	2.49	3.31	6.31	2.52	6.85	2.03	2.92	.92	1.36
Standard error	.23	.48	.65	1.63	.49	2.17	.68	.45	.31	.38
Range	.10-2.39	.12-10.83	.18-12.67	.36-19.80	.01-8.26	.51-23.23	.25-5.58	.12-10.30	.06-2.50	.06-4.62
Stem (dry grams)										
Number of observations	10	27	26	15	27	10	9	43	9	13
Mean	69.62	87.99	78.69	43.38	89.39	76.30	48.18	88.23	19.49	19.24
Standard deviation	73.00	87.81	77.76	63.38	84.50	81.78	50.14	102.96	19.69	22.14
Standard error	23.09	16.90	15.25	16.36	16.26	25.86	16.71	15.70	6.56	6.14
Range	.81-207.11	.34-345.90	.34-268.00	.36-171.40	.48-258.72	.51-247.69	1.30-131.57	.57-380.75	.27-52.52	.20-65.20
Total woody (dry grams)										
Number of observations	10	27	26	15	27	10	9	43	9	13
Mean	70.66	90.47	81.41	48.39	91.70	80.65	50.60	91.00	20.46	20.39
Standard deviation	73.50	89.10	78.74	68.93	86.07	83.38	52.12	105.66	20.54	23.02
Standard error	23.24	17.15	15.44	17.80	16.56	26.37	17.37	16.11	6.85	6.38
Range	.94-208.19	.66-351.90	1.05-271.00	.72-181.37	.96-259.83	1.02-251.62	1.55-137.15	.60-391.05	.54-54.86	.27-66.98

Table 2.--*Regressions for estimation of biomass of*

Regression factors on stem diameter class (cm) (X)	*Acer rubrum*	*Acer spicatum*	*Alnus crispa*	*Alnus rugosa*	*Amelanchier* spp.	*Betula papyrifera*	*Cornus rugosa*	*Corylus cornuta*	*Lonicera canadensis*	*Lonicera hirsuta*
Leaf biomass (dry grams) (Y)	---									
a		2.869	5.650	3.123	5.432	3.421	8.616	4.808	6.592	3.926
b		3.669	2.222	3.071	2.008	1.838	2.541	3.571	2.681	1.163
R^2		.608	.748	.718	.875	.990	.940	.991	.901	.242
S y.x		7.788	4.706	4.815	2.486	.524	2.701	1.568	.586	2.644
Probability of larger F value		.005	.005	.005	.005	.010	.005	.005	.100	NS
Current annual woody twig biomass (dry g)										
a	0.7676	2.174	2.349	4.122	1.510	.588	1.813	1.196	1.325	1.974
b	1.4903	1.008	1.119	2.318	1.870	4.802	2.478	3.070	1.866	1.571
R^2	.724	.260	.196	.815	.426	.282	.946	.774	.801	.281
S y.x	.4021	2.186	3.028	2.815	1.947	6.155	.506	1.406	.440	1.208
Probability of larger F value	.005	.010	.025	.005	.005	NS	.005	.005	.005	.100
Stem biomass (dry grams)										
a	21.0780	41.074	37.137	27.452	36.439	22.260	30.648	36.858	26.766	44.156
b	3.6892	2.706	2.772	3.122	2.995	3.452	3.184	3.272	2.180	3.578
R^2	.908	.779	.845	.985	.922	.717	.955	.845	.930	.684
S y.x	23.5026	42.107	31.242	8.069	24.132	46.119	11.340	41.061	5.566	13.006
Probability of larger F value	.005	.005	.005	.005	.005	.005	.005	.005	.005	.010
Total woody biomass (dry grams)										
a	21.7300	43.660	39.684	31.328	37.909	22.865	32.421	38.031	28.090	46.002
b	3.6535	2.630	2.696	3.050	2.963	3.502	3.152	3.267	2.166	3.402
R^2	.911	.778	.855	.991	.924	.764	.957	.847	.931	.678
S y.x	23.3043	42.776	30.571	6.824	24.158	42.982	11.590	41.881	5.759	13.635
Probability of larger F value	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005

[1] *All the woody growth was determined to be current annual. Stem and total woody biomass regressions were identical to current twig.*

In this study, then, the data for each species-variable combination were subjected to an iterative nonlinear, least squares regression analysis using the allometric relation

$$Y=aX^{b} \quad (1)$$

where Y is the biomass in grams dry weight of the dependent variable and X is the shrub diameter in cm at 15 cm above ground. The regressions were tested for significance using a standard F-test.

The resultant equation elements are presented in table 2.

cies from northeastern Minnesota

s oides	*Prunus pensylvanica*	*Prunus virginiana*	*Rhamnus alnifolia*	*Ribes* spp.	*Rosa acicularis*	*Rosa blanda*	*Rubus parviflorus*	*Rubus strigosus*	*Salix* spp.	*Sorbus americana*	*Viburnum rafinesquianum*
	9	9	6	9	8	9	9	11	9	9	9
	1.17	.75	1.08	.50	.53	.50	.50	.48	1.17	1.17	1.00
	.54	.43	.49	.22	.21	.22	.22	.21	.54	.54	.43
	.18	.14	.20	.07	.07	.07	.07	.06	.18	.18	.14
	.50-	.25-	.50-	.25-	.25-	.25-	.25-	.25-	.50-	.50-	.50-
	1.75	1.25	1.75	.75	.75	.75	.75	.75	1.75	1.75	1.50
	3	4	6	9	8	9	9	11	9	3	8
	.68	2.33	5.66	.30	1.06	1.07	1.17	.87	15.57	.26	11.08
	.43	1.52	6.21	.34	.73	1.10	1.04	1.09	16.49	.40	12.27
	.25	.76	2.54	.11	.26	.37	.35	.33	5.50	.23	4.34
	.26-	.16-	.32-	.08-	.24-	.14-	.10-	.10-	.37-	.01-	.46-
	1.11	3.68	17.24	1.14	2.19	3.69	3.17	3.64	43.28	.72	33.96
	9	9	6	9	8	9	9	11	9	9	9
	2.57	.97	1.91	.11	.48	.64	1.41	.15	2.08	3.41	2.60
	1.80	.92	2.06	.09	.44	.61	1.40	.13	1.83	4.16	3.30
	.60	.31	.84	.03	.16	.20	.47	.04	.61	1.39	1.10
	.72-	.06-	.11-	.01-	.12-	.09-	.07-	.03-	.46-	.01-	.20-
	6.13	2.50	5.23	.23	1.28	1.78	3.62	.48	5.72	11.73	9.48
	9	9	6	9	8	9		11	9	9	9
	97.74	75.67	51.91	2.59	2.54	3.32	---	1.17	109.34	83.60	82.89
	89.27	68.67	54.01	3.64	2.36	4.13		1.61	131.46	99.72	95.10
	29.76	22.89	22.05	1.21	.83	1.38		.49	43.82	33.24	31.70
	1.19-	.70-	1.10-	.09-	.24-	.18-		.08-	.64-	.30-	1.45-
	247.12	185.79	139.82	10.69	6.56	10.42		5.39	351.67	269.03	222.19
	9	9	6	9	8	9	9	11	9	9	9
	100.31	78.78	53.82	2.70	3.03	3.96	2.81	1.32	111.42	87.01	85.49
	90.42	71.49	56.06	3.71	2.74	4.69	2.80	1.73	133.21	103.07	98.01
	30.14	23.83	22.89	1.24	.97	1.56	.93	.52	44.40	34.36	32.67
	2.38-	.71-	1.21-	.16-	.36-	.36-	.14-	.16-	1.28-	.31-	1.85-
	251.57	193.49	145.05	10.92	7.84	12.20	7.24	5.87	357.39	278.12	231.67

northeastern Minnesota (allometric relation $Y=aX^{b}$

s oides	*Prunus pensylvanica*	*Prunus virginiana*	*Rhamnus alnifolia*	*Ribes* spp.	*Rosa acicularis*	*Rosa blanda*	*Rubus parviflorus*	*Rubus strigosus*	*Salix* spp.	*Sorbus americana*	*Viburnum rafinesquianum*
	4.947	7.953	2.009	1.513	3.286	4.160	4.595	7.081	4.514	2.885	8.526
	2.836	1.954	3.835	3.023	2.004	2.302	2.376	3.871	3.692	3.454	3.007
	.000	.900	.881	.549	.879	.597	.720	.748	.894	.000	.951
	.601	3.522	2.394	.245	.275	.745	.586	.577	5.735	.560	2.925
	NS	.005	.010	.025	.005	.025	.005	.005	.005	NS	.005
	2.095	1.516	1.040	.321	1.671	2.230	8.214	.491	.545	.841	1.096
	1.037	2.605	2.885	1.719	2.312	2.078	3.283	1.498	3.690	4.023	4.362
	.257	.837	.808	.604	.513	.568	.957	.332	.787	.717	.766
	1.654	1.317	1.011	.059	.333	.429	.312	.110	.902	2.366	1.707
	NS	.005	.025	.025	.050	.025	.005	.100	.005	.005	.005
	48.927	34.049	29.929	32.958	12.890	30.900	---[1]	10.782	17.344	13.177	38.820
	2.545	2.708	2.760	5.458	3.162	4.519		4.111	4.939	4.393	4.125
	.950	.856	.874	.776	.908	.873		.745	.923	.917	.981
	21.366	27.863	21.452	1.843	.773	1.570		.857	39.009	30.800	14.172
	.005	.005	.010	.005	.005	.005		.005	.005	.005	.005
	49.916	35.575	30.971	32.001	14.527	31.182	---[1]	11.519	17.815	13.982	39.921
	2.547	2.704	2.764	5.256	3.042	4.074		4.032	4.919	4.900	4.132
	.952	.861	.872	.780	.878	.844		.734	.923	.922	.981
	21.233	28.520	22.456	1.861	1.035	1.979		.938	39.551	30.738	14.504
	.005	.005	.010	.005	.005	.005		.005	.005	.005	.005

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RESEARCH NOTE NC-227

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Folwell Avenue, St. Paul, Minnesota 55101
1977

SOME INDIVIDUAL PLANT BIOMASS VALUES FROM NORTHEASTERN MINNESOTA

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ABSTRACT.--As part of a study describing vegetation biomass dynamics following wildfire in standing virgin forest communities, mean dry weight per individual for immature and mature tree, shrub, and herbaceous species for the 1971 through 1975 growing seasons in northeastern Minnesota are presented.

OXFORD: 182.41:182.46:182.47:181.5(776).
KEYWORDS: standing crop, plant productivity, wildfire, virgin forest, vegetation dynamics.

A recent search of the literature revealed that, except for mature tree species, there is a striking lack of published data on biomass of individual plants (Ohmann and Grigal, in preparation). This note provides mean biomass for individuals of some immature and mature tree, shrub, and herbaceous species.[1] The data were collected during a study of the post-fire vegetation biomass changes following the Little Sioux Wildfire of 1971 in northeastern Minnesota.

The aboveground crop of vegetation was harvested during August of each of the first 5 years following the fire. All vegetation in 10 randomly located plots (each 0.605 m^2) within each of seven post-fire plant communities was clipped at ground level. Thus, a total of 70 plots or 42 m^2 was sampled each year. Each plot was marked following clipping to ensure that it would not be clipped again in succeeding years.

All vegetation from the clipped plots was sorted by species in the laboratory. The number of individuals of each species on a plot was recorded, and the samples for a plot were bagged, dried at 70 C to constant weight, and weighed by species to the nearest 0.01 gram.

The total weight of each species from all seven communities was divided by the total number of individuals of that species in the sample to derive the mean dry weights (table 1).

Year-to-year variability in mean individual dry weights can be ascribed to growth (particularily of the woody species), the presence of many smaller individuals resulting from germination of the previous year's seed crop (Aster macrophyllus, for example), disease infestation (Venturia shoot blight on Populus grandidentata in 1973, for example), variation in annual precipitation available for growth (the precipitation from August 1972 through July 1973 was lower than that for the other growing seasons and lower than the 30-year average for the area), sampling variation, and experimental error.

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[1] *We thank Ms. Devvie Cercine for help in sample collection and processing.*

Table 1.--*Average individual dry weights and numbers of individuals sampled at the end of the 1971 through 1975 growing seasons on the Little Sioux Wildfire Area of northeastern Minnesota*

Species	Post-fire growing season									
	1971		1972		1973		1974		1975	
	gms	*no*	*gms*	*no*	*gms*	*no*	*gms*	*no*	*gms*	*no*
Trees										
Acer rubrum	1.93	46	6.51	37	16.64	48	28.82	34	48.37	46
Betula papyrifera	6.04	5	2.18	89	6.82	19	37.78	23	108.37	33
Picea mariana	---	--	.01	2	.08	5	---	--	10.20	1
Pinus banksiana	.01	240	.12	204	1.30	213	3.81	213	13.96	209
Pinus strobus	---	--	---	--	---	--	---	--	98.95	3
Populus grandidentata	19.99	24	59.84	39	53.74	21	112.05	23	255.19	40
Populus tremuloides	4.51	277	27.49	153	52.67	125	51.88	86	192.71	64
Quercus rubra	---	--	6.75	2	.18	1	111.96	3	---	--
Sorbus americana	---	--	.04	3	---	--	11.10	4	88.27	2
Shrubs										
Acer spicatum	1.86	15	4.37	9	---	--	---	--	---	--
Alnus crispa	---	--	---	--	---	--	---	--	263.86	3
Amelanchier spp.	1.48	16	.58	4	4.59	44	17.12	63	37.91	17
Chimaphila umbellata	.07	15	---	--	.33	57	.29	30	.46	7
Comptonia peregrina	.35	238	5.37	146	4.62	322	14.10	111	17.90	159
Corylus cornuta	3.09	59	7.69	98	13.46	189	13.62	90	31.56	92
Diervilla lonicera	.18	51	.32	55	1.82	86	4.24	4	3.80	27
Gaultheria procumbens	.05	291	.10	563	.10	792	.14	1,208	.14	503
Lonicera canadensis	.68	34	3.05	13	1.69	65	5.00	69	2.86	91
Prunus pumila	---	--	1.39	18	---	--	---	--	---	--
Prunus pensylvanica	.36	236	3.04	158	4.98	171	7.50	147	20.95	118
Ribes glandulosa	---	--	---	--	.05	1	4.94	1	---	--
Ribes triste	---	--	---	--	.19	1	.06	7	---	--
Rosa acicularis	---	--	2.72	12	.74	12	4.23	1	4.50	7
Rubus pubescens	.16	3	.47	59	.68	22	.27	49	.29	2
Rubus strigosus	.82	215	1.72	193	.88	449	1.56	312	1.54	256
Salix spp.	1.88	29	24.33	6	---	--	60.75	1	66.55	6
Vaccinium angustifolium	.16	330	.59	822	.65	620	.79	482	.84	152
Vaccinium myrtilloides	.16	140	.75	29	.70	64	1.43	84	1.60	151
Herbaceous plants										
Anemone quinquefolia	.01	3	.01	8	.06	10	.06	6	---	--
Apocynum androsaemifolium	.58	1	2.34	4	---	--	---	--	---	--
Aralia hispida	.04	90	.90	264	1.55	290	2.06	121	2.63	54
Aralia nudicaulis	.24	271	.61	260	.68	272	1.00	170	1.23	129
Aster macrophyllus	1.48	790	.77	3,113	.69	1,305	.71	1,040	1.04	656
Clintonia borealis	.17	171	.38	250	.41	303	1.06	255	.62	195
Coptis groenlandica	.01	10	.01	12	---	--	.01	357	.03	12
Cornus canadensis	.13	867	.20	2,192	.14	2,563	.13	3,606	.18	2,781
Corydalis sempervirens	.20	62	---	--	---	--	---	--	---	--
Epilobium angustifolium	.80	3	2.71	6	.20	133	.76	14	2.25	12
Fragaria vesca	.09	6	---	--	.11	3	.15	53	.19	51
Galium triflorum	.13	10	.01	26	---	--	---	--	.16	4
Geranium bicknellii	.84	161	.32	41	.05	213	---	--	.82	1
Goodyera repens	---	--	---	--	.01	1	---	--	---	--
Gramineae	.02	372	.29	687	.72	530	.18	718	.12	1,003
Lathyrus ochroleucus	.03	14	---	--	---	--	---	--	---	--
Linnaea borealis	.08	65	.13	112	.24	261	.47	187	1.01	107
Lycopodium clavatum	---	--	.02	3	---	--	---	--	---	--
Lycopodium complanatum	.18	13	.17	23	.75	39	.36	40	.49	29
Lycopodium obscurum	.24	49	.22	57	.40	142	.44	55	.74	182
Maianthemum canadense	.01	1,434	.04	1,588	.05	1,793	.05	2,233	.06	1,158
Melampyrum lineare	---	--	.05	13	.14	9	.08	8	.20	44
Polygonum cilinode	1.24	106	3.03	175	.79	324	.26	112	.13	58
Pteridium aquilinum	3.99	149	3.90	230	6.11	187	7.00	87	8.12	93
Pyrola spp.	.04	17	.23	13	.08	83	.06	21	.05	56
Streptopus roseus	.05	7	.15	64	.26	5	.14	16	.28	5
Trientalis borealis	.05	31	.10	33	.10	18	.08	34	.16	12
Viola spp.	.02	17	.01	17	.01	5,794	---	--	---	--
Vicia americana	---	--	---	--	---	--	---	--	1.19	1
Polytrichum spp.	0.01	137	.01	3,069	.01	2,194	.01	1,826	.01	4,736

In our analysis of the revegetation dynamics of the seven burned communities (Ohmann and Grigal, in preparation), we found that the low shrub and herb strata had stabilized in terms of dry weight per unit area by 1974. On that basis, we assume that most low shrub and herb weights presented for 1974 and 1975 represent weights that can be found in mature forest communities. The trees and tall shrubs were still increasing in biomass in 1975, and so the values presented can generally be considered to represent immature individuals.

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USDA FOREST SERVICE

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1992 Folwell Avenue, St Paul, Minnesota 55108

1978

NUTRITION AND *IN VITRO* DIGESTIBILITY OF TALL FESCUE FOR WHITE-TAILED DEER, MAY THROUGH NOVEMBER

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ABSTRACT.–Describes a study of the nutritive quality and digestibility of fertilized and unfertilized tall fescue in spring, summer, and fall. The grass may be most valuable as food in early spring and late fall, and on unfertilized sites.

OXFORD: 268.3:149.6 CERVID. KEY WORDS: range, wildlife, food habits, wild ruminants, *Odocoileus virginianus*, forage quality.

Conversion of low-quality hardwood forest to tall fescue (*Festuca arundinacea* Schreb.) grassland (fig. 1) in the Ozarks is producing different food and cover conditions for the resident white-tailed deer (*Odocoileus virginianus*) population. Resource managers are concerned about the impacts of this conversion on wildlife populations and question the contribution of this process to the life requirements of deer. Deer have been known to utilize tall fescue, a cool season perennial grass, because animals collected in converted areas during the November hunting season sometimes have fescue in their rumens. Also, Short and Segelquist (1975) have found Elbon rye (*Secale cereale* L.), a cool season annual grass, to be heavily used by deer when available.

The present study was designed to examine the nutritive quality and digestibility of fertilized and unfertilized tall fescue with respect to use in late spring, summer, and fall, when it is most abundant.

Figure 1. – *A typical converted area. Number board is 24 inches tall.*

METHODS

Forage samples were collected from fertilized and unfertilized fescue stands during May, July, September, and November. Collection sites were upper north- and south-facing slopes located in the White River basin of southern Missouri. Forage samples were clipped to a 2-inch stubble, ovendried at 70C using a 2-mm screen to provide samples for chemical analysis and *in vitro* digestibility trials. Percents of crude protein, calcium, phosphorus, and acid detergent fiber were determined by the Agricultural Experiment Station Chemical Laboratories, University of Missouri, Columbia. *In vitro* digestion trials were performed by the ARS-University of Missouri facilities using the two-stage technique of Tilley and Terry (1963).

Deer rumen fluid samples were collected through the assistance of the Missouri Department of Conservation research personnel, Columbia, Missouri. Captive animals were maintained on a diet similar to that described by Snider and Asplund (1974). Rumen fluid samples were transported to the laboratory in sealed, insulated containers; inoculation of forage samples began within 2 hours after collection.

The experimental design was a three-factor factorial with two levels of fertilizer (0 and 48 pounds/acre, N, P, K), two aspects (north and south) with two plots on each aspect, and four harvest dates. All data were subjected to standard analysis of variance procedures. Statements of significance are based on this analysis; significant effects were further subjected to Duncan's New Multiple Range Test at the 5 percent level.

RESULTS AND DISCUSSION

Fescue in May had a crude protein content of 16.2 percent (table 1)—a value higher than the 13 percent Murphy and Coates (1966) determined as adequate for reproduction and close to the 16.8 percent protein figure which McEwen *et al.* (1957) cited as yielding good growth and antler production. Protein in fescue declined in July to 9.1 percent and remained at about that level in September (9.3) and November (9.5). These values are comparable to the 9 to 10 percent ratio used by McEwen *et al.* (1957) to obtain some growth but retarded antler development. Protein level in fescue during the summer is below the 15.0 percent average found for the preferred native summer foods of Missouri deer (Torgerson and Pfander 1971). Protein did not vary significantly with respect to fertilizer treatment or aspect.

Table 1. — *Mean nutritive values and dry matter digestibility of tall fescue forage by harvest date*

Harvest date	Protein	Ca	P	Ratio of Ca/P	ADF[1]	DMD[2]
	- - - Percent - - -				- Percent -	
May	16.2	0.31	0.29	1.13	30.7	61.3
July	9.1	.43	.21	2.31	35.2	51.4
September	9.3	.36	.26	1.53	37.5	50.9
November	9.5	.29	.25	1.28	31.0	55.9

[1] ADF-acid detergent fiber.
[2] DMD-dry matter digestibility.

Calcium and phosphorus levels (table 1) are considerably lower than the 0.64 and 0.56 percent respectively maintained by McEwen *et al.* (1957) in an ideally complete ration. Our values are closer to what they considered to be the winter minimum of 0.30 percent for these minerals. The calcium levels varied from 0.31 percent in May to 0.43 percent in July, 0.36 percent in September, and 0.29 percent in November. This was considerably below the 1.95 percent average found for the preferred summer foods of Missouri deer (Torgerson and Pfander 1971). Fescue phosphorus levels varied little from those of the preferred summer deer foods.

When fertilizer was applied, calcium content of fescue increased on the north slopes but decreased on the south slopes.

Phosphorus levels attained the minimum of 0.30 percent recommended by McEwen *et al.* (1957) only on the fertilized plots. The average phosphorus content over the sampling period was 0.29 percent in May, 0.21 percent in July, 0.26 percent in September, and 0.25 percent in November.

The Ca/P ratio exhibited a significant response to both date of harvest and fertilizer treatment. All values of the ratio remained close to or within the acceptable limits (2:1 to 1:2) for ruminant animals (Maynard and Loosli 1962). Ca/P ratio varied over the sample period from 1.13 in May to 2.31 in July, 1.53 in September, and 1.28 by November. Samples from fertilized plots had a Ca/P ratio of 1.19, while samples from unfertilized plots had a Ca/P ratio of 1.93.

Fiber content (table 1) did not change appreciably over the sampling period: acid-detergent fiber values were 30.7 percent in May, 35.2 percent and 37.5 percent for the mature forage of July and September respectively, and 31.0 percent for the fall growth accumulated to November. There were no significant differences due to fertilizer or aspect; however, there was an interaction (fig. 2) between harvest date and fertilizer treatment because samples from fertilized plots contained lower amounts of fiber initially. The fiber content increased

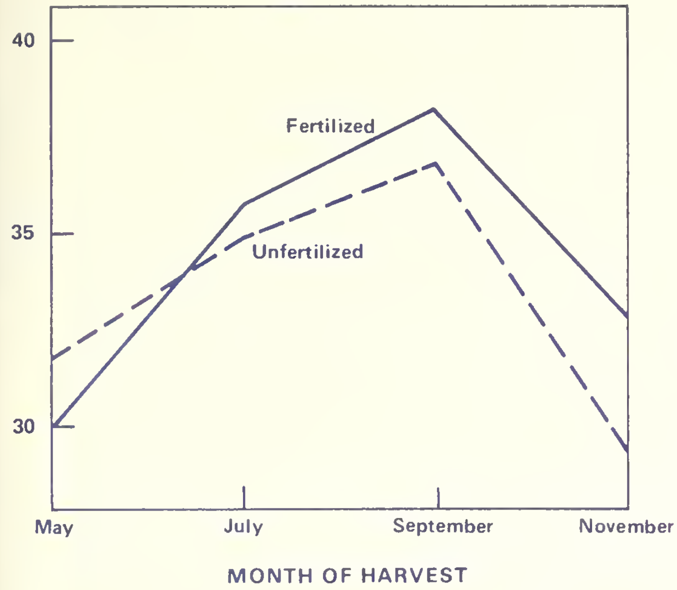

Figure 2. – *Graph of the interaction between fertilizer treatments for acid-detergent fiber.*

after the first sample date thus unfertilized samples contained less fiber for the remainder of the sampling period. This effect may be a result of increased growth due to fertilizer application.

Dry matter digestibility coefficients (table 1) varied as the fescue developed throughout the season, dropping from 61.3 percent in May to 51.4 percent in July, to 50.9 percent in September, and rising up to 55.9 percent for November. Fertilizer treatment significantly influenced dry matter digestibility. Samples from fertilized plots had a coefficient of 53.2 and those from unfertilized plots 56.6. This difference seems due to the ranker growth and increased fiber production which may have resulted from fertilization.

Tall fescue is not an important spring or summer deer food in Missouri according to Korschgen *et al.* (1976). They found fescue in only 34 of 304 Ozark deer stomachs during spring and summer and it contributed only 0.2 percent of the total food volume. The widespread availability of fescue and low consumption indicates low palatability for deer from April through September. But when eaten, fescue is above average in digestibility. Digestibility coefficients in this study were higher than the average of 47.9 percent found for preferred summer foods of Missouri deer (Snider and Asplund 1974). Fescue does have less crude protein and calcium than preferred summer deer foods. Tall fescue as a food source for deer may be most valuable in early spring, late fall, or both, and on unfertilized areas, because fescue on these areas was higher in dry matter digestibility.

SUMMARY

1. Harvest date and fertilizer treatment have more effect on nutritive value and digestibility of fescue than exposure.

2. Protein, acid-detergent fiber, and dry matter digestibility were at the most desirable levels early and late in the sampling period. Calcium and phosphorus were very low throughout the study. The calcium-phosphorus ratio did not appear to be limiting, however.

3. Acid-detergent fiber and dry matter digestibility values for unfertilized samples were superior to the values for fertilized samples.

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RESEARCH NOTE NC-229

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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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TWO YEARS NECESSARY FOR SUCCESSFUL NATURAL SEEDING IN NONBRUSHY BLACK SPRUCE BOGS

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ABSTRACT.—Natural seeding in a strip-cut black spruce bog was adequate, averaging 1,800 stems per acre and 80 percent milacre stocking. Natural seeding in a completely cut bog was inadequate, averaging 630 stems per acre and 40 percent milacre stocking. Slash was removed to expose sphagnum seedbeds in both cases. Progressive cutting every other year is recommended.

OXFORD: 231.3:372:174.7(776) *Picea mariana*. KEY WORDS: *Picea mariana*, direct seeding, swamp conifers, conifer reproduction, peatlands, Minnesota.

Guidelines for black spruce (*Picea mariana* (Mill.) B.S.P.) regeneration are well established from studies on the Big Falls Experimental Forest in north-central Minnesota—an area of extensive peatlands on the bed of glacial Lake Agassiz (Johnston 1977). Clearcutting and slash removal is all that is required for black spruce to reproduce rapidly and abundantly if (1) the peatland is not brushy, (2) *Sphagnum* spp. moss seedbeds are well distributed, and (3) natural seeding is ample. However, the success of these conditions has not been documented for small, isolated, lake-filled peatlands in glacial moraine country, nor has the success of natural seeding been measured where the entire stand is harvested and no standing seed source remains. We had the opportunity to measure natural seeding success on a 20-acre black spruce bog on the Marcell Experimental Forest in the Marcell Hills country 50 miles south of the Big Falls Experimental Forest.

PROCEDURE

The study area was a nonbrushy black spruce bog about 2,000 feet long and 500 feet wide oriented approximately north-south along the major axis. The bog had two stands with the following characteristics in 1968:

Stand characteristic	*Older stand*	*Younger stand*
Age (years)	73	62
Site Index (feet at 50 years)	40	31
Basal area (square feet/acre)		
(Stems > 0.5 inches d.b.h.)	157	122
Volume (cords/acre)	20	14

Apparently the southern half of the bog burned and black spruce seedlings were re-established in 1906. Both stands had practically a continuous ground cover of lush sphagnum moss with clumps of Labrador-tea, leather-leaf, and fine-leaved sedges scattered throughout.

Both black spruce stands were partially harvested in February 1969 by clearcutting 100-foot-wide, east-west strips and leaving 150-foot-wide uncut strips. All slash was put into a few piles, thus exposing practically all of the ground in the clearcut strips. Three growing seasons later (August 1971) seedlings were counted on 25 ¼-milacre plots in the clearcut strips of each stand and advance reproduction was similarly counted in the uncut strips.

The remaining 150-foot-wide strips were harvested in January, 1974, and all slash was progressively piled and burned. In November, 1975 (seven growing seasons after harvesting), reproduction in the 100-foot-wide strips was resampled on 38 milacre plots in each stand. In November, 1976 (three growing seasons after harvesting), reproduction in the 150-foot-wide strips was counted on 51 milacre and 51 ¼-milacre plots in each stand. All regeneration data were converted to number of stems per acre and percent milacre stocking. Between densities of 500 and 2,000 stems per acre, ¼-milacre stocking times 2.63 equals milacre stocking in each stand.

RESULTS AND DISCUSSION

The 100-foot-wide strips regenerated successfully. Three growing seasons after cutting there were about 1,800 seedlings per acre in each stand (table 1). Although these densities are only 8 to 15 percent of those reported for similar conditions in black spruce stands on the Big Falls Experimental Forest (Johnston 1975), milacre stocking is about 80 percent for each stand on the Marcell Experimental Forest. Therefore, we conclude that the new black spruce forest is adequately stocked. Seven growing seasons after cutting (5 years with a standing seed source), seedling numbers increased to about 2,300 per acre, and milacre stocking remained about 80 percent.

One reason for the lower densities on the Marcell study area may be the lush sphagnum growth which is typical on small, nonbrushy, acid bogs. Measurements for 3 years showed that sphagnum moss grows about 4 inches each spring and 2 inches each fall during periods of cool temperatures and high humidities. Therefore, some young seedlings may have been smothered by the moss and those that survive typically produce adventitious roots in the new moss growth (fig. 1).

The 150-foot-wide strips had a nonbrushy, well-distributed sphagnum seedbed, but the only seed source was seed dispersed before or during cutting. Advance reproduction in the younger stand survived the logging, but the larger advance reproduction in the older stand was either cut or crushed. Both stands had about 225 stems of advance reproduction after harvesting (table 2).

About 400 new seedlings per acre were present after cutting with 30 percent milacre stocking in each stand. When new seedlings and advance reproduction are combined, they total about 625 stems per acre and 40 percent milacre stocking for each stand (table 2). Sixty percent milacre stocking is considered necessary for an adequately stocked stand (Johnston 1977); therefore, harvesting the entire seed source and relying on previously dispersed seed will not result in adequate, rapid regeneration. Black spruce seed remains viable for only about 12 months on upland

Table 1.—*Black spruce reproduction 3 and 7 growing seasons after strip cutting with slash removed on a nonbrushy, medium site with well-distributed* Sphagnum *moss*

Growing seasons after strip cutting	Stems per acre		Milacre stocking	
	Older stand	Younger stand	Older stand	Younger stand
	- - *Number* - -		- - *Percent* - -	
3	1,770	1,770	81	76
[1]7	2,380	2,220	81	81

[1] Remaining 150-foot wide strips (seed source) were harvested after 5 years.

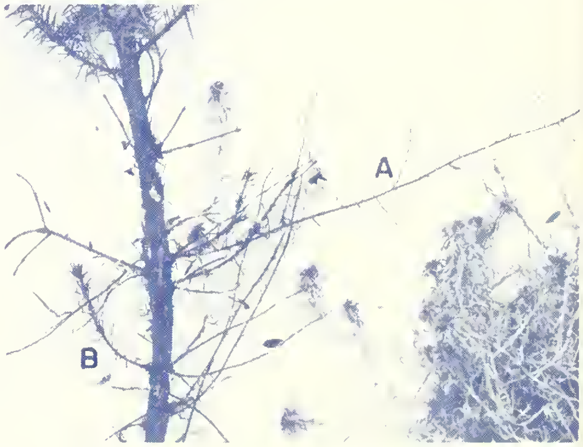

Figure 1.—*Seven-year-old black spruce seedling that grew in* Sphagnum *moss. Note adventitious root (A) at old stem node and above branch (B) smothered by lush* Sphagnum *growth.*

Table 2.—*Black spruce reproduction 2 years before and 3 years after clearcutting with slash removed on a nonbrushy, medium site with well-distributed* Sphagnum *moss and no adjacent seed source*

Time of reproduction establishment	Stems per acre		Milacre stocking	
	Older stand	Younger stand	Older stand	Younger stand
	- - *Number* - -		- - *Percent* - -	
Advance reproduction				
2 years before cutting	790	200	29	5
3 years after cutting	230	220	17	14
New reproduction				
3 years after cutting	450	360	30	30
Total reproduction				
3 years after cutting	680	580	40	42

or peatland seedbeds (Fraser 1976), thus seed storage in the moss cannot be relied on to increase milacre stocking in subsequent years.

Overall, our data show about 40 percent milacre stocking after one growing season, with only the previous fall's seed, and about 80 percent milacre stocking after three growing seasons with 2 years of standing seed source and the fall seed prior to harvesting. Interpolating, we might assume a 60 percent milacre stocking after two growing seasons with a continuous seed source. Since 60 percent milacre stocking is the lower limit of adequate stocking, we suggest that two years of seed (the fall before cutting and the fall after cutting) are required to secure the minimum stocking level in black spruce stands on small, nonbrushy bogs. To secure stocking levels greater than the minimum we suggest that three years of seed (the fall before cutting and two falls after cutting) are needed.

MANAGEMENT IMPLICATIONS

Nonbrushy, black spruce bogs can be regenerated successfully if they have a well-distributed sphagnum seedbed and if slash is removed to expose it. Full-tree skidding, with slash burning at the landing, has been recommended as a practical method for achieving these conditions (Johnston 1975). Though much of the slash removal was done by hand in our study, it closely simulates a full-tree skidding operation. However, completely harvesting black spruce bogs of 5 to 50 acres during one season will not leave sufficient seed to regenerate the stand rapidly.

Areas larger than 50 acres should be progressively strip-cut no more frequently than every other year in order for the clearcut area to reach 80 percent milacre stocking. Although risky, it is possible that the cutting could be done every year if only the minimum stocking level (60 percent) is desired. Some wind mortality will occur along exposed edges of stands that are left but most trees can be salvaged every other year. Strip widths should not exceed natural seeding distance (about 400 feet). After the last cut, direct seeding may be necessary if a natural seed source is not available.

Bogs of 50 acres or less can also be progressively cut although only two cuts may be feasible. Entire bogs can be harvested with full-tree skidding to expose the seedbed and then be direct seeded. If slash removal and direct seeding are not done the regeneration will have less than full stocking (probably less than 40 percent), and it will take about 15 years for the new trees to begin to provide seed to fill in the nonstocked or understocked areas.

The choice will depend on management goals, the cost of direct seeding, and the presence of dwarf mistletoe. If dwarf mistletoe is abundant, slash should be broadcast and burned (Johnston 1977). Most small bogs can be seeded by hand with a cyclone seeder at the recommended seeding rate of ¼-pound per acre (Johnston 1977). Seed cost is about $50 per pound, thus regeneration costs for seeding alone should be about $15 per acre. Skidding and slash burning will add to costs. Usually natural seeding can be relied on if sale areas in nonbrushy black spruce peatlands are laid out skillfully, but some small areas will need direct seeding to provide full and rapid stocking.

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RESEARCH NOTE NC-230

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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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SOIL WATER DEPLETION AFTER FOUR YEARS OF FOREST REGROWTH IN SOUTHWESTERN WISCONSIN [1]

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ABSTRACT.—The effect of cutting on water depletion from a 150-cm soil mantle does not appear to have diminished by the 7th year after the trees were cut. Mean seasonal depletion was 41, 64, and 146 mm for all vegetation removed, woody vegetation only removed, and uncut treatments, respectively. After 4 years of regrowth, the original bare and clearcut treatments depleted only 21 and 35 percent as much water as the uncut forest.

OXFORD: 114.122:116.254(775). KEY WORDS: evapotranspiration, percolation, water storage.

METHODS

The study site, a forested north slope on the Coulee Experimental Forest in southwestern Wisconsin, has been described previously (Sartz 1972a). Annual precipitation averages 800 mm, about two-thirds of which falls as rain during the growing season (May to mid-October). Soil water content is normally greatest in early spring, diminishing gradually over the growing season because of evapotranspiration and drainage. Rarely do summer rains recharge the soil mantle enough to deliver water to the ground water system.

The original study design included four treatments: (1) woody vegetation only removed ("clearcut"); (2) all vegetation removed ("bare") (in addition to cutting the trees, the herbaceous vegetation was killed or clipped for 3 years on a circular plot 2 m in diameter to minimize transpiration loss); (3) uncut; and (4) uncut forest with litter removed. However, after it was found that litter removal did not affect water depletion, the data for the two uncut treatments were combined.

Each treatment had four replicates in a paired-plot design for the secondary treatments (plots with woody vegetation removed vs. plots with all vegetation removed, and plots with litter removed vs. undisturbed plots). The paired plots were centered in 62- by 44-m blocks that were laid out along a 265-m stretch of slope. A block width of 44 m was considered to be the minimum needed to overcome border affects. Mean slope is 32 percent.

Originally one neutron meter access tube was installed in each plot, but after analysis of sampling variation in the first year's data (Sartz 1972a), a second tube was added. Each tube was

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[1] *The research was conducted in cooperation with the State of Wisconsin Department of Natural Resources.*

treated as an independent sample, resulting in 8 samples for each of the clearcut treatments and 16 for the uncut forest treatment after the first year. Details of the study site, installation of access tubes, and a description of the neutron meter and measuring procedure, are given in two previous papers (Sartz 1972a, 1972b).

Soil water content was logged with the neutron meter in early spring (about mid-May) and again in late summer. Readings were taken at 30-cm intervals beginning at a depth of 30 cm. Sampling depth differed among plots according to depth to the layer that could be penetrated by hand augering. This was assumed to be the lower limit of the soil mass affected by transpiring vegetation. All plots (tubes) could be sampled to 120 cm, and 4 bare, 4 clearcut, and 11 uncut plots to 150 cm or deeper. Depletion values are based on the modal depth of 150 cm.

Seasonal depletion was assumed to be the difference between early spring and late summer water contents during the 4-year period of regrowth reported here. Measurements were made at 2-year intervals.

RESULTS AND DISCUSSION

Water content at the beginning of the growing season was similar for each of the 5 years (3 initially, plus 2 during the 4-year regrowth period) studied. Means for the 150-cm soil mantle ranged from 468 to 481 mm for the three conditions (table 1). This is about 30 percent by volume, and approximates field capacity. Considering the sampling errors involved (Sartz 1972a) it seems reasonable to assume that the soil mantle was fully charged on all plots each spring.

Vegetation Changes

Herbaceous vegetation was suppressed on the bare plots but was allowed to grow on the clearcut plots during the initial 3 years of study. Ferns grew denser and blackberries (*Rubus* spp.), hazel (*Corylus americana* Marsh), and other weed species invaded many plots. The cut plots were covered with a dense tangle of blackberries, ferns, and tree sprouts by 1973 (5 years after cutting, and 2 years after vegetation was allowed to grow). Two years later, the area was an impenetrable jungle. Aspen sprouts were up to 3 m tall, and trails cut through the plots for the spring measurements were completely grown over by the end of the summer. Some of the bare plots that had been treated with the herbicide simazine 80W in 1969 still had sparse growth around the neutron meter access tubes, but most could not be distinguished from the tangle that surrounded them.

Table 1.—*Water content of a 150-cm soil mantle at the beginning of the depletion period.*

Forest Condition	Before regrowth			After regrowth		Mean
	1969	1970	1971	1973	1975	
	- - - - - - - - - -	- - - - - -	*mm*	- - - - - -	- - - - - -	- - - -
Bare	484	508	482	463	466	481
Clearcut	466	490	460	467	461	469
Uncut	471	472	460	481	455	468

Soil Water Depletion

Four years of regrowth appeared to have little effect on soil water depletion (table 2). Since the data showed no trend with time, means were computed from the five sets of measurements. The values, expressed as a percent of depletion by the uncut forest, were 26 and 42 for the bare and clearcut treatments, respectively. Mean seasonal water depletion by depth for a 7-year period was similar for cut and uncut plots as seen in the following tabulation:

Depth (cm)	*Bare*	*Clearcut*	*Uncut*
	---	(Percent)	---
30	25	21	25
60	21	18	21
90	23	21	21
120	18	23	18
150	13	17	15

Because depletion values reflect rainfall gains as well as evapotranspiration losses, one would expect the values to vary from year to year, even with an unchanging vegetation. Thus, in 1973, high July-August rainfall (280 mm compared with 100 to 140 mm the other years) tended to mask the losses from evapotranspiration. Differences in the length of the depletion period and in potential

Table 2.—*Seasonal water depletion in a 150-cm soil mantle*

Forest condition	Before regrowth			After regrowth		Mean
	1969	1970	1971	1973	1975	
	- - - - - - - - - -	- - - - - -	*mm*	- - - - - -	- - - - - -	- - - -
Bare	[1]29(15)	77(41)	64(35)	8(17)	25(21)	41(26)
Clearcut	58(29)	120(64)	85(47)	15(33)	42(35)	64(42)
Uncut	197	187	181	46	120	146

[1] Figures in parentheses are seasonal water depletion as a percent of depletion in uncut plots.

evapotranspiration would also affect the amount of depletion measured from one year to another. This is an inherent weakness in the depletion method of comparing water use by different vegetations.

Soil water depletion by cut and uncut forest in the Driftless Area of southwestern Wisconsin was studied by Sartz (1972b). Seasonal depletion attributed to evapotranspiration in a 150-cm soil mantle averaged 188 mm on uncut plots, 87 mm on clearcut plots, and 57 mm on plots without vegetation. Similar relations have been reported from other regions using streamflow as the measured parameter; however, the initial effect of forest cutting diminished rapidly with the regrowth of vegetation (Lull and Reinhart 1967). Four years after clearcutting, the initial gain in streamflow had diminished 53 percent on a West Virginia stream (Lull and Reinhart 1966) and 36 percent on a North Carolina stream (Kovner 1956). An exception to this was reported by Mader, MacConnell, and Bauder (1972) in Massachusetts when the vegetation removed was in the riparian zone. They showed that increases in soil water storage were maintained in spite of rapid regrowth of herbaceous vegetation.

The change in soil water depletion reported by Sartz (1972b) in the Driftless Area was the result of 3 consecutive years of maintaining the vegetation according to the prescribed treatments. Beginning with the fourth year after timber removal, vegetation was allowed to regrow to assess the effect of regrowth on water depletion. This paper reports the results from a 4-year period of regrowth.

In view of the rapid reduction in streamflow with forest regrowth found on Appalachian catchments (Lull and Reinhart 1967, Troendle 1970) it seems surprising that the soil water depletion differences between cut and uncut forest reported here persisted with no apparent diminution through a period of vigorous vegetation regrowth. Perhaps the difference between their results and these is related to differences in the kind of regrowth. The dominant regrowth on these plots was largely herbaceous; and even though it appeared to provide a continuous green cover, its transpiring surface was obviously much smaller, and its root system much less developed than in the uncut forest. Regrowth on the Appalachian catchments probably included more tree sprouts, which, using the already developed root systems of the parent trees, would be able to extract more water from the soil.

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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S.DEPARTMENT OF AGRICULTURE
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1978

SURVIVAL AND EARLY GROWTH OF SELECTED TREES ON WASTE WATER APPLICATION SITES

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ABSTRACT. — The response of six tree species and three *Populus* hybrids to irrigation with oxidation pond effluent were compared. When weeds were intensively controlled, a *P. deltoides* x *P. nigra* cross responded best, but when weeds were less intensively controlled, *P. canescens* x *P. tremuloides* responded best.

OXFORD: 232.43:(628.35). KEY WORDS: sewage effluent, growth, survival, irrigation, waste water, nutrient removal.

Land application of waste water has many advantages for small and medium sized communities, especially if construction and operating costs can be partially offset by growing crops on application sites. In the north-central United States, agricultural crops cannot be grown on many sites, because of the soil, terrain, and climate, but tree crops can be grown on most sites in the region. We conducted this study in the Lower Peninsula of Michigan, at Middleville and Harbor Springs, to evaluate the response of selected tree species and *Populus* hybrids to irrigation with oxidation pond effluent.

MIDDLEVILLE

The first test site was at Middleville in Barry County, on a gravelly morainal soil of the Boyer series, a typic hapludalf. Most of this site was nearly flat and had a plow layer of fine loamy sand. There were some slopes of more than 5 percent where surface soil had eroded exposing a gravelly sand, and part of the area was filled and covered with approximately 30 cm (1 foot) of very stony loamy sand.

Approximately 30mm (1.18 inches) and 70 mm (2.75 inches) of effluent was applied in 8 to 10 hours each week during the growing season. Nitrogen loading increased in 1975 and 1976 because concentration in the effluent increased sharply (table 1).

A split-plot design was used to test the effect of irrigation on the survival and growth of the trees. Application rate was the main plot treatment and subplots were planted to the species and hybrids selected for testing. In one set of nine plots each application rate and a control were replicated three times. In 1972, seedlings of *Populus*

Table 1. — *Nitrogen and phosphorus loadings for Middleville test plantings* (In kg/ha)

Year	30 mm/week	70 mm/week
TOTAL N		
1972	33	77
1973	36	91
1974	36	85
1975	60	140
1976	52	123
TOTAL P		
1972	19	45
1973	13	29
1974	13	31
1975	17	39
1976	20	48

canescens x *P. grandidentata* hybrid, Japanese larch *(Larix leptolepis)*, European larch *(Larix decidua)*, and tulip poplar *(Liriodendron tulipifera)* were planted in 25-tree subplots and northern red oak *(Quercus rubra)* seedlings were planted in a 28-tree subplot on each of the nine plots. Each application rate and the control were replicated twice in another set of six plots. Seedlings of green ash *(Fraxinus pennsylvanica)* and white-cedar *(Thuja occidentalis)* were each planted in two 25-tree subplots and 8-inch hardwood cuttings of 'Raverdeaux' poplar (a *P. deltoides* x *P. nigra* hybrid) were planted in one 28-tree subplot on each of these six plots. In 1973, a sixth 25-tree subplot in each plot of the nine-plot set was planted with hardwood cuttings of 'Raverdeaux' poplar taken from the 1972 planting. Spacing in all plots was approximately 1.2 m by 1.2 m (4 feet by 4 feet).

Plots were rototilled thoroughly before planting. Plots were not kept weed free but weed growth was greatly reduced by tilling, mowing, and using herbicides during the first 2 years.

Survival

The species and hybrids differed in their ability to survive without irrigation. Nearly all of the nonirrigated 'Raverdeaux' poplars planted in 1972 and 88 percent of the green ash were alive after five growing seasons (table 2) whereas only 65 percent of the *P. canescens* x *P. grandidentata* hybrid and 53 percent of the northern red oak survived without irrigation. Less than 50 percent of the other selections lived.

Irrigation increased survival of tulip poplar but had no significant effect on survival of any of the other selections planted in 1972. Apparently rainfall was adequate to prevent critical moisture stress during establishment. The 'Raverdeaux' poplar planted in 1973 survived significantly better with irrigation than it did without because there was not enough rain in 1973 to prevent critical moisture deficits on nonirrigated plots. Irrigation with 70 mm/week did not increase survival significantly more than irrigation with 30 mm/week.

Many of the *P. canescens* x *P. grandidentata* that died after the first year appeared to be girdled by a canker that has not yet been positively identified. Because cankers were only associated with mortality that occurred during the first 2 years and inoculation did not produce cankers in

Table 2. — *Survival, total height, and dry weight of selections included in Middleville test plantings after the 1976 growing season*

Selection	Survival			Total height			Total dry weight[1]		
	0	30 mm/week	70 mm/week	0	30 mm/week	70 mm/week	0	30 mm/week	70 mm/week
	Percent			*cm*			*kg*		
'Raverdeaux' poplar:									
Planted 1973	41 a[2]	85 b	89 b	183 a	443 b	542 b	0.221	2.144	3.601
Planted 1972	98 a	100 a	98 a	382 a	635 b	623 b	2.767	10.637	10.113
P. canescens x *P. grandidentata*	65 a	91 a	87 a	298 a	351 a	445 a	1.638	2.364	4.020
Green ash	88 a	93 a	93 a	163 a	260 b	219 b	0.495	1.675	1.070
Tulip poplar	24 a	59 b	67 b	157 a	249 a	242 a	0.282	1.145	1.050
European larch	21 a	29 a	24 a	128 a	192 a	258 a	0.135	0.431	1.004
Japanese larch	48 a	60 a	41 a	182 a	253 a	328 a	1.155	1.850	2.681
White-cedar	37 a	63 a	31 a	61 a	101 b	103 b	0.291	0.406	0.411
Red oak	53 a	67 a	61 a	113 a	104 a	142 a	0.168	0.141	0.275

[1] Dry weights are estimates based on average height using equations derived by weighing a random sample of 24 to 58 trees from each selection.

[2] Different letters following means for the same selection denote significant differences ($P \leq 0.10$).

vigorous 4-year-old trees, it appears that the canker only kills trees that are under stress during establishment.

Much of the mortality that occurred on irrigated plots was related to the grass and weeds that developed despite control efforts. Many of the Japanese larch that died during the first 3 years had sustained heavy feeding by June beetle larvae *(Phyllophaga* sp.*)*. The heaviest feeding was on irrigated plots that had the most herbaceous ground cover. Mice girdled many of the white-cedar on irrigated plots after weed control was stopped.

Growth

After five growing seasons, average height of nonirrigated trees ranged from about 1/2 m for white-cedar to nearly 4 m for the 'Raverdeaux' poplar (table 2). The average dry weight of whole trees ranged from 0.135 kg for European larch to 2.767 kg for 'Raverdeaux' poplar. The average height of all irrigated trees exceeded the average of those that were not irrigated, but the differences were only significant ($P < 0.10$) for 'Raverdeaux' poplar, green ash, and white-cedar. Irrigation increased the average height of these trees by 64, 46, and 67 percent, respectively, and their average dry weight by 275, 177, and 40 percent. Irrigation with 70 mm/week did not increase growth significantly more than irrigation with 30 mm/week.

Irrigation increased average height of the 'Raverdeaux' poplar planted in 1973 by 169 percent and its dry weight by nearly 1,200 percent. Again there was no significant difference in the effects of the two irrigation rates. The difference in response of the two 'Raverdeaux' plantings could be a reflection of differences in age or differences in weather during the year of establishment. However, it seems likely that removal of shoots from the first planting when it was 1 year old to provide cuttings for the second planting partially offset its response to irrigation.

HARBOR SPRINGS

The second test planting was on the application site for the Harbor Springs Area Sewage Disposal Authority near Petoskey in Emmet County. Soils were sands and loamy sands of the Kalkaska and Blue Lake Series, typic and alfic haplorthods, respectively, underlain at 45 to 120 cm (1.5 to 4 feet) with gravel. This site had a well established ground cover of grasses and forbes.

Populus hybrids were selected for a larger scale trial on this site because of their superior performance in the initial trial at Middleville. Nonrooted cuttings of 'Raverdeaux' poplar were planted as at Middleville, and some rooted cuttings were planted as well. *Populus canescens* x *P. tremuloides* was planted instead of *P. canescens* x *P. grandidentata* because it was thought to be more suited to the climate and soils at Harbor Springs. Instead of tilling to prepare for planting, a 2-foot strip was sprayed with a herbicide. Weed control after planting was much less intensive than it was at Middleville.

Each of the two hybrids was planted in two plots 36.6 m by 61.0 m (120 feet by 200 feet) and two that were 21.3 m by 61.0 m (70 feet by 200 feet). Rooted cuttings of 'Raverdeaux' poplar were planted in one of the smaller plots. Trees were spaced approximately 2.7 m by 2.7m (9 feet by 9 feet). One-hundred and twelve 'Raverdeaux' poplars and 47 *P. canescens* x *P. tremuloides* seedlings were planted outside the irrigated area.

One half of each plot was irrigated at the rate of 3.9 mm (0.15 inch) per hour and the other half at the rate of 8.6 mm (0.34 inch) per hour (table 3).

Survival

After three growing seasons, 72 percent of the *P. canescens* x *P. tremuloides* seedlings on irrigated plots were still alive (table 4). Survival of nonirrigated seedlings was 89 percent.

Table 3. — *Annual effluent, nitrogen, and phosphorous loadings for two effluent application rates at Harbor Springs, Michigan*

3.9 mm/hour

Year	Effluent	N	P
	mm	*kg/ha*	
1974	604	13.2	11.9
1975	1,521	19.4	4.3
1976	3,871	206.0	77.2
8.6 mm/hour			
1974	1,333	29.1	23.4
1975	3,354	39.0	8.5
1976	8,514	412.2	154.6

Table 4. — Populus *hybrids at Harbor Springs after three growing seasons*

Hybrid	Survival		Height	
	Not irrigated	Irrigated	Not irrigated	Irrigated
	Percent		*cm*	
P. canescens x *P. tremuloides*	89	72	61	120
'Raverdeaux' poplar	50	<1	--	--

Even though 92 percent of the rooted cuttings and 21 percent of the nonrooted cuttings of 'Raverdeaux' poplar planted on irrigated plots were alive after the first growing season, only 1 percent of the rooted cuttings and none of the nonrooted cuttings were alive after 3 years. Without irrigation, about 50 percent of the cuttings were still alive after 3 years.

The major causes of first year mortality were shading by grass and feeding by defoliators. Trees that survived the first year were girdled by mice. The rank grass that grew on irrigated plots seemed to provide a favorable habitat for both defoliators and mice. Grass was much shorter and less dense in nonirrigated plots.

Growth

Irrigation has nearly doubled growth of the *P. canescens* x *P. tremuloides* on this site. Irrigated trees average 120 cm in height after 3 years and nonirrigated trees averaged only 61 cm. 'Raverdeaux' poplar survival was so poor that we did not measure its growth.

SUMMARY AND CONCLUSIONS

The 'Raverdeaux' poplar has demonstrated the greatest response to effluent irrigation. If rainfall is abundant and well distributed throughout the growing season, irrigation is not necessary to establish nonrooted cuttings but it will greatly enhance establishment if moisture deficits occur. Field planting of nonrooted cuttings has not been successful without intensive weed control. But grass and weeds between tree rows probably serve as temporary storage sites for nitrogen and enhance denitrification.[1] Therefore, nitrogen losses associated with clean cultivation need to be evaluated.

Populus canescens x *P. grandidentata* grew faster than any of the other selections except 'Raverdeaux' poplar. *Populus canescens* x *P. tremuloides* seedlings were established successfully where neither rooted nor nonrooted cuttings of 'Raverdeaux' poplar were successful. If plantations are not to be cultivated intensively for the first year or two, a hybrid of *P. canescens* with one of the native species would be a better choice than the more demanding 'Raverdeaux' poplar.

Green ash is the only other selection that has demonstrated good survival and growth.

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A SYSTEM FOR PREDICTING THE AMOUNT OF *PHELLINUS (FOMES) IGNIARIUS* ROT IN TREMBLING ASPEN STANDS

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ABSTRACT.—The occurrence of *Phellinus* (*Fomes*) *igniarius* white trunk rot in 45- to 50-year-old trembling aspen stands can be predicted by applying a constant to the stand basal area with *P. igniarius* conks to estimate the total basal area with *P. igniarius* rot. Future decay projections can be made by reapplying the basal area of hidden decay for each 6 years projected. This paper describes the methods used to determine the constant and how to use it in the field.

OXFORD: 443.3—172.8 FO:176.1. *POPULUS TREMULOIDES.* KEY WORDS: *Populus tremuloides,* decay, projection.

White trunk rot, caused by *Phellinus igniarius* (L. ex Fr.) Quel., is the most important rot of trembling aspen (*Populus tremuloides* Michx.) in North America. For years, foresters have needed an easy method to estimate the extent of *P. igniarius* rot in trembling aspen stands. Site index, soil, aspect, and a variety of other variables have been examined for predictive use but their correlation with white trunk rot incidence was poor. Many stands that were identified as low *P. igniarius* occurrence areas broke up from white trunk rot in the following 10 years.

In view of the volume of aspen in the Lake States and the magnitude of the problem, this study was begun to find a better way to estimate the amount of white trunk rot in aspen stands.

MATERIALS AND METHODS

Eighteen 45- to 50-year-old trembling aspen stands were examined for incidence of *P. igniarius* decay (Schipper and Anderson 1978). This age class was selected because stand breakup due to *P. igniarius* is usually not a problem in younger stands in the Lake States. Six stands each in Michigan, Minnesota, and Wisconsin were examined. These stands were located in the Ottawa, Chippewa, and Chequamegan National Forests, respectively.

The examination procedure was to arbitrarily select a starting point 1 chain (20.1 m) in from the edge of the stand to be examined, and to proceed from that point in a cardinal direction along a transect 20 feet (6.1 m) wide. The first 85 trembling aspen trees encountered on the transect were measured for d.b.h., examined for visible *P. igniarius* conks, and tested for hidden decay by taking a core sample at d.b.h.

RESULTS

Analysis of the data from the 18 stands after d.b.h. had been converted to basal area revealed a relation between the basal area of aspen trees on a plot with visible conks and the total basal area of aspen trees with decay (table 1). The average basal area of trees with visible conks ranged from 2.31 feet squared (0.21 m^2) in Michigan to 3.31 feet squared (0.31 m^2) in Minnesota. Hidden decay ranged from 1.16 feet squared (0.11 m^2) in Michigan to 2.76 feet squared (0.26 m^2) in Wisconsin. However, when the conversion factor needed to compute the total amount of decay on a plot was determined, we found that the basal area of total decay averaged 1.9 times the basal area of trees with conks, with a standard error of 0.17.

Table 1.—The average basal area and factor determination for the six stands examined on each of the three National Forests

National Forest	Average basal area of aspen on plots	Average basal area of aspen with conks/plot	Average basal area of hidden decay/plot[1]
		Ft^2	
Ottawa	29.354	2.312	1.166
Chippewa	26.853	3.313	2.696
Chequamegon	29.93	3.176	2.756

[1] Hidden decay factor ranged from 2.89 to 1.01; averaged 1.9 with a standard error of 0.17

DISCUSSION

In the Lake States, aspen stands older than about 40 years are subject to breakup due to *P. igniarius* decay. Elsewhere, such early breakup is rare. Breakup refers to the physical loss of trees in the stand through loss of wood fiber due to decay and stem breakage during wind storms due to weakening of the stems by decay.

When a stand in the Lake States is about 40 years old, the land manager must be able to predict whether it must be harvested quickly to salvage the wood before breakup or where harvest can safely be delayed to allow additional volume increment. Although stands can be examined for *P. igniarius* conks, an average 6 years is required between the time infection occurs and the first conks become visible. Therefore conks only reveal trees that have been infected for a least 6 years. If stands are examined every 10 years or even more infrequently, breakup may occur in a stand thought to be relatively free of decay. By examining trees for visible conks and then estimating total basal area of trees with decay, the general health of the stand at the time of the survey can be determined. By then using the factor for total basal area with decay at present as the basal area of trees with conks 6 years in the future, the land manager can determine whether the stand is approaching breakup or whether it can safely be retained for future harvest. Using the current amount of hidden decay as an estimate of future decay assumes that infection occurs at a constant rate. This may not be a valid assumption and in fact may err toward a higher infection rate than would actually occur.

ESTIMATION PROCEDURE

1. Determine the basal area of trembling aspen trees with one or more *P. igniarius* conks. At least 10 sample plots should be used per stand, more in less uniform stands (fig. 1).

2. Multiply the basal area of aspen with conks by the factor 0.9 to estimate the amount of hidden decay, then add this basal area to the basal area of trees with visible conks to estimate total decay.

3. Correct present volume for 6 years growth (table 2) and reapply the hidden decay factor to the total basal area with decay determined above. Add this hidden decay basal area to the total basal area with decay to estimate total decay in 6 years.

4. Repeat step 3 for 12 years' growth and estimate the total decay that will be present in the stand in 12 years.

5. Decide whether to harvest now or whether it can be defered, based on the estimates for decay at present and in 6 and 12 years.

Age 45 Basal area factor 1.9

I. TREE COUNT

	(1) Plot	(2) All trees	(3) Trees with conks
	1	☒ ··	:
	2	⊔	·
	⋮		
	10	⧄	:·
Σ	10	80	20
x̄		8	2
Basal area/acre (multiply x̄ by basal area factor)		80	20

II. CALCULATIONS

	Basal area per acre
A. Current stand - Age 45	
1. Stocking, all trees : from tally	80
2. Observed decay : last line, col. 3, tally	20
3. Hidden decay : line 2 x 0.9	18
4. Total decay : sum lines 2 and 3	38
B. Stand in 6 years - Age 51	
5. Stocking, all trees : line 1 plus growth (table 2)	91
6. Total decay : sum lines 3 and 4	56
C. Stand in 12 years - Age 57	
7. Stocking, all trees : line 5 plus growth (table 2)	100
8. Total decay : sum lines 3 and 6	74

Figure 1.—Example of initial survey and the subsequent calculations. Assumes a 10-factor point sample cruise on 10 plots.

Table 2.—Net periodic basal area growth by age and stand density (Schlaegel 1972)

(In ft^2/acre)

Total stand age (years)	Basal area 20	40	60	80	100	120	140
20	2.39	3.40	3.89	4.03	3.92	3.62	3.14
25	1.92	2.72	3.11	3.23	3.04	2.69	2.51
30	1.60	2.27	2.59	2.69	2.62	2.41	2.09
35	1.37	1.94	2.22	2.30	2.24	2.07	1.79
40	1.20	1.70	1.94	2.02	1.96	1.81	1.57
45	1.06	1.51	1.73	1.79	1.74	1.61	1.40
50	.96	1.36	1.56	1.61	1.57	1.45	1.26
55	.87	1.24	1.41	1.47	1.43	1.32	1.14

Examples of the results of two surveys are shown below.

45

	Stand 1			Stand 2		
	Age			Age		
	45	51	57	45	51	57
Basal area per/acre	80	91(table 2)	100	80	91	100
Basal area/acre of trees with conks (*P. igniarius*)	20 (x1.9)			5 (x1.9)		
Basal area/acre of trees with rot—estimate (*P. igniarius*)	38(+18)	56(+18)	74	9.5(+4.5)	14.0(+4.5)	23.5
Basal area/acre of trees with sound wood—estimate	42	35	26	70.5	77	76.5

Stand 1 has a high amount of decay and is predicted to begin breakup within the next 10 years. Stand 2 has a much smaller amount of decay and is predicted to continue to produce sound wood during the next 10 years. Using these criteria alone, stand 1 would be harvested in the near future and harvest of stand 2 would be defered until after another survey and decay estimate had been made 10 years in the future. However, in practice the decision to harvest or retain a stand will depend upon stand objectives, markets, and a variety of other management objectives.

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ESTIMATING INFILTRATION RATES FOR A LOESSAL SILT LOAM USING SOIL PROPERTIES

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ABSTRACT. — Soil properties were related to infiltration rates as measured by single-ring steady-head infiltrometers. The properties showing strong simple correlations were identified. Regression models were developed to estimate infiltration rate from several soil properties. The best model gave fair agreement to measured rates at another location.

OXFORD: 114.123. KEY WORDS: Bulk density, organic carbon, ground cover, pore volume, modeling.

Land-use practices affect soil properties that, in turn, are related to infiltration rates and overland flow (Sartz 1970). A knowledge of these relations is particularly important if land-use is changing and overland flow and erosion are serious problems. These conditions exist in the Driftless Area of southwestern Wisconsin, northeastern Iowa, and southeastern Minnesota (Hays *et al.* 1949). Inferences about hydrology are often drawn from measured soil properties because direct hydrologic measurements are difficult, expensive, and time-consuming to obtain. The present study was undertaken to improve our ability to make inferences concerning small agricultural watershed response to infiltration in the Driftless Area when only soil properties are measured. Infiltration rates on different soils were measured to find which soil properties most affect infiltration on abandoned hay meadows. A model was then developed to relate soil properties to infiltration rate.

Steady-head infiltration using single-ring infiltrometers may be expected to closely parallel conditions in settling basins where Swartzendruber and Huberty (1958) successfully modeled infiltration rates so I used their model as a basis for the present study.

It is:

$$F = AT^{B} \qquad (1)$$

where F is cumulative infiltration in mm, A and B are constants, and T is time elapsed in minutes. The instantaneous infiltration per unit time interval (f) may be written:

$$f = ABT^{B-1} \qquad (2)$$

where A is numerically equal to the mean rate for the first unit time interval and B is an expression of curvature. The magnitude of B indicates how well the infiltration rate holds up under continuing infiltration. A and B reflect different aspects of the infiltration process and, therefore, may be affected by different soil properties. Soil properties related to A and B were identified and prediction models were developed for each constant.

METHODS

Infiltration rates were measured with single-ring steady-head infiltrometers on abandoned hay meadows on the Coulee Experimental Forest in southwestern Wisconsin. Twenty sites were selected (Knighton 1977). The soils were Fayette and Dubuque silt loams (*Typic hapludolf*) of loessal origin and were positioned on broad ridges overlying a fractured dolomitic cap rock. Hay had not been harvested from the sites for 3 years and the predominant vegetation was alfalfa (*Medicago sativa* L.). Cumulative infiltration was measured at each site with three infiltrometer rings. Two-hour infiltration runs were made simultaneously for all three rings while maintaining a steady-head of 4 cm (1.6 in.) (Harris 1972). One sample of the surface 4.3 cm (1.7 in.) of soil was taken adjacent to each ring to determine bulk density, organic carbon content, air-filled pore space, water content, and texture. Infiltration and soil property data were averaged for each site. Ground cover was sampled at each site using 10 settings of a 10-point frame (Goodall 1952) on a line transect. Point strikes were classed as follows: (1) bare, (2) litter, (3) alfalfa, (4) forb, or (5) grass.

The infiltration constants in equations (1) and (2) were determined for each site using the measured cumulative mean curves. Points along the mean curve were then used in a least squares analysis of the log transformation of equation (1):

$$\log F = \log A + B \log T. \qquad (3)$$

The resulting constants for each site were examined by multiple linear regression analysis using the constant as the dependent variable and soil and cover factors as independent variables. Significant correlations were noted and the regression models that best predicted A and B were determined (Draper and Smith 1966).

To test the regression model selected, actual and predicted infiltration curves were compared from data taken at a site 6 km (10 miles) away on a field with a Fayette silt loam soil that had been abandoned for 6 years (Harris 1972). Infiltration rates at this site were measured with single-ring steady-head infiltrometers identical to those used in the present study.

RESULTS

The infiltration constant A was negatively correlated (α = 0.01) with soil bulk density and positively correlated (α = 0.05) with air-filled pore volume (table 1). These properties reflect how quickly water enters the soil. Bulk density has long been used to indicate the hydrologic condition of soils (Parr and Bertrand 1960) and it is evidently important for the soils considered in the present study. Air-filled pore volume is related to bulk density (Knighton 1977) and reflects a similar hydrologic condition.

The infiltration constant B was significantly correlated (α = 0.05) with several properties that reflect the capability of the soil to maintain high infiltration rates (table 1). Organic carbon content, for example, is related to the structural stability of the soil and it increased with B. The density of alfalfa cover and litter cover were also significantly correlated (α = 0.01 and α = 0.05, respectively) with B. However, the relation decreased with alfalfa and increased with litter cover which suggests that the invading herbaceous vegetation (primarily grass) encourages higher infiltration rates. The constant B was significantly (α = 0.01) related to soil moisture content and the relation was positive. This is consistent with the definition of B in that the wetter a soil is at the onset of infiltration the less change there will be in infiltration rate as wetting continues. The opposite is reflected in the negative correlation with air-filled pore space.

Table 1.—*Simple linear correlation coefficients for infiltration constants and soil properties (only those soil properties that significantly related to at least one infiltration constant are reported)*

Infiltration constant	Simple correlation coefficient					
	Bulk density	Organic carbon	Water filled pores	Air filled pores	Alfalfa cover	Litter cover
A	[1]-0.77	0.23	-0.18	[2]0.49	-0.28	-0.10
B	0.19	[2]0.53	[1]0.60	[2]-0.52	[1]-0.60	[2]0.47

[1] Significant at α = 0.01.
[2] Significant at α = 0.05.

THE MODEL

As expected the soil properties were correlated with each other, thereby limiting the number that provided significant information in each model. Also, some variables that were not significant in simple correlation with the constants A and B did provide important information in the multiple regression models. The best model for estimating A included bulk density, clay content, and moisture content (table 2); however, similar results were obtained by deleting either clay content or moisture content. The best model for estimating B included organic carbon content and moisture content (table 2). The standard error was reduced when clay content was used in place of organic carbon content.

The infiltration model, using estimated values for A and B, closely estimated the infiltration curve at the test site (fig. 1, table 3).

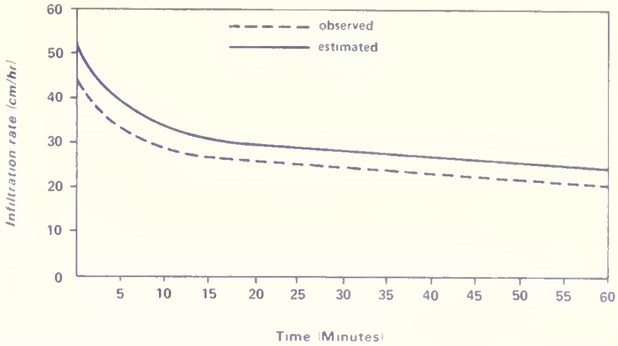

Figure 1. — *Observed and estimated infiltration rates for an abandoned field studied by Harris (1972).*

Table 2. — *Significant regression coefficients ($\alpha = 0.05$) and standard errors associated with the selected regression models for estimating the constants A and B in the infiltration model* $f = ABT^{B-1}$

Infiltration constant and model	Measured variables: Bulk density	Organic carbon	Clay	Moisture	Estimated constants and confidence intervals (95%)	Mean observed constants
	gm/cc	*Percent*				
A						
I	1.13	-	17	33.5	8.6 ± 1.6	10.7
II	1.13	-	17	-	8.3 ± 1.6	10.7
III	1.13	-	-	33.5	9.4 ± 1.4	10.7
B						
I	-	2.32	-	33.5	0.85 ± 0.04	0.81
II	-	-	17	33.5	.80 ± .05	.81

Table 3. — *Estimated value and confidence interval for the infiltration constants A and B given the independent variables measured on an abandoned field by Harris (1972) compared with associated mean observed constants*

Infiltration constant and model	Regression coefficients: Constant	Bulk density	Organic carbon	Clay	Moisture	r	Standard error of estimate
		gm/cc	*Percent*				
A							
I	33.185	-29.699	-	0.281	0.124	0.83	2.189
II	33.743	-25.758	-	.216	-	.80	2.267
III	32.590	-22.584	-	-	.0710	.78	2.386
B							
I	0.348	-	0.111	-	.00734	.74	0.0696
II	.387	-	-	.00802	.00841	.71	.0726

The range of soil properties used to construct the model were as follows:

Soil Property	*Range*
Bulk density	0.94 - 1.44 g/cc
Total pore space	43 - 61 percent
Vacant pore space	7 - 40 percent
Water-filled pore space	17 - 38 percent
Organic carbon	2 - 3 percent
Texture	
Clay	15 - 29 percent
Silt	60 - 71 percent
Sand	11 - 15 percent
Cover	
Alfalfa	8 - 50 percent
Forb	0 - 32 percent
Grass	4 - 60 percent
Litter	8 - 42 percent
Bare	0 - 46 percent

APPLICATION

The procedure for estimating infiltration rate is as follows:

1. Select the appropriate models for estimating the constants A and B from table 2 depending on what soil properties have been measured on the sites in question.
2. Estimate A and B using the regression coefficients from table 2. For example, using Model I, the equations would be:

   A = 33.185 - 29.699 (bulk density) + 0.281 (% clay) + 0.124 (% moisture)

   and

   B = 0.348 + 0.11 (% organic carbon) + 0.00734 (% moisture).
3. Substitute estimated A and B in equation (2) to calculate infiltration rate in mm/min.
4. Plot the results for several areas and compare.

This model is intended for use in estimating the effect of changes in soil properties on infiltration rate and should be used only if soil properties are within the range of those used in constructing the model. Infiltration rates will vary greatly within a watershed and the estimated value will only approximate the mean. These estimated rates are for infiltration by a steady-head single-ring infiltrometer. Final rates may be as much as 10 times those for a sprinkling infiltrometer on similar soils (Green *et al.* 1964). Similar differences could be expected when comparisons are made to precipitation infiltration rates.

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THREE TOOLS FOR MEASURING HEIGHT GROWTH IN FIELD PLANTINGS COMPARED

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ABSTRACT. — Three methods of measuring height growth in field plantings are compared.

OXFORD: 522.522.2. KEY WORDS: embossing tape, bamboo sticks, meter stick.

Three devices for measuring tree height growth were compared for accuracy: embossing tape, bamboo sticks, and a standard meter stick. The bamboo sticks were used in a prior study (Rudolph 1964), but the use of embossing tape has not been previously described in the literature.

METHODS AND MATERIALS

The study was done in a jack pine plantation near Rhinelander, Wisconsin. Heights were measured weekly for each method on 60 trees.

Before the growing season, we inserted a stainless steel pin into the terminal shoot of each tree 20 to 25 cm below the bud to serve as a reference mark for all three measurement methods. A second pin was inserted about 30 cm below the first pin as an undisturbed reference point to obtain a pre- and post-season measurement for total seasonal growth. This accumulated seasonal growth measurement served as a control. The three measuring devices were prepared and used as follows:

1. *Embossing tape.* — A strip of embossing tape about 90 cm long was attached to the base of a lateral branch 15 to 25 cm below the terminal bud by exposing a portion of the adhesive surface, wrapping it around the lateral branch, and adhering the two adhesive surfaces together (fig. 1). This joint was further secured by stapling. Where large amounts of growth occurred, more tape was added by sticking and stapling. Weekly growth was marked by stretching the tape taut in a vertical position parallel to the leader and punching a hole in the tape opposite the tip of the leader with a tool made from an ordinary laboratory forceps.

2. *Bamboo stick.* — A thin bamboo stick was taped to the main stem of each tree with 3M[1] bonded tape so that the stick extended well above the leader. A coping saw was used to mark the stick each week at the tip of the terminal bud.

3. *Meter stick.* — For the meter stick, measurements were taken each week from the reference pin to the tip of the terminal bud and recorded.

The authors took turns recording weekly measurements to eliminate bias. Total time for set-up, field measurements, and raw data work up to summary stage was 1,022 minutes for the meter stick, 938 minutes for the bamboo sticks, and 742 minutes for the embossing tape.

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[1] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

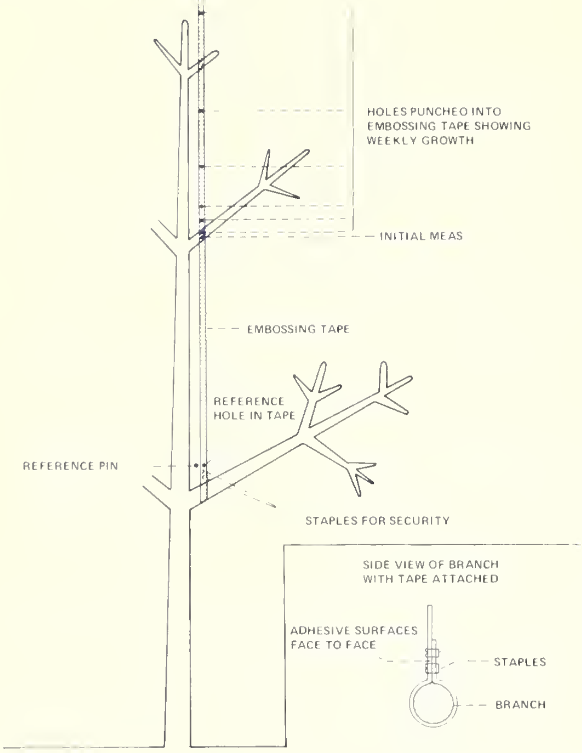

Figure 1. — *Schematic diagram showing use of embossing tape to obtain growth measurements.*

RESULTS AND DISCUSSION

Weekly growth. — In comparing mean weekly growth for all 60 trees by correlation coefficients and paired "t" tests, the meter stick method served as the control against which the other methods were tested. The growth data showed that the three methods were highly correlated (0.999), for both the bamboo stick and embossing tape when compared with the meter stick method. The paired "t" test showed no significant differences between methods. Hence, any of the three methods is technically acceptable and the choice of method should be based on time or cost.

Seasonal growth. — In comparing total seasonal growth, the pre- and post-seasonal measurements for total growth using the undisturbed pin served as the control. These data showed a high correlation with all three methods (table 1). The paired "t" test, however, showed the meter stick method as the only one not significantly different from the control at the 0.05 percent level. A coefficient of variation of overall means of all methods was approximately the same.

Table 1. — *Accuracy of measurements using the three tools*

Tool	Mean total height for all trees	"t" value	Coefficient of variation of x
	mm		*percent*
Meter stick	492.8	2.067	9.23
Bamboo stick	499.0	[1]3.912	9.38
Embossing tape	499.5	[1]2.669	9.17
Control	494.9	--	9.44

[1] Significant at 0.05 percent level.

The meter stick underestimated the true value by about 0.05 percent, where as the bamboo stick and embossing tape overestimated the true values by 0.9 and 1.0 percent. The paired "t" test showed the meter stick method to be more precise, but this test is extremely sensitive to variation in paired observations and should not influence the decision on which method to use.

Stretching of the embossing tape could be partly responsible for the slightly larger error associated with this method. However, we feel this method has advantages such as saving in time and manpower, less damage to trees, and ease of application. Moreover, the tape can be pre-labeled with all identification, can easily be added to if large amounts of growth occur, and can easily be stored at collection time.

The bamboo stick method resulted in occasional loss of terminal shoots due to cuts from the saw, or by girdling with the tape or ribbon used to secure the stick to the tree. Breakage of the sticks from too deep a cut by the saw was yet another problem.

The bamboo stick and embossing tape methods also offer the advantage of requiring only one person to obtain the measurements.

Costs of materials were not compared but we feel the time and manpower saved by using the embossed tape method would compensate for any difference in cost of materials.

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HERBICIDE TRIALS IN INTENSIVELY CULTURED *POPULUS* PLANTATIONS IN NORTHERN WISCONSIN

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ABSTRACT.—*Populus* had good survival and growth when planting sites had been treated with linuron, a pre-emergent herbicide, alone or in combination with paraquat, a post-emergent herbicide. The herbicide treatments that are most effective in intensive culture are discussed.

OXFORD: 441—414.1:238:236.1. KEY WORDS: Competition, pre-emergent, post-emergent, hardwood cuttings, weeds.

Using intensive plantation culture to increase yields is one way to help meet the rising demand for wood products. Many practices have already been found to increase yield of intensive culture plots—use of genetically improved stock, fertilization, irrigation—but further investigations may discover even more ways to increase biomass production. Although the use of herbicides to control weeds and thereby increase production has already been proven (Erdmann 1967, Erdmann and Green 1967, von Althen 1970), the toxic effect of specific chemicals and the proper application rates are not known for *Populus*.

Cram (1967) recommended local testing of herbicide treatments and other adaptation for the specific sites that may be used in intensive culture. Information should be developed locally on the different levels of treatment intensity by using both a post-emergent in combination with a pre-emergent herbicide and by varying the application rates.

We conducted a study to evaluate the effects of 12 herbicide treatments on competing vegetation and growth of *Populus 'Tristis #1'* (*Populus balsamifera L. x P. tristis* Frisch.) cuttings. The locations represent sites where intensive culture plantations may be established in future studies. These included a clearcut forested site, an abandoned farm field with established sod, and a well-cultivated field.

PROCEDURES

Sodded and clean-tilled sites were located on the Hugo Sauer Nursery in Rhinelander, Wisconsin, and the clearcut site was located on the Harshaw Experimental Farm approximately 10 miles west of Rhinelander. Three pre-emergent herbicides were tested—simazine (Princep),[1] linuron (Lorox), and dichlobenil (casoron)—as well as two post-emergent herbicides—paraquat (Ortho Paraquat) and glyphosate (Roundup). Dichlobenil was applied in granular form and raked into the soil surface. Simazine and linuron were mixed in a 2-gallon sprayer in the amounts required to cover one plot. Glyphosate and paraquat were applied in a tank mix with the pre-emergents in the first year and direct sprayed in the second year. Pre-emergent herbicides were applied prior to planting. Post-emergent herbicides were applied in combination with the pre-emergents the first season and alone the second season. The codes that will be used in the rest of the publication for the 12 herbicide treatments are shown in table 1.

Each herbicide treatment was replicated 3 times on each of the 3 sites in a randomized block design. Thirty-six 4- by 4-foot plots with a 4-foot buffer strip were established at each site (on a 44- by 44-foot area) and 16 trees were planted on each plot at 1- by 1- foot spacing. Before planting the nursery site was rototilled, the sod site was disked and rototilled, and the clearcut site was prepared by clearing all woody vegetation and clipping volunteer sprouts. The herbicides were first applied on June 28, 1974.

Populus cuttings (6 to 8 inches long and 3/8-to 5/8-inch diameter) from the previous year's growth were collected in April 1974 and stored in a freezer until they were planted on July 1 to 3, 1974. Cuttings planted on the nursery and sod sites were unrooted, but cuttings planted on the aspen site were prerooted in styrofoam blocks using a 1-1-1 media of soil-sand-peat because they could not be watered after planting. The nursery site was irrigated continually as needed throughout the growing season and the sod site was hand watered for 2 weeks. Cuttings on the clearcut site received a cup of water at planting.

Height, diameter (1 inch above the ground), and survival were determined at the end of the growing seasons in 1974, 1975, and 1976. Before the first frost in 1974 and 1975, weeds from each plot were clipped, separated by genus, ovendried, and weighed. Two-way analysis of variance, regression analysis, and Duncan's new multiple range test (Li 1964) were run at the 5 percent significance level.

RESULTS

Analysis of variance showed that there were significant treatment effects on survival on the nursery site in 1975, the sodded site in 1975 and 1976, and the clearcut site in 1975, and on height on the sodded site in 1976. Correlations of *Populus*

Table 1.—*Treatment codes for herbicide combinations, application rates*[1], *and sequences*

Treatment code	First year		Second year
	Pre-emergent and rate[1]	Post-emergent and rate	Post-emergent and rate
L4	4 lb. Linuron	--	--
L4, P½	4 lb. Linuron	½ lb. Paraquat	--
L4, P½, 2	4 lb. Linuron	½ lb. Paraquat	½ lb. Paraquat
L4, G3, 2	4 lb. Linuron	3 lb. Glyphosate	3 lb. Glyphosate
L8	8 lb. Linuron	--	--
D150	150 lb. Dichlobenil	--	--
D150, P½,2	150 lb. Dichlobenil	--	½ lb. Paraquat
S2	2 lb. Simazine	--	--
S4, P½,2	4 lb. Simazine	½ lb. Paraquat	½ lb. Paraquat
S4, G3, 2	4 lb. Simazine	3 lb. Glyphosate	3 lb. Glyphosate
S6	6 lb. Simazine	--	--
Control	--	--	--

[1] Application rates refer to total rather than active ingredient of the herbicide.

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[1] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

eight and survival with weights of the competing egetation by species were nonsignificant.

Three treatments involving moderate applicaion rates of linuron alone and in combination with araquat or glyphosate showed promise for ventually improving biomass production. Cutings raised under the treatment of 4 lb. acre of inuron alone (L4) or in combination with ½ lb. of paraquat applied in the first year (L4,P½,1) or first and second year (L4,P½,2) generally had superior survival. Survival in 1976 for these treatments was 33, 40, and 38 percent, respectively, on the sodded site (table 2). Treatment (L4) resulted in 90 percent survival in 1976 on the nursery site compared to 81 percent for treatment L4,P½,1) and 71 percent for treatment L4, P½,2). In 1976, survival on the clearcut site was 31 percent for treatment (L4) contrasted to 31 percent (L4,P½,1) and 42 percent for treatment L4,P½,2). Treatments (L8), (S2), and (L4,G3,2) also resulted in good survival of the cuttings.

Low dosages of linuron and simazine gave etter results than high dosages, possibly because f a toxic affect. Surprisingly, survival was highest n the nursery control plots in both years. This may indicate either a herbicide toxic effect or no real competition from the small amount of vegetation present on this site.

Table 2.—*Effect of herbicide treatment on mean survival of* Populus *cuttings planted on three northern Wisconsin sites*

(In percent)

Treatment code[1]	Site: Nursery 1975	Nursery 1976	Sod 1975	Sod 1976	Clearcut 1975	Clearcut 1976
L4	[2]85^{ab}	[3]85	50^{b}	33^{ab}	54^{a}	[3]31
L8	88^{a}	67	52^{b}	25^{bc}	42^{abc}	31
D150	65^{bc}	65	4^{c}	2^{c}	10^{c}	6
S2	77^{abc}	56	29^{c}	8^{c}	63^{a}	44
S6	38^{c}	35	8^{c}	2^{c}	17^{c}	8
L4,P½,1	81^{abc}	81	69^{a}	40^{a}	56^{a}	31
L4,P½,2	73^{abc}	71	48^{bc}	38^{ab}	48^{ab}	42
S4,P½,2	54^{bc}	54	17^{c}	13^{c}	35^{bc}	19
D150,P½,2	46^{c}	44	4^{c}	0^{c}	8^{c}	2
L4,G3,2	75^{abc}	75	29^{c}	19^{c}	42^{abc}	19
S4,G3,2	48^{c}	48	4^{c}	4^{c}	33^{bc}	15
Control	94^{a}	94	10^{c}	0^{c}	48^{ab}	33

[1] See table 1 for explanation of treatment description codes.

[2] Letters following the means indicate differences that are significant at the 95 percent probability level.

[3] No significant differences at 0.05 level of confidence.

Treatments (L4), and (L4,P½,1) resulted in superior height growth (table 3). Treatment (S4,P½,2) also gave good results as did treatments (L4,P½,2) and (L4,G3,2). Height growth was 43 cm in treatments (L4), (L8), and (L4,P½,1) on the sodded site and was 40 cm in treatment (S4,P½,2). On the clearcut site treatment (L4), (S2), (L4,P½,1), and (L4,P½,2) gave good height results—41 cm, 53 cm, 50 cm, and 41 cm, respectively. On the nursery site the treatments (L4), (L8), (S2), and (L4,P½,2) resulted in heights of 233 cm, 224 cm, 240 cm, and 246 cm, respectively.

The weed species present on the control plots of the three sites in 1974 are shown below.

The weed species present on the control plots of the three sites in 1974 are shown below.

Genus	Common Name	Weight (Pounds/acre)
	—NURSERY—	
Spergula	Sand spurry	257
Portulaca	Purslane	323
Mollugo	Carpetweed	158
Other		38
Total		776
	—SOD—	
Agropyron	Quackgrass	1.008
Polygonum	Bindweed	335
Chenopodium	Lambsquarter	301
Lychnis	Cockle	187
Taraxacum	Dandelion	97
Other		86
Total		2.014
	—CLEARCUT—	
Prunus	Cherry	889
Corylus	Hazel	369
Pteridium	Bracken fern	345
Populus	Aspen	324
Waldsteinia	Barren strawberry	198
Rubus	Blackberry	160
Aster	Large leaf aster	102
Other		162
Total		2.549

Neither seedling height nor survival was significantly correlated with the weights of competing plants.

Table 3.—*Effect of herbicide treatment on mean height of* Populus *in 1976 on three sites in northern Wisconsin*

(In cm)

Treatment code[1]	Site		
	Nursery	Sod	Clearcut
L4	[2]233	[3]43^{a}	[2]41
L8	224	43^{a}	29
D150	182	8^{c}	17
S2	240	9^{bc}	53
S6	220	6^{c}	12
L4,P½,1	222	43^{a}	50
L4,P½,2	246	36^{ab}	41
S4,P½,2	189	40^{a}	30
D150,P½,2	204	0^{c}	15
L4,G3,2	202	33^{abc}	33
S4,G3,2	188	16^{bc}	30
Control	212	0^{c}	38

[1] See table 1 for explanation of treatment description codes.

[2] No significant differences at the 0.05 level of confidence.

[3] Letters following the means indicate differences that are significant at the 95 percent probability level.

DISCUSSION

Compared to the control, herbicide treatments improved survival and growth on the sodded site, had no effect on the clearcut area, and possibly had an adverse effect in the nursery. Apparently the thorough tilling on the nursery site eliminated the need for weed control after planting. Linuron at 4 lb/acre on the sodded site increased survival, as did the additional use of paraquat through this contribution is small. Simazine increased survival on the clearcut site. Treatments (L4), (L4,P½,1), (L8), (L4,P½,2), and (L4,G3,2) showed consistently good results. For the most part these are combinations of linuron with a post-emergent herbicide. The use of simazine with the post-emergent glyphosate also increased survival and height growth.

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AVAILABILITY OF FOREST AND ASSOCIATED LAND RESOURCES IN ILLINOIS

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ABSTRACT.—Describes the extent of forest land resources in Illinois and estimates their availability for timber and recreational uses using both conventional definitions of forest land and the broader concept of forest and associated land.

OXFORD: 619.0:905.2(773). KEY WORDS: Timber supplies, recreational use, Illinois, resource availability, private woodlands.

Although recent statistics on timber stocking, growth, and harvest are available throughout the United States, the volumes of timber actually available to supply the nation's needs are not precisely known. Various economic, social, technical, and institutional factors can have an important impact on availability of timber supplies. Availability is a particularly crucial issue in States like Illinois where most of the timber resource is in small, private tracts. Owners of such forest land have a wide range of management objectives that are often unrelated to the production and sale of wood products.

It is even more difficult to give the availability of all forest-related resources including wood, water, recreation, erosion control, wildlife, and aesthetics. Conventional definitions (USDA Forest Service 1973) of forest land[1] and commercial forest land[2], which include the provision that the land be at least 10 percent stocked with trees, seem unduly restrictive if all forest-related resources are to be considered.

The purpose of the present paper is to provide an initial realistic, if somewhat imprecise, view of availability of forest-related resources in Illinois using existing resource data and information already available from various woodland owner studies. Forest and associated lands include not only the conventionally-defined forest lands, but also all noncommercial farms, unimproved pasture, and brush lands. The acreage of forest and associated lands more closely approximates the total acreage available for production of forest and forest-related goods and services.

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[1] *Forest land is defined as land at least 10 percent occupied by forest trees of any size, or formerly having had such tree cover, and not currently developed for nonforest use. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width at least 120 feet wide to qualify as forest land. Unimproved roads and trails, streams, or other bodies of water or clearings in forest areas are classed as forest if less than 120 feet in width.*

[2] *Commercial timberland is defined as forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization. Areas qualifying as commercial timberland have the capability of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included, except when the areas involved are small and unlikely to become suitable for production of industrial wood in the foreseeable future.*

CONVENTIONALLY DEFINED FOREST LAND RESOURCES

The most current data (USDA Forest Service 1973) on the forest land area in Illinois were based on an updating of a survey (Essex and Gansner, 1965) completed in 1962. The basic purpose of the survey was to inventory timber. In 1970 Illinois contained 3,786 thousand acres of forest land, 3,677 thousand acres commercial and 109 thousand acres noncommercial. If one allows for the fact that commercial forest land on the Shawnee National Forest increased by 13 thousand acres (presumably transferred from the private sector) since the 1973 publication, the breakdown of ownership is as follows:

Ownership	**Commercial forest land acreage**	**Noncommercial forest land acreage**
	--------(thousand acres)--------	
Private-nonindustrial	3,382	79
National forest	227	27
Other Federal	41	--
State	11	3
Forest industry	16	--
Total	3,677	109

With the exception of 3.5 thousand acres of national forest land which is reserved for experimental forests, research plots, developed recreation sites, and administrative sites, most of the Federal, State, and forest industry commercial forest land in Illinois (a total of 291.5 thousand acres) can realistically be considered as available for timber harvest consistent with multiple-use management priniciples.

An estimate of the availability of private, nonindustrial commercial forest land was made by reviewing various woodland owner studies that obtained information relating to availability. Neuzil[3] in a study of owners who had recently acquired woodlands in a 7-county area of Illinois found that 45 percent planned to make commercial timber sales; a recent computation from the Neuzil study showed these owners controlled about 50 percent of the sampled acreage. Beazley and Holland (1973) found that 40 percent of the woodland owners in a central county (Fulton) and 30 percent of those in a southern county (Jackson) planned to sell timber. Recent estimates from the original data showed that the Jackson County owners planning sales controlled about 40 percent of the woodland acreage and the Fulton County owners about 50 percent.

Considering these data and the fact that some owners in the Beazley-Holland study who did not plan sales looked on their woodland as a reserve convertible to cash in case of a special need, roughly 50 percent or 1,691 thousand acres of the private, nonindustrial commercial forest land in Illinois is available for timber production. When this figure is added to the 291.5 thousand acres of Federal, State, and industry-owned land that is available, a total of 1,982.5 thousand acres, or about 54 percent of the States' commercial forest land is obtained. (Noncommercial forest land is assumed to be unavailable for timber production.)

The preceding studies looked at harvest objectives at a single point in time. A more long-run view may yield different results. A recent Delaware study (Turner *et al.*, 1977) concludes that at some time most forest crops will come under the control of an owner who will consider harvesting.

The forests of Illinois also provide opportunity for various forms of outdoor recreation. Callahan, *et al.* (1974) estimated that about 95 percent of the Shawnee National Forest was available for recreation. Applying this percentage to the current national forest acreage of 254 thousand acres gives an availability figure of 241 thousand acres. Assuming a similar percentage for other Federal, State, and industry forest land, 67 thousand acres may be added, giving a total of 308 thousand acres of public and industrial forest land available for recreation in Illinois.

Two Illinois studies provided a basis for estimating the availability of private, nonindustrial forest land for recreation. Neuzil found that 38 percent of the new woodland owners in a 7-county area of southern Illinois allowed some use of their land for outdoor recreation by the public. McKibben[4] reported that 42 percent of rural

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[3] *Neuzil, Michael A. 1970. A study of the new landowner in Southern Illinois. 66 p. Unpublished M.S. thesis on file at Southern Illinois University, Department of Forestry, Carbondale, Illinois.*

[4] *McKibben, William G. 1968. A study of the outdoor recreation policies of the private landowners in the Shawnee Hills Planning Region, Illinois. 59 p. Unpublished M.S. thesis on file at Southern Illinois University, Department of Forestry, Carbondale, Illinois.*

landowners owning 160 acres or more in southern Illinois allowed some public recreational pursuits on their land.

The estimates by Neuzil and McKibben were reduced because of several factors. First, a portion of the landowners in both the above studies restricted use primarily to friends, relatives, and neighbors. Second, McKibben found that those landowners with larger farms were less inclined to allow public recreation. Finally, both Neuzil and McKibben studied landowners in counties with limited urban development. We scaled their estimates downward to 30 percent since it seemed likely that other owners close to large urban areas would be more reluctant to allow public recreational use. Applying this percentage figure yields a total of approximately 1,014.6 thousand acres. Table 1 summarizes the availability of "conventionally defined" forest land in Illinois.

Table 1.—*Conventionally defined*[1] *forest land acreage in Illinois by ownership category, availability for timber harvest, and recreational use*

(Thousands of Acres)

Owner	Commercial	Noncommercial	Total	Available for timber harvest	Available for recreation
Private-nonindustrial	3,382	79	3,461	[2]1,691	[3]1,038
National Forest	227	27	254	[4] 224	[5] 241
Other Federal	41		41	41	[5] 39
State	11	3	14	11	[5] 13
Forest industry	16		16	16	15
Total	3,677	109	3,786	1,983	1,346

[1] As defined by the Forest Service (1973).

[2] Fifty percent of private-nonindustrial commercial forest land.

[3] Thirty percent of total private-nonindustrial forest land.

[4] Commercial national forest land minus 3,500 acres reserved for nontimber uses.

[5] Ninety-five percent of total forest land in each ownership category.

FOREST AND ASSOCIATED LAND RESOURCES

Beazley (1965) estimated that roughly 9 million acres, or 25 percent of the State land area, is "forest and associated land";[5] (including "conventionally-defined forest land", brush lands, unimproved pasture, and land on noncommercial farms—in short all nonurban, nontransportation or service, and noncommercial agriculture lands) and provide the "forest-related resources" mentioned earlier. This is more than twice the "conventionally-defined forest land" estimates of 10.5 percent of the State, and closely approximates the total of what assessors call "unimproved land". Beazley maintained that these lands have an essential unity in producing the forest-related resources mentioned earlier, and that they are sufficiently similar to be considered as a group for multiple-use, integrated land use planning and management. Further studies showed that these lands could be accurately determined from aerial photos, and that they show a much more extensive, unified, less fragmented, spatial arrangement for planning and management than do "conventionally-defined forest lands". Table 2 summarizes the ownership and availability of "forest and associated land" in Illinois using the same estimated availability percentages of 50 percent for timber and 30 percent for recreation that were used for conventionally-defined forest land.

IMPROVING AVAILABILITY ESTIMATES

The availability figures presented here are based on owner attitudes at a single point in time resulting from a given set of economic, technological, and social circumstances. Obviously the circumstances and owner attitudes change and new owners with new attitudes arrive on the

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[5] *Beazley arrived at his estimate as follows: (1) The ratio of land in commercial farms to all land in all farms was first determined. Call it "R". (2) The following areas were summed: woodland pastured and not pastured; other pasture, not cropland, or improved pasture; and wasteland (wasteland = "other land" less 2 percent of farm area for buildings and roads). Call this total "W". (3) An estimate of the acreage of actual commercial farm land in commercial farms was then determined by subtracting the proportional amount of "W". That is, commercial land = land in commercial farms - (R x W). An estimate of urban, service and transportation land (6 percent for the State; which varied by counties) was added to commercial farm land to provide an estimate of "urban, service, and (genuinely) agricultural land." (4) The figure for urban, service, and agricultural land area was subtracted from the total land area in each case to arrive at the figure for area in "forest and associated land".*

Table 2.—*Forest and associated land acreage in Illinois by ownership category and availability for timber harvest and recreational use*

(Thousands of Acres)

Ownership category	Total forest and associated land	Available for timber harvest	Available for recreation
Private-nonindustrial	8,675	[1]1,691	[2]2,612
National Forest	254	[3] 224	[4] 241
Other Federal	41	41	[4] 39
State	14	11	[4] 13
Forest industry	16	16	[4] 15
Total	9,000	1,983	2,920

[1] Fifty percent of private-nonindustrial commercial forest lands.

[2] Thirty percent total private-nonindustrial forest and associated land.

[3] Commercial national forest land minus 3,500 acres reserved for nontimber uses.

[4] Ninety-five percent of forest and associated land in respective ownership category.

scene. Data indicating long term trends in owner attitudes are generally unavailable but recent studies indicate that change can occur quite rapidly and over longer time periods most owners will harvest timber when it become economically feasible to do so. For recreation, however, a trend to closing more and more private land to public use seems clear. In both cases frequent monitoring of availability to indicate changes and trends would be desirable.

SUMMARY AND CONCLUSIONS

Resource statistics based on conventional definitions of forest land can be misleading, particularly in States like Illinois where most of the forest land is in small parcels owned by a diverse group of private, nonindustrial owners. We estimate that no more than 50 percent of the conventionally-defined, private, nonindustrial forest land is actually available for timber harvest and only about 30 percent for recreational uses. These figures could be higher over the long run for timber but availability for recreation is likely to decrease if past trends continue and new public incentive devices are not adopted.

There is more land available to the public for forest recreation on the greater acreage of ''forest and associated land'', but not necessarily more timber, at least in the short run.

Although more and more small private owners are not harvesting their timber for aesthetic or noneconomic reasons, the *primary* reason that owners of small private tracts are not selling their timber is because they think their tracts are too small or the trees too small and low in quality (Quinney, 1962) to be worth harvesting.

''Forest and associated lands'' as defined earlier have a greater potential for producing a full range of forest-related resources than the smaller, more narrowly defined ''forest lands'' and provide a useful concept for resource planning. To encourage owners to make these lands available for timber, recreation, and other resources, a comprehensive statewide or regionwide management plan with incentives and cooperative agreements is needed.

Fear of liability for injuries and damage to property has prevented owners from making more ''forest and associated land'' available for public recreational use. Still, about 10 percent of owners not allowing public recreational use responded favorably to leasing programs, and 30 percent were interested in cooperative agreements with their neighbors to allow public use of their lands.

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1978

ALTERNATE HOST OF JACK PINE NEEDLE RUST IN NORTHERN MINNESOTA

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and **Neil A. Anderson,** *Professor, Department of Plant Pathology, University of Minnesota, St. Paul, Minnesota*

ABSTRACT.—The pine needle rust of jack pine on the Little Sioux Burn in northeastern Minnesota infected large-leaf aster but not goldenrod. The rust was most severe when asters were abundant on the plots. Less than 10 percent of the jack pine were infected over a 3-year period when asters were more than 10 feet (3.05 m) from the mil-acre plots.

OXFORD:172.8:415.15(776). KEY WORDS: *Coleosporium asterum, red pine, aster, goldenrod, races.*

Early literature, including Arthur (1934), indicates that both goldenrod, *Solidago* sp., and aster, *Aster* sp., are alternate hosts for the pine needle rust, *Coleosporium asterum* (Diet.) Syd. After inoculating alternate host plants of both genera, Hedgcock and Hunt (1922) suggested that, in the eastern United States *Coleosporium solidaginis* (Schw.) Thum (*C. asterum*) either included two races each infecting only one of the alternate host genera or else should be considered as two species of rust. In the western United States, however, Weir and Hubert (1916) obtained infection of both alternate host genera from single sources of inoculum and Weir (1925) repeatedly transferred the rust from *Aster* to *Solidago* and from *Solidago* to *Aster* by means of urediospores. Apparently no further attention was given to this problem until the studies by Nicholls *et al.* (1968) in Wisconsin. They suggest that there are at least three forms or races of *C. asterum*, one specific to *Solidago*, another specific to *Aster*, a third occurring on some species of both genera. They also suggest that infection of red pine, *Pinus resinosa* Ait., jack pine, *P. banksiana* Lamb., and Austrian pine, *P. nigra* Arnold, in Wisconsin is limited to the form or race of the rust found on *Solidago* sp.

Our purpose here is to identify the alternate host of the needle rust on jack pine on the "Little Sioux Burn" in northeastern Minnesota and to present further evidence suggesting that *C. asterum* is composed of a complex of races or forms.

In May 1971, a large fire, the Little Sioux Fire, burned several thousand acres on the Superior National Forest in northeastern Minnesota. On those sites occupied by jack pine or aspen, *Populus tremuloides* Michx., abundant natural regeneration occurred. In the summer of 1972, experiments were set up to determine the influence of diseases on jack pine seedling survival on the burn. Two sites were selected for study, one a good jack pine site on deep sandy soil, the other a poor site on very shallow soil overlying bed rock. On each site 100 mil-acre sample plots were set up along a transect, across the site, approximately one-fourth mile in length. Plots were examined in June 1973, 1974, and 1975.

Needle rust infection was abundant on both sites. This posed two interesting questions: Although *Aster macrophyllus* L. was abundant on both sites, no *Solidago* sp. were found on any of the plots. A reconnaissance of both sites in the vicinity of the plots also failed to reveal any *Solidago* sp. This suggested that *Solidago* was not involved and that *Aster* was the alternate host, contrary to Nicholls *et al.* (1968) in Wisconsin. It was also noted that the needle rust infection was not distributed at random. Instead, it was severe on some plots and absent on others.

An analysis was made to determine whether there was any correlation between local abundance of *A. macrophyllus* on and in the immediate vicinity of individual plots and the prevalence of *C. asterum* infection of jack pine on the plots. The results, essentially identical for both sites, suggest a close relation between the presence of aster and prevalence of needle rust on jack pine (table 1). They also indicate that aster must be abundant within a few feet of the jack pine seedlings to cause heavy infection, at least under the conditions that prevailed on the Little Sioux Burn.

Table 1.—*Prevalence of needle rust infection in relation to presence and abundance of aster*

(In percent)

Presence and abundance of aster	Jack pine infected		
	1973	1974	1975
Abundant on plots	40	85	80
Moderately abundant on plots	41	80	73
Rare on plots	10	44	37
None on plots, but present within 10 feet	7	34	41
None within 10 feet of plots	6	10	9

The information obtained in the field suggested that it would be desirable to follow-up with a greenhouse inoculation study using inoculum collected from several locations in the Lake States region. *Aster macrophyllus* and *Solidago* sp. were potted in the fall of 1974 and held over winter in the greenhouse. Pine needles bearing needle rust aeciospores were collected from several locations in early June 1975; three jack pine and one red pine collections were used.

Five aster and five goldenrod plants were inoculated from each aeciospore collection, and incubated. Five aster and five goldenrod plants were incubated without inoculation to serve as controls. The test was repeated a second time using the same aeciospore inoculum and a third time using urediospores produced in the first test. No infection occurred on any of the control plants, and all the results were identical for all three tests on all collections.

Inoculations from two of the jack pine collections (one from the Little Sioux Burn in northeastern Minnesota and the other from a Washburn area in northern Wisconsin) infected aster but not goldenrod. Inoculations from the third jack pine collection (from the Beltrami Island area in northwest Minnesota) infected goldenrod but not aster. The red pine aeciospore collection (from the Chippewa National Forest in north-central Minnesota) also infected goldenrod but not aster.

These results support the conclusion that large-leaf aster is the alternate host for the jack pine needle rust on the Little Sioux Burn. They also indicate that both aster and goldenrod serve as alternate hosts for needle rust on jack pine, but that different forms or races of the rust are involved on each of these alternate host genera. Beyond this, because of the small number of collections tested, more questions are raised than answered.

Are there forms or races of the pine needle rust that can infect eastern species of pines and both genera of alternate hosts as was indicated in the West by Weir and Hubert (1916)? There appears to be no reason why, on some sites, a mixture of forms or races, one on goldenrod the other on aster, could not result in mixed infection on a single pine or even a single needle. Proof would require alternate host inoculation studies with aeciospore in oculum form single aecium sources on pine needles to avoid mixed inoculum and assure that the rusts tested are in fact pathogenic on pine. Uredia arising from successful inoculations should then be tested for transfer between alternate host genera as was done by Weir (1925) in the West.

Are there forms or races of the pine needle rust occuring on red pine that use aster as an alternate host? The single red pine isolate tested in this study, plus those by Nicholls *et al.* (1968), are too limited a sample. Testing results from a large number of inoculum sources would be needed to answer this question.

The needle rust fungus has developed forms or races that differ on the alternate hosts. Does it also differ on the pine hosts, i.e., do the races or forms infecting jack pine also infect red pine and the other hard pine species susceptible to needle-rust infection? If the rust called *C. asterum* is composed of "forms or races" that differ, not only in the genera of alternate hosts infected but also in the pine species infected, then it would seem questionable to regard the rust as a single species, unless the various races could interbreed and change. Attempts to answer this question would require pine host range inoculation studies using inoculum originating from known pine and alternate host sources.

To complicate the picture further, it has been shown that *Coleosporium viburni,* which causes a needle rust of jack pine indistinguishable in the field from *C. asterum*, has as its alternate host the Arrow-wood, *Viburnum cassinoides* L., Ouellette (1966).

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NORTH CENTRAL
FOREST
EXPERIMENT STATION

Research Note NC-238

1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.

1978

PULPWOOD PRODUCTION IN THE LAKE STATES

BY COUNTY, 1977

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and W. Brad Smith, *Associate Mensurationist*

ABSTRACT.--This 32nd annual report shows 1977 pulpwood production by county and species group in Michigan, Minnesota, and Wisconsin. Production in these three Lake States inched ahead to 4.74 million cords from 4.69 million cords in 1976.

OXFORD: 861.0(77):792. KEY WORDS: Residue, Minnesota, Wisconsin, Michigan.

Lake States pulpwood production advanced slightly to 4.74 million cords in 1977 from 4.69 million cords in 1976. Production rose 3 percent in Michigan to 1.59 million cords and 2 percent in Minnesota to 1.33 million cords. Wisconsin output dropped 1 percent to 1.82 million cords.

For every 89 cords cut from roundwood (including chips) 11 cords were derived from mill residue such as slabs, edgings, veneer cores, and chips from those materials. Output from softwood and hardwood residue by State was:

State	*Softwood*	*Hardwood*
	Hundred standard cords	
Michigan	208	1,708
Minnesota	353	779
Wisconsin	480	1,486

Production changes were small to moderate for all species. Major increases were for aspen (68,000 cords), soft maple (33,000 cords), and balsam fir (29,000 cords). Lake States hardwood residue procured for pulping rose 38,000 cords. Largest declines in the pulpwood harvest were for elm (55,000 cords) and birch (33,000 cords).

Harvesting increased mainly in Michigan's western Upper Peninsula and southern Lower Peninsula and north-central Minnesota while the major decline was in central Wisconsin.

Top-producing counties were Iron, Delta, and Marquette in Michigan; St. Louis, Koochiching, and Itasca in Minnesota; and Marinette, Oneida, and Forest in Wisconsin.

Pulpmills using Lake States timber in 1977 reported their pulpwood receipts by species groups and State and county of origin. Their cooperation is gratefully acknowledged. Thanks are also due the Michigan Department of Natural Resources for collecting the data from pulpmills in Michigan.

Table 1.--*Lake States pulpwood production from roundwood by county and species, 1977*

(Hundred standard cords, roughwood basis)

MICHIGAN

UNIT AND COUNTY 1/	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
E. UPPER PENINSULA												
ALGER	483	156	14	30	76	1	5	66	36	1	65	33
CHIPPEWA	344	155	56	42	22	1	2	35	9	X	16	6
DELTA	1021	117	58	152	63	3	10	354	71	2	106	85
LUCE	394	184	26	42	60	1	2	22	13	1	26	17
MACKINAC	225	40	10	55	17	X	8	42	15	0	9	29
MENOMINEE	936	19	68	105	28	8	4	428	49	1	85	141
SCHOOLCRAFT	492	140	42	53	44	1	5	113	28	1	27	38
TOTAL	3895	811	274	479	310	15	36	1060	221	6	334	349
W. UPPER PENINSULA												
BARAGA	632	69	22	64	67	2	9	225	40	1	104	29
DICKINSON	730	11	20	51	13	4	1	490	40	1	57	42
GOGEBIC	404	27	5	44	61	1	3	177	21	X	45	20
HOUGHTON	175	23	5	17	22	X	1	43	17	X	32	15
IRON	1167	88	80	147	54	4	7	484	70	1	157	75
KEWEENAW	9	1	1	X	2	X	X	X	X	0	4	1
MARQUETTE	971	258	66	113	51	2	9	228	82	4	97	61
ONTONAGON	493	14	3	15	40	X	1	307	21	0	69	23
TOTAL	4581	491	202	451	310	13	31	1954	291	7	565	266
N. LOWER PENINSULA												
ALCONA	424	3	0	0	0	0	0	259	16	111	27	8
ALPENA	160	6	X	2	0	0	0	92	11	8	32	9
ANTRIM	7	0	0	0	0	0	0	6	0	0	1	X
ARENAC	6	0	0	0	0	0	0	4	1	0	1	X
BENZIE	106	3	0	0	0	0	0	58	4	8	27	6
CHARLEVOIX	7	7	0	0	0	0	0	0	0	0	0	0
CHEBOYGAN	185	40	X	1	0	0	0	84	5	2	41	12
CLARE	322	32	0	0	0	0	0	152	4	86	38	10
CRAWFORD	105	38	0	0	0	0	0	12	1	40	11	3
EMMET	14	8	0	0	0	0	0	4	1	0	1	0
GLADWIN	90	2	0	0	0	0	0	62	7	11	7	1
GRAND TRAVERSE	75	20	0	0	0	0	0	40	1	2	9	3
IOSCO	143	122	0	0	0	0	0	8	X	5	7	1
ISABELLA	57	X	0	0	0	0	0	37	X	16	3	1
KALKASKA	197	51	0	X	X	0	0	95	2	23	21	5
LAKE	475	51	0	0	0	0	0	184	1	149	76	14
LEELANAU	22	0	0	0	0	0	0	8	1	4	3	6
MANISTEE	172	18	0	0	0	0	0	60	3	34	47	10
MASON	158	X	0	0	0	0	0	74	4	44	33	3
MECOSTA	167	27	0	0	0	0	0	108	1	25	4	2
MIDLAND	54	0	0	0	0	0	0	35	2	4	11	2
MISSAUKEE	83	19	0	0	0	0	0	31	2	18	11	2
MONTMORENCY	314	87	1	3	0	0	0	148	7	51	13	4
NEWAYGO	207	61	0	0	0	0	0	79	1	56	8	2
OCEANA	141	32	0	0	0	0	0	51	1	32	12	13
OGEMAW	138	57	0	0	0	0	0	32	2	37	7	3
OSCEOLA	205	22	0	0	0	0	0	142	3	27	9	2
OSCODA	238	91	X	1	0	0	0	94	6	29	13	4
OTSEGO	72	63	X	1	0	0	0	7	0	1	0	0
PRESQUE ISLE	213	41	1	7	1	0	0	114	19	14	13	3
ROSCOMMON	235	92	0	0	0	0	0	81	2	48	12	X
WEXFORD	364	199	0	0	0	0	0	54	2	55	49	5
TOTAL	5156	1192	2	15	1	0	0	2215	110	940	547	134
S. LOWER PENINSULA												
ALLEGAN	33	23	0	0	0	0	0	4	X	5	1	X
BARRY	2	2	0	0	0	0	0	X	0	0	0	0
CALHOUN	1	1	0	0	0	0	0	0	0	0	0	0
GRATIOT	17	0	0	0	0	0	0	6	0	5	4	2
KENT	87	4	0	0	0	0	0	9	X	43	19	12
MONTCALM	131	12	0	0	0	0	0	36	X	57	18	8
MUSKEGON	78	38	0	0	0	0	0	31	X	8	1	X
OTTAWA	39	39	0	0	0	0	0	X	0	0	0	0
SAGINAW	4	1	0	0	0	0	0	2	X	1	X	X
WASHTENAW	1	1	0	0	0	0	0	0	0	0	0	0
TOTAL	393	121	0	0	0	0	0	88	X	119	43	22
STATE TOTAL	14025	2615	478	945	621	28	67	5317	622	1072	1489	771

(CONTINUED ON NEXT PAGE)

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1977.
X=LESS THAN 50 CORDS.

MINNESOTA

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
NORTHERN ASPEN-BIRCH												
CARLTON	316	50	11	21	0	3	0	200	31	0	X	0
COOK	370	34	97	38	0	0	0	201	0	0	0	0
KOOCHICHING	2430	161	516	220	0	199	0	1247	19	0	1	67
LAKE	757	215	194	91	0	2	0	233	22	0	0	0
ST.LOUIS	3060	512	279	225	0	38	0	1869	81	0	2	54
TOTAL	6933	972	1097	595	0	242	0	3750	153	0	3	121
NORTHERN PINE												
AITKIN	324	5	12	10	0	26	0	241	14	10	1	5
BECKER	15	10	0	0	0	X	0	5	0	0	0	0
BELTRAMI	750	104	85	119	0	18	0	380	42	0	2	X
CASS	727	156	12	18	0	11	0	504	26	0	X	0
CLEARWATER	213	26	12	13	0	21	0	134	6	0	1	0
CROW WING	167	66	0	1	0	0	0	94	6	0	0	0
HUBBARD	381	101	5	7	0	11	0	247	10	0	0	0
ITASCA	1658	75	142	226	0	29	0	1147	12	0	2	25
LAKE OF THE WOODS	297	49	127	3	0	24	0	92	0	0	0	2
MAHNOMEN	18	12	0	0	0	1	0	5	0	0	0	0
ROSEAU	182	75	39	X	0	11	0	47	10	0	0	0
WADENA	68	47	0	0	0	0	0	20	1	0	0	0
TOTAL	4800	726	434	397	0	152	0	2916	127	10	6	32
CENTRAL HARDWOOD												
BENTON	41	0	0	0	0	0	0	21	4	10	1	5
CHISAGO	1	0	0	0	0	0	0	1	0	0	0	0
HENNEPIN	9	0	0	0	0	0	0	0	0	0	0	9
KANABEC	48	0	0	0	0	0	0	28	4	10	1	5
MILLE LACS	74	0	0	0	0	3	0	51	4	10	1	5
MORRISON	111	10	X	0	0	0	0	81	4	10	1	5
OTTER TAIL	5	5	0	0	0	X	0	0	0	0	0	0
PINE	140	14	0	0	0	0	0	121	5	0	0	0
RAMSEY	9	0	0	0	0	0	0	0	0	0	0	9
TODD	6	6	0	0	0	0	0	0	0	0	0	0
TOTAL	444	35	X	0	0	3	0	303	21	40	4	38
PRAIRIE												
POLK	24	0	0	0	0	24	0	0	0	0	0	0
TOTAL	24	0	0	0	0	24	0	0	0	0	0	0
STATE TOTAL	12201	1733	1531	992	0	421	0	6969	301	50	13	191

(CONTINUED ON NEXT PAGE)

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1977.
X=LESS THAN 50 CORDS.

WISCONSIN

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
NORTHEASTERN												
FLORENCE	780	23	10	40	17	1	X	381	18	4	119	167
FOREST	982	64	32	124	51	3	1	432	42	X	110	123
LANGLADE	507	8	2	21	11	4	0	114	29	5	142	171
LINCOLN	798	56	15	75	31	5	2	357	37	11	84	125
MARINETTE	1190	145	13	79	15	X	1	755	115	0	28	39
OCONTO	438	106	3	21	4	X	0	270	22	0	7	5
ONEIDA	1157	166	51	128	8	3	X	482	174	26	74	45
SHAWANO 2/	495	14	0	9	151	X	0	196	9	X	38	78
VILAS	814	104	28	70	32	2	3	360	91	6	70	48
TOTAL	7161	686	154	567	320	18	7	3347	537	52	672	801
NORTHWESTERN												
ASHLAND	723	66	13	63	21	2	3	401	28	1	68	57
BARRON	12	7	0	0	0	0	0	0	5	0	0	0
BAYFIELD	896	107	1	13	1	X	X	611	136	6	12	9
BURNETT	214	208	0	1	0	0	0	2	1	0	1	1
DOUGLAS	570	322	X	2	0	2	0	217	23	0	2	2
IRON	620	16	3	8	8	1	X	500	24	2	24	34
POLK	14	14	0	0	0	0	0	0	0	0	0	0
PRICE	867	48	8	37	19	5	1	361	80	9	79	220
RUSK	244	1	X	3	3	X	0	84	29	6	52	66
SAWYER	772	64	5	8	23	X	X	406	62	9	90	105
TAYLOR	480	10	2	16	10	4	1	212	46	4	62	113
WASHBURN	668	165	1	1	0	1	0	488	7	0	3	2
TOTAL	6080	1028	33	152	85	15	5	3282	441	37	393	609
CENTRAL												
ADAMS	347	268	0	0	0	0	0	1	X	78	X	X
CHIPPEWA	165	7	X	1	4	3	X	86	19	3	18	24
CLARK	191	37	0	X	1	X	0	20	4	112	9	8
EAU CLAIRE	57	52	0	0	0	0	0	3	X	1	1	X
JACKSON	184	166	0	0	0	X	0	1	1	11	3	2
JUNEAU	274	208	0	0	0	X	0	5	3	50	5	3
MARATHON	775	20	X	15	23	1	0	75	8	22	251	360
MARQUETTE	67	30	0	0	0	1	0	0	1	0	15	20
MONROE	57	48	0	0	0	0	0	X	2	0	5	2
PORTAGE	153	65	0	X	2	X	0	33	X	48	4	1
WAUPACA	122	27	0	X	1	X	0	67	4	0	10	13
WAUSHARA	93	79	0	0	0	1	0	2	1	7	2	1
WOOD	265	122	X	0	0	0	0	24	3	104	7	5
TOTAL	2750	1129	X	16	31	6	X	317	46	436	330	439
SOUTHWESTERN												
BUFFALO	1	1	0	0	0	0	0	0	0	0	0	0
CRAWFORD	X	0	0	0	0	0	0	X	0	0	0	0
DUNN	21	21	0	0	0	0	0	0	0	0	0	0
GRANT	50	X	0	0	0	0	0	7	2	23	5	13
IOWA	1	1	0	0	0	0	0	0	0	0	0	0
LACROSSE	9	9	0	0	0	0	0	0	0	0	0	0
PEPIN	1	1	0	0	0	0	0	0	0	0	0	0
RICHLAND	1	1	0	0	0	0	0	0	0	0	0	0
SAUK	32	32	0	0	0	0	0	0	X	0	X	X
TREMPEALEAU	15	15	0	0	0	0	0	0	0	0	0	0
TOTAL	131	81	0	0	0	0	0	7	2	23	5	13
SOUTHEASTERN												
BROWN	1	1	0	0	0	0	0	0	0	0	0	0
COLUMBIA	20	13	0	0	0	0	0	0	X	0	2	5
DANE	1	1	0	0	0	0	0	0	0	0	0	0
GREEN	4	4	0	0	0	0	0	0	0	0	0	0
GREEN LAKE	X	X	0	0	0	0	0	0	0	0	0	0
MANITOWOC	X	0	0	0	0	0	0	X	0	0	0	0
OUTAGAMIE	22	1	0	0	0	0	0	7	4	0	7	3
ROCK	X	X	0	0	0	0	0	0	0	0	0	0
WAUKESHA	23	23	0	0	0	0	0	0	0	0	0	0
TOTAL	71	43	0	0	0	0	0	7	4	0	9	8
STATE TOTAL	16193	2967	187	735	436	39	12	6960	1030	548	1409	1870

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1977.
2/ INCLUDES MENOMINEE COUNTY.
X=LESS THAN 50 CORDS.

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DISTRIBUTION OF BIOMASS AND PRODUCTION FOR SEVERAL NORTHERN WOODY SPECIES

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ABSTRACT.—Relative distributions of biomass and net primary production among plant components are reported for three tree species and four shrub species common to the northern deciduous forest.

OXFORD: 161.4:182.46:182.41. KEY WORDS: Biomass, birch, maple, net primary production, Wisconsin.

Biomass and production relations for several woody species common to the northern forest were determined as part of a study conducted in the Enterprise Forest near Rhinelander, Wisconsin (Rudolph 1974, Zavitkovski 1977). Four shrubs, *Vaccinium myrtilloides*, *Rubus allegheniensis*, *Corylus cornuta*, *Ilex verticillata*, and three trees, *Acer rubrum*, *Acer saccharum*, *Betula papyrifera*, were sampled. These species represent a spectrum of growth forms and plant sizes. The relative distributions of biomass and production by plant component, with comparisons among species, are reported here.

The procedures for selection of samples and the determination of biomass and net primary production have been reported (Crow 1978). The figures presented in tables 1 and 2 were determined from dry weight values.

The obvious differences in proportionalities of biomass and production between *Rubus* and other shrub species can be attributed to its growth form (table 1). From an underground, perennial base, several aerial, biennial stems are produced; these stems were harvested in this study. During the first growing season, the biennial stems (primocanes) are usually unbranched and rarely produce inflorescence; during the second growing season, these stems (floricanes) cease growth but produce a number of short lateral branches, often with terminal inflorescence. Leaves and current twigs accounted for all the biomass of primocanes. Biomass distribution for the floricanes was divided among the first-year stem (36 percent stem and branches), the lateral branches (63 percent leaves and current twigs), and fruit (1 percent).

Among the other shrub species, stem and branch biomass ranged from 64 to 89 percent and current twig and leaf weight ranged from 35 to 11 percent

Table 1.—*A summary of mean dimensional and functional relations for shrub species sampled in the Enterprise Forest*

Item	*Vaccinium myrtilloides*	*Rubus allegheniensis*		*Corylus cornuta*	*Ilex verticillata*
		primocanes	floricanes		
Sample number	69	62	41	70	20
Basal diameter (mm)					
Mean	4.0	4.6	4.9	11.8	14.9
Range	2.3-6.3	2.4-8.2	3.1-7.9	4.0-24.4	8.6-24.9
Stem length (cm)					
Mean	46.4	71.6	56.7	175.1	196.2
Range	30-90	30-137	30-105	42-355	110-290
Biomass distribution (percent of total aboveground dry weight)					
Stem and branches	64.5	0	36.3	75.9	89.2
Leaves and current twigs	35.1	100	62.5	23.6	10.7
Fruit	<1.0	0	1.2	<1.0	<1.0
Net production distribution (percent of total aboveground dry weight)					
Stem and branches	13.8	0	0	11.1	17.6
Leaves and current twigs	84.3	100	99.2	86.4	81.9
Fruit	1.9	0	<1.0	2.5	<1.0

for the small shrub *Vaccinium* to the large shrub *Ilex*, respectively. For all species, the fraction of dry weight represented by fruit and fruiting bodies was 1 percent or less of the aboveground biomass.

Despite structural differences, the distribution of production among various components was very similar for *Vaccinium*, *Corylus*, and *Ilex* (table 1). Radial growth on stems accounted for only 11 to 18 percent of the aboveground shrub production. The proportions of growth in current twigs and leaves ranged from 82 to 86 percent of aboveground production.

Among the trees sampled, bolewood accounted for 64 to 69 percent of the aboveground biomass, bolebark 8 to 11 percent, branches 16 to 22 percent, and leaves and current twigs 3 to 5 percent (table 2). The distribution of biomass for the two maples corresponded closely for all components. Birch had more biomass in the stem and less in the canopy than did maple.

Distributional differences among species can be explained in part by morphological differences. For example, birch has many short-shoot twigs, each with a cluster of leaves. Minimal apical growth by these twigs results in less biomass classified as current twigs. The branching habit of birch—few large branches, many short, pendulous branches—could account for the lesser proportions of branch biomass in birch than in the maples.

Size is an important determinant in biomass distribution among components. There was a marked decrease in the proportion of bolebark with increasing stem size, a trend associated with the decrease in the surface-area/stem-volume ratio. Also present was a trend of increasing concentrations of woody tissue with increasing size of a plant. Except for *Rubus*, the percentage of woody biomass and net production increased from the smallest species to the largest species (tables 1 and 2). Net production in stem and branches together ranged from 55 to 66 percent for the trees and from 11 to 18 percent for shrubs (excluding *Rubus*).

The proportions of belowground and aboveground biomass also varied with plant size. The mean belowground/aboveground ratio for aspen, obtained from the excavation of 20 trees between 2 and 8 cm d.b.h., was 0.24±0.02 (±SE). For *Corylus*, a shrub of intermediate size, the mean ratio

Table 2.—*A summary of mean dimensional and functional relations for tree species sampled in the Enterprise Forest*

Item	*Acer rubrum*	*Acer saccharum*	*Betula papyrifera*
Sample number	23	25	21
D.b.h. (cm)			
Mean	10.4	10.4	13.7
Range	3.1-24.6	3.5-26.0	3.5-26.3
Total height (m)			
Mean	11.54	11.53	14.04
Range	5.29-18.50	5.50-19.31	5.68-21.18
Biomass distribution (percent of total aboveground dry weight)			
Bolewood	63.8	64.6	68.8
Bolebark	10.3	8.3	12.3
Branches	20.5	22.2	15.8
Leaves and current twigs	5.4	4.9	3.1
Net production distribution (percent of total aboveground dry weight)			
Bolewood	29.7	29.8	36.9
Bolebark	5.5	6.9	8.8
Branches	22.7	18.8	19.9
Leaves and current twigs	42.1	44.5	34.4

was 1.03±0.07 (N=49) and for *Vaccinium*, a small shrub, the mean ratio was 1.96±0.32 (N=7). Other reports of belowground/aboveground biomass ratios for trees ranged from 0.2 to 0.3 for young trees to less than 0.2 for large trees (Ovington 1962), and ratios for shrubs range from 0.6 to 1.8 (Whittaker 1962). The average belowground/aboveground ratio for herbaceous species harvested at Enterprise ranged from 2.98 to 4.79 (Zavitkovski 1976). Thus, 19 percent of the total dry weight for the tree was belowground, compared to 51 percent for the intermediate shrub, 66 percent for the small shrub, and 75 to 83 percent for the herbaceous species.

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EFFECTS OF STOCK REMOVAL RATES ON BELT LOADING FOR ABRASIVE PLANING HARDWOODS

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ABSTRACT.—Belt loading increases up to a point and then decreases as stock removal rate increases for red oak and yellow-poplar.

OXFORD: 832.16. KEY WORDS: Machining, sanding, surfacing, tool life.

Abrasive planing hardwoods precludes knife planing defects and may upgrade the lumber enough to offset the added cost. A common problem with abrasive planing, however, is "belt loading"— the accumulation of waste material on the belt, decreasing its abrasiveness and hence shortening belt life. If belt loading could be eliminated, or at least reduced, abrasive planing of hardwoods would be more efficient.

In a study of abrasive planing ponderosa pine (Stewart 1976), belt loading increased and belt life decreased as depth of cut was increased up to a point. However, as depth of cut was further increased, belt loading decreased and belt life increased until the rate of stock removal caused excessive stress in the belt and greatly reduced belt life. A study was undertaken to determine if the belt-loading pattern for hardwoods is similar to that for ponderosa pine.

METHODS

Air-dry (12 percent average moisture content) red oak and yellow-poplar boards 3½ inches wide and 5 feet long were surfaced to a uniform thickness of 7/8 inch. Red oak and yellow-poplar represent high and moderate density hardwoods, respectively.

The red oak was machined at 45-feet-per-minute(fpm) feed rate and six depths of cut (0.005, 0.010, 0.020, 0.040, 0.080, and 0.120 inch). Yellow-poplar was machined at three feed rates (60, 75, and 90 fpm) and the same depths of cut as red oak. The abrasive belts were aluminum oxide, 18 by 103 inches, grit size No. 36. The nominal belt speed was 5,800 feet per minute.

RESULTS

The belt-loading pattern for both hardwood species did indeed prove to be similar to that for ponderosa pine. Belt loading increased up to 0.040-inch depth of cut at 45 fpm feed rate for red oak and 0.080-inch depth of cut at 60 fpm feed rate for yellow-poplar. (Higher forces developed at lower stock removal rates when planing red oak, hence beltloading for red oak began to decrease at a lower removal rate than for yellow-poplar). Beyond these feed rates and cutting depths belt loading decreased for both species. Apparently, either the depth of cut or feed rate may be increased to reduce belt loading (fig. 1).

DISCUSSION

Belt loading may be similar to the formation of "built-up edge" (BUE) in metal cutting. The BUE is a result of the normal loads on the tool face leading to adhesion between the chip and tool (Armarego and Brown 1969). The adhesion is probably similar to a pressure weld and/or a result of Van der Waals forces, which cause two surfaces to adhere when they are pressed together. The mechanics of adhesion of sliding systems (Armarego and Brown 1969), such as where the workpiece and tool meet, involves:

1. The tool rubbing a freshly cut surface from the workpiece.
2. Plastic deformation of the workpiece material when forming the chip.
3. High temperature and pressure at the sliding interface of the tool and workpiece material.

The same relation between cutting speed (stock removal rate) and belt loading that we found appears to exist also for metal work (Cook 1966). At very low speeds a BUE may not form. At a relatively moderate, critical cutting speed BUE begins to develop. As the cutting speed increases, more of the BUE is carried away and may disappear.

Other things that reduce belt loading include increasing air velocity for removing waste to reduce pressure between the sliding belt and workpiece (this may also reduce the temperature of the wood) and increasing belt speed which reduces chip load and also reduces belt pressure. However, both these methods require increased energy to maintain the same productivity.

So, for the present at least, it appears that, when abrasive planing hardwoods, belt loading can be reduced and belt life prolonged by using high stock removal rates. Extensive testing will be required to determine the optimum rates and conditions for hardwooods.

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Figure 1.—*Loading of the Grit No. 36 aluminum oxide belts up to a point as stock removal rate increases for yellow-poplar: (A) Yellow-poplar, 60 fpm feed rate and 0.040-, 0.080-, and 0.120-inch depths of cut; (B) Yellow-poplar, 75 fpm feed rate and 0.040-, 0.080-, and 0.120-inch depths of cut; and (C) Yellow-poplar, 90 fpm feed rate and 0.040-, 0.080-, and 0.120-inch depths of cut.*

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ASPEN SUCKER PRODUCTION AND GROWTH FROM OUTPLANTED ROOT CUTTINGS

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ABSTRACT.—Aspen suckers from 1-m-long root cuttings survived and grew better than those from 12.5-cm-long cuttings. Sucker survival and growth were also inversely related to parent root diameter. Discusses the practical implications for aspen management.

OXFORD: 231.5:161.4:176.1. *Populus tremuloides.* KEY WORDS: *Populus tremuloides,* regeneration, propagation, planting, site-preparation.

Suckering is a major regeneration mode of quaking aspen (*Populus tremuloides* Michx.). With rare exception, aspen will not sucker appreciably until (1) the flow of inhibitory auxin from apical meristems to roots is interrupted (Farmer 1962)—which occurs when the bole or roots are severed—and (2) the root temperature is raised above some critical level (Maini and Horton 1966).

Studies have shown that the number of suckers produced is governed by hormones (Eliasson 1971), and that initial sucker growth is dependent on stored carbohydrate reserves (Schier and Zasada 1973, Steneker 1972, Zasada and Schier 1973).

Full growth potential of new aspen sucker stands is further dependent on an intact parent root system. Zahner and Debyle (1965) found that parent roots of *Populus grandidentata* (Michx.) (especially those distal to the sucker) contributed more to sucker growth than did new roots until about age 25. Sectioning of parent roots appears to reduce sucker growth (Sandberg 1951, Steneker and Walters 1971).

Most quaking aspen suckers arise from parent roots less than 2.5 cm in diameter (Farmer 1962, Maini 1968a, Sandberg 1951), but it is not clear if large-diameter parent roots are poor sucker producers, or if they are simply less abundant.

To determine more about the relations between sucker growth and parent root systems, I outplanted long (1 m) and short (12.5 cm) quaking aspen root cuttings of varying diameter.

Survival, height growth, and biomass of the suckers were measured over a 6-year period, and the feasibility of establishing aspen by outplanting root cuttings was evaluated.

METHODS

On May 8 and 9, 1972 (about 10 days prior to bud burst), six 1-m root cuttings free of serious injury or defect were taken from one average tree in each of 10 widely separated mature, well stocked good site aspen stands in Cass and Itasca Counties, Minnesota. Root cuttings from each tree were relatively uniform in diameter but varied significantly between trees. There was no significant correlation of root diameter with any tree characteristic. Three of these six cuttings selected at random were immediately clipped into eight 12.5-cm cuttings to prevent polar redistribution of auxin (Maini 1968b). The cuttings were kept moist and cool during transport, and stored at 4C until outplanted. On May 26, 1972, the outplanting site (a former agricultural field) was prepared with a rototiller. After all fine roots were trimmed for the sake of uniformity, the cuttings were washed, blotted dry, and weighed. Because of within-cutting variation in diameter due to swellings and taper, average diameters were estimated from average cutting weight based on an independently determined relation of 58 g fresh weight per square centimeter cross-sectional area per meter length. Most of the cuttings exhibited sucker primordia, often clustered at swellings. A few primordia had already formed suckers up to 2 cm long. On May 30, the cuttings were planted horizontally at a depth of 2 to 3 cm, lightly mulched with straw to retard moisture loss, and thoroughly watered.

All cuttings from a tree were planted 0.5-m apart in adjacent 1.5-m^2 plots; long cuttings in one plot and short cuttings in the other. The short cuttings were laid end to end to make three 1-m aggregate lengths. Twenty-nine surplus short root cuttings were planted in sand in a greenhouse and automatically watered twice daily.

A maximum-minimum recording thermocouple installed at cutting depth showed the 1972 summer had favorable soil temperatures for sucker initiation (12.7 to 28.6C). Rainfall (26 cm) was generally adequate; however, irrigation (0.4 cm) was needed on both June 27 and July 6. During the first three summers, the plots were hand-weeded. Suckers were counted bi-weekly during 1972, weekly in 1973, and at the end of the 1974-1977 growing seasons. Survivor heights were measured after each summer; d.b.h. was measured in 1977.

The data were statistically analyzed using one-way analysis of variance or multiple regression, as appropriate. Logarithmic or square-root transformations were used to obtain homogeneous variance.

RESULTS AND DISCUSSION

Suckers began to emerge 14 days after outplanting and continued to come up rapidly through the third week of July (fig. 1). Suckering then quickly decreased. Although the first three suckers arose from the short cuttings, suckers emeraged faster from the long cuttings . However, total numbers of suckers on both cutting lengths were equal at the end of the first growing season. Five additional suckers were produced by long cuttings during the second year, while none emerged from the short cuttings. The number of suckers did not vary significantly by cutting diameter, except that fewer were produced on short cuttings greater than 2.5 cm diameter (table 1).

Suckers began to die 20 days after the first ones appeared. Most mortality on short cuttings occurred during the first year. Loss of suckers on long cuttings was more gradual and for the most part was evenly distributed from July 1972 to September 1974. Overall, cutting length significantly affected survival; this was mostly accounted for by the highest survival on long cuttings less than 1.6 cm diameter (table 1). Neither long nor short cuttings greater than 2.5 cm diameter had any survivors.

In the green house, 41 suckers emerged (many more were initiated but did not reach the sand surface) but only 6 survived. Excavation of all these cuttings after 67 days revealed that only the survivors had initiated root systems.

The percentage of long cuttings with suckers declined from 80 percent after the first year to 30 percent after the sixth year, and for short cuttings, from 53 to 17 percent (table 2). These calculations are on a per meter cutting bases. If individual short cuttings are considered ($3 \times 10 \times 8 = 240$), only 2.1 percent of them had surviving suckers after the sixth year.

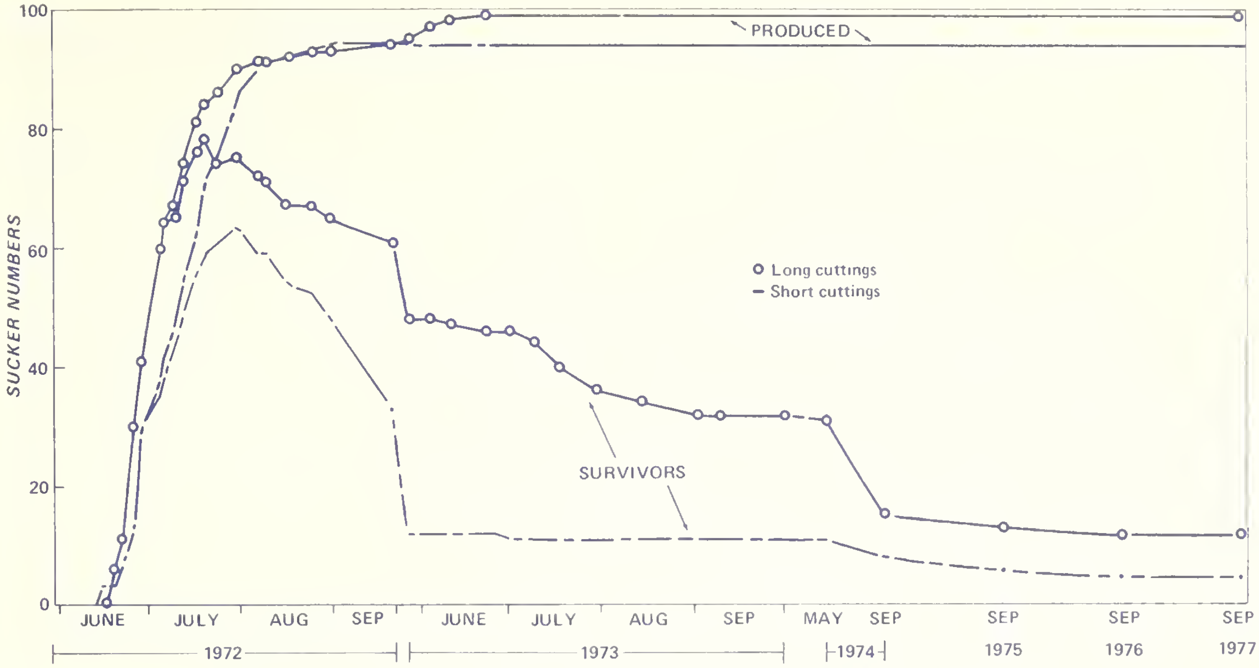

Figure 1.—*Accumulated production and survival of quaking aspen suckers on long and short root cuttings (cutting diameters combined). Note change in seasonal scale after 1973.*

Height growth of dominant suckers surviving the study period was significantly greater (5 percent level) for long cuttings (fig. 2). Sucker biomass and d.b.h. after 6 years tended to vary directly with cutting length and inversely with cutting diameter, although not significantly (table 3).

Table 1.—*Total aspen sucker production and 6-year survival by cutting length and diameter*

(In numbers per meter)

Cutting	Total sucker production		6-year survival	
diameter (cm)	Long cuttings	Short cuttings	Long cuttings	Short cuttings
<1.6	2.80 a[1]	3.88 a	0.88 c	0.25 d
1.6-2.0	3.14 a	3.38 a	.43 cd	.25 d
2.1-2.5	3.00 a	3.10 a	.50 cd	.10 d
>2.5	3.73 a	0.25 b	.00 d	.00 d
Mean[2]	3.30	3.13	.40	.17

[1] Values followed by the same letter are not statistically different ($p<0.05$).

[2] Overall means differ from column means due to unequal number of observations per cutting diameter class.

The sucker production from long and short cuttings supports other findings that sucker production is independent of cutting length (Schier 1978, Steneker and Walters 1971). On the other hand, sucker growth was much better on long cuttings than on short ones, presumably because long cuttings have a greater store of available carbohydrates (Schier and Zasada 1973, Steneker 1972, Zasada and Schier 1973).

Table 2.—*Cuttings (1-m basis) with surviving suckers 1 and 6 years after planting, and by cutting length and diameter*

(In percent of cuttings)

Cutting	First year		Sixth year	
diameter (cm)	Long cuttings	Short cuttings	Long cuttings	Short cuttings
<1.6	100	75	63	25
1.6-2.0	71	50	29	25
2.1-2.5	75	60	50	10
>2.5	73	0	0	0
Mean[1]	80	53	30	17

[1] Overall means differ from column means due to unequal number of observations per cutting diameter class.

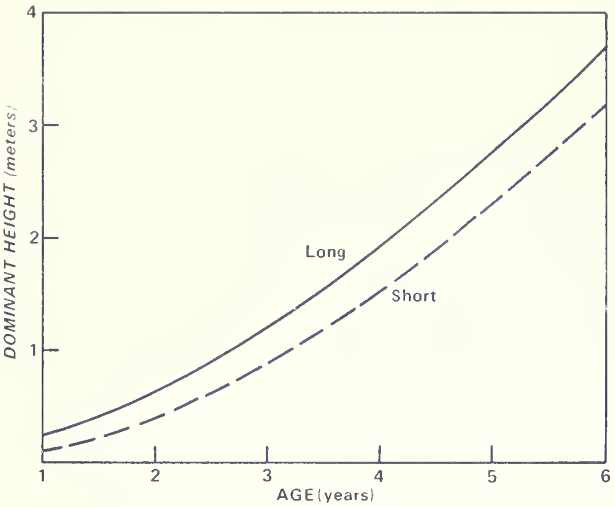

Figure 2.—*Mean height growth of dominant suckers on long and short quaking aspen root cuttings.*

Table 3.—*Sixth-year sucker measurements by root cutting length and diameter*

Cutting diameter (cm)	Mean sucker biomass[1]		Mean sucker d.b.h.	
	Long cuttings	Short cuttings	Long cuttings	Short cuttings
	grams		centimeters	
<1.6	421	301	2.4	1.9
1.6-2.0	280	63	2.0	1.1
2.1-2.5	243	159	1.9	1.6
>2.5	0	0	0	0
Mean[2]	389	177	2.2	1.5

[1] Biomass calculated according to Zavitkovski (1971), based on a biomass index of d^2h, where d is dbh (cm) and h is tree height (m).

[2] Overall means differ from column means due to unequal number of observations per cutting diameter class.

The reason for poorer production, survival, and growth of suckers from cuttings with greater diameters (particularly short cuttings) is not known.

CONCLUSIONS

This study provided further evidence that disruption of the parent root system can be detrimental to the establishment and growth of aspen suckers. The practical implication is that disking or roller-chopping are questionable practices for regeneration of aspen sucker stands. The best silvicultural practices in aspen appear to be those that leave the parent root system intact.

Establishment of aspen by planting root cuttings is inefficient because of the extremely low ratio of suckers established per unit length of cutting. Survival of suckers under field conditions is extremely poor, even with site preparation and control of competing vegetation. Efficient greenhouse techniques to vegetatively propagate large numbers of suckers from a minimum of root cuttings have been developed by Starr (1971) and Zufa (1971), although little is known of their survival after outplanting.

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NORTH CENTRAL FOREST EXPERIMENT STATION
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1978

JET DRYING OF SOUTHERN PINE AND DOUGLAS-FIR: EXPLORATORY STUDY

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ABSTRACT.—Southern pine and Douglas-fir boards, containing both heart- and sapwood and 1.75 inches thick, were jet dried at temperatures from 160 to 400°F and air velocities from 3,000 to 9,000 fmp. Jet drying was more effective for southern pine than for Douglas-fir.

OXFORD: 847.1—087. KEY WORDS: *Pseudotsuga taxifolia*, high temperature, shrinkage, drying defects, softwood.

Because of our success with high temperature jet drying several easy-to-dry hardwoods such as yellow-poplar and silver maple (Rosen 1977a), we felt that two of the most popular commercial softwoods, southern pine and Douglas-fir, could be jet dried. Previous work by the Australian CSIRO Forest Conversion Engineering Group (Anon. 1975) and Koch (1977) showed that green southern pine studs could be dried in less than 14 hours at temperatures to 300°F. On the other hand, reports of high-temperature drying of Douglas-fir have not been as promising. Salamon (1963) found that drying 2- by 8-inch Douglas-fir at temperatures to 225°F increased honeycomb and reduced strength more than conventional drying. So we decided to try jet drying southern pine and Douglas-fir lumber ourselves.

METHODS

Southern yellow pine and costal Douglas-fir boards, 40 inches long by 3¾ inches wide by [illegible] inches thick, were shipped to our Carbondale Laboratory wrapped in tightly sealed plastic packages.[1] Green specific gravity averaged 0.43 for both species. Immediately before a jet dryer run, three boards were trimmed to 30 inches by cutting 5 inches from each end. One-quarter-inch cross sections were cut from the trimmings of the boards for moisture content determination by oven drying. Boards were not endcoated except for six boards for the final two runs with Douglas-fir.

Boards were dried in a prototype jet dryer (Rosen 1977b) to approximately 12 percent moisture content at the conditions listed in tables 1 and 2. The drying period included one or two drying steps. Boards were periodically removed for 3 minutes from the jet dryer and weighed to the nearest 0.01 pound to establish drying curves for each board. Width and thickness to 0.001 inch were measured at four places along the length of each board before and after drying to determine volumetric

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[1] *The southern yellow pine was cut from small logs; most of it included the pith and a small amount of heartwood. Douglas-fir contained both sapwood and heartwood.*

Table 1.—*Drying data for southern pine*[1]

	Drying			Conditioning[2]			Moisture content			
Run	Temperature DB/WB[3]	Air velocity	Time	Temperature DB/WB[3]	Time	Total time	Initial	After drying	After conditioning	Volumetric shrinkage[4]
	°F	fpm	Hours	°F	Hours		Percent			
1	400/180	3,000	2.0	200/190	3.0	5.0	118	14	14	5.7
2	300/180	3,000	3.5	200/190	3.0	6.5	127	21	18	5.1
3	300/180	6,000	3.3	200/190	6.0	9.3	111	10	11	5.4
4	300/180	9,000	3.0	200/190	3.0	6.0	105	9	10	5.8
5	240/160	3,000	11.4	195/185	3.0	14.4	111	9	10	5.3
6	220/180	3,000	14.3	200/190	8.5	22.8	89	12	12	4.8
[5]7	350/180	3,000	1.5	200/190	3.0	14.5	92	8	9	5.6
	225/180	3,000	10.0							

[1] Averages based on three boards.

[2] Air velocity for conditioning, 3,000 fpm for all runs.

[3] Dry bulb/wet bulb.

[4] Corrected to 12 percent moisture content.

[5] Drying done in two steps prior to conditioning.

Table 2.—*Drying data for Douglas-fir*[1]

	Drying		Conditioning				Moisture content		
Run	temperature DB/WB[2]	Time	Temperature DB/WB	Time	Total time	Initial	After drying	After conditioning	Volumetric shrinkage[3]
	°F	Hours	°F	------ Hours -----		Percent			
8	300/180	1.0	—	—	7.0	30	12	—	5.6
	225/180	6.0							
9	220/180	8.0	200/190	3.0	11.0	63	17	17	7.2
10	190/180	23.0	—	—	31.5	78	12	—	7.6
	220/200								
11	160/154	48.0	—	—	57.3	88	12	—	6.6
	215/200	9.3							
12	190/182	24.0	190/185	6.0	38.0	74	12	12	7.2
	220/200	8.0							
13	190/182	23.0	190/185	6.0	37.0	93	12	12	6.6
	220/200	8.0							
[4]14	190/182	23.0	—	—	31.0	109	11	—	6.3
	220/200	8.0							
[4]15	300/180	4.7	—	—	4.7	78	6	—	5.6

[1] Averages based on three boards, air velocity for all runs was 3,000 fpm.

[2] Dry bulb/wet bulb.

[3] Corrected to 12 percent moisture content.

[4] Endcoated with asphalt mastic.

shrinkage. After drying, all southern pine and several Douglas-fir boards were subjected to a high humidity conditioning period to reduce moisture content gradients and relieve internal stresses in the wood caused by the severe drying conditions. Boards were examined for surface darkening, collapse, honeycomb, and checking. One board from each southern pine run and two boards from each Douglas-fir run were crosscut into several sections to examine internal defects and to obtain 1-inch sections for moisture content determination.

The uncut dried boards were placed in a constant temperature and humidity room until an equilibrium moisture content of 6 percent was reached. Boards were then weighed and moisture contents of the boards during drying were calculated.

RESULTS AND DISCUSSION

Figure 1 is typical of the moisture-content/time curves for boards dried under constant air velocity and wet bulb temperature. The rate of drying slowly dropped as the drying proceeded. Surface darkening was observed on all boards dried above 212°F. High drying temperatures and low final moisture contents produced the most discoloration: as moisture content dropped below 10 percent, the board surface darkened rapidly at temperatures above 250°F.

SOUTHERN PINE

Southern pine withstood drying temperatures up to 400°F with minimal degrade. Except for slight end checking and surface checks around knots, the quality of the boards dried at all conditions was good. A previous study with 4/4 silver maple found increases in air velocity above 3,000 fpm did not reduce drying time (Rosen 1977a). But, for southern pine increasing in air velocity reduced drying time (compare the drying times of Runs 2, 3, and 4 in table 1).

Although southern pine can be dried in a few hours at temperatures higher than 300°F, the possibility of overdrying the lumber and the wide range of final moisture contents of the boards are undesirable. The mixed high and moderate temperature schedule of Run 7 (table 1) would reduce the problems involved with a straight high temperature schedule.

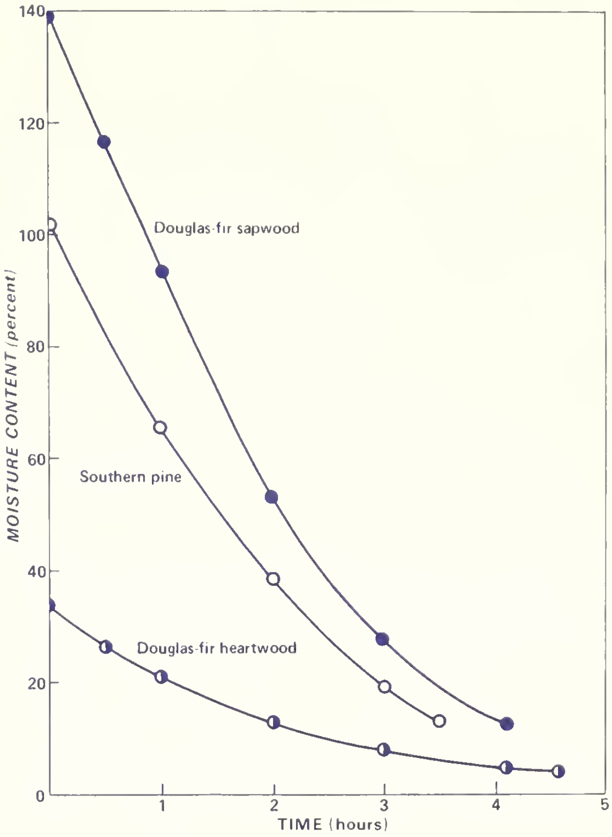

Figure 1.—*Moisture content versus time for 1.75-inch-thick southern pine (Run 2 conditioning period not shown) and Douglas-fir (Run 15) jet dried at 300°F dry bulb, 180°F wet bulb and 3,000 fpm air velocity.*

DOUGLAS-FIR

Rapid drying of coastal Douglas-fir is confounded by the wide range of green moisture contents 28 to 146 percent found in the wood. Heartwood boards were drier than sapwood. When drying Douglas-fir at a single high temperature, the heartwood was overdried and the sapwood underdried (fig. 1). Several combinations of high and low temperatures, with and without conditioning steps, were attempted (table 2), but honeycomb and end checking persisted. Honeycomb was more severe in the boards dried at high temperature only than in those dried at low temperature followed by high temperature (fig. 2). End-coatings did not reduce end checks or honeycomb. Jet drying 1.75-inch-thick Douglas-fir at a constant high temperature is not recommended. A mixed low and high temperature schedule can dry the wood in less than 31 hours, provided some honeycomb of the wood is acceptable.

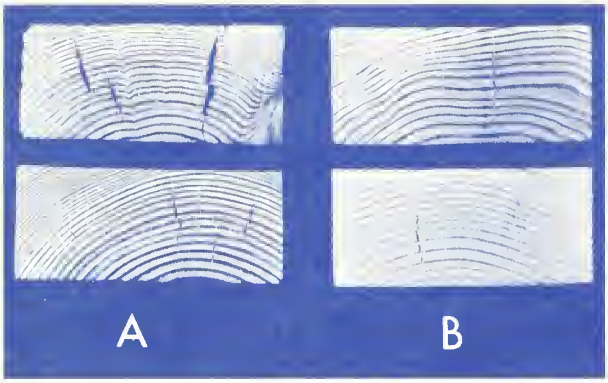

Figure 2.—*Typical honeycomb in Douglas-fir jet dried by a high temperature schedule (A-Run 8) and a low followed by a high temperature schedule (B-Run 11).*

CONCLUSION

Our results indicate that southern pine can be high temperature jet dried in less than 15 hours. The most effective schedule over the range of conditions studied was a short exposure of the wood to very high temperature (above 300°F) followed by a moderately high temperature (220 to 240°F), and finally a high humidity conditioning period. The process could be adapted to a continuous kiln similar to that described by Koch (1977), whereby wood is carried through three sections of a kiln set for the respective conditions stated above. High temperature jet drying of Douglas-fir produced defects in the wood, although drying at low temperature and then increasing to high temperature near the end of drying minimized these defects.

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Research Note NC-243

1978

SPRUCE BUDWORM DEFOLIATION IN MINNESOTA: 1954-1977

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ABSTRACT.— A series of maps showing spruce budworm defoliation in Minnesota, 1954-1977.

OXFORD: 453— 145.718(776). KEY WORDS: Insect outbreaks, maps, history.

The spruce budworm, *Choristoneura fumiferana* (Clemens) is one of the most destructive insect pests of the spruce-fir forests of North America. Between 1910 and 1925 the budworm destroyed 200 million cords of balsam fir and red spruce in the eastern United States and Canada (Metcalf *et al.* 1962). Brown (1970) mapped the spread of spruce budworm outbreaks from 1909 to 1966 in eastern Canada and northern Minnesota. The most recent outbreak in Minnesota (before the present infestation) occurred from 1912 through 1926 (Blais 1968).

This report documents the amount and location of budworm defoliation in northern Minnesota from 1954 through 1977.

The current outbreak was first detected in Minnesota in 1954 along the Canadian border north of Ely and on the Kabetogama Peninsula east of International Falls. The budworm defoliation increased in area and severity until 1958 when nearly 1 million acres were affected (fig. 1). No formal survey was conducted in 1962. Defoliation continued until 1963 when Ryan and Batzer (1964) reported a decrease in budworm population. As a result of the extended defoliation, up to half (10-50 percent) of the balsam fir died on 112,200 acres and more than half (51-100 percent) died on an additional 130,200 acres.

Because budworm population was low, no extensive surveys were made in 1964 and 1965. However, in 1966 Doerner[1] found heavy defoliation in small areas in the Superior National Forest. Since then, defoliation gradually expanded southward from spruce-fir types along the Canadian border to those in the southern and western portions of the Superior National Forest and adjoining State and private land.

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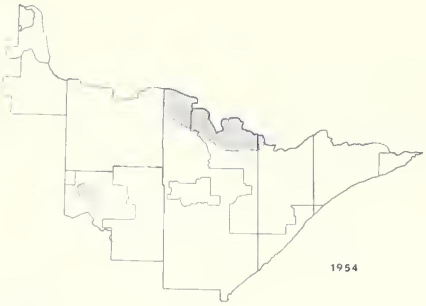
[1] *Doerner, Robert G. 1966. Detection survey of spruce budworm on the Superior National Forest, 1966. Unpublished processed Rep. (File 5220, 2 p).*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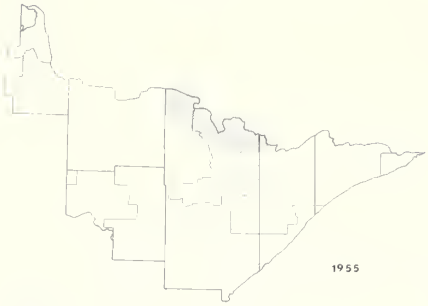
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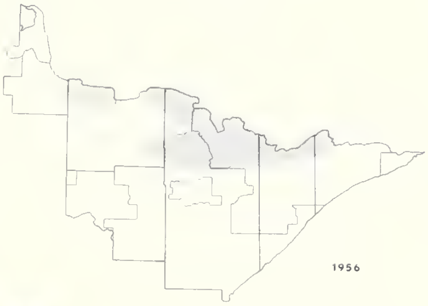
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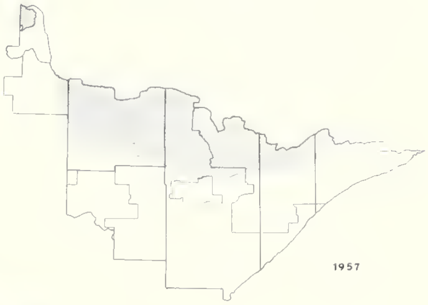
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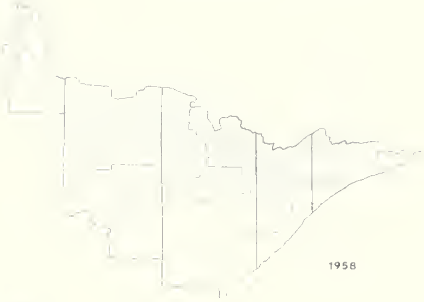
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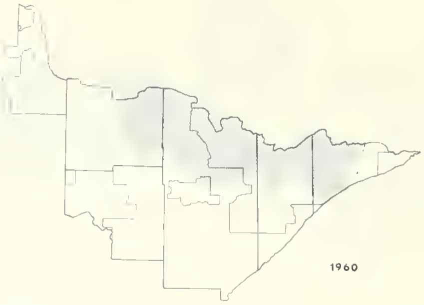
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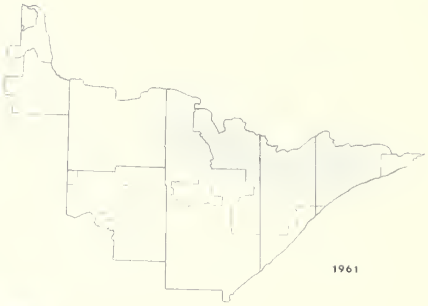
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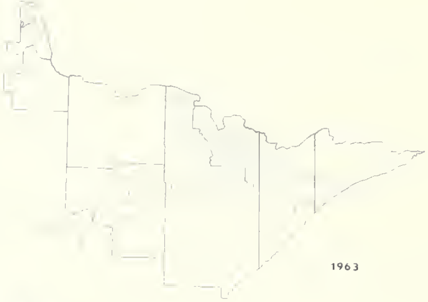
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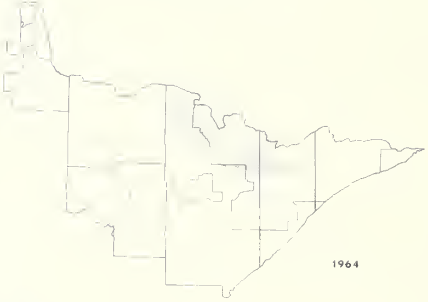
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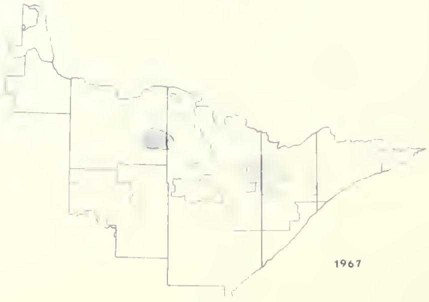
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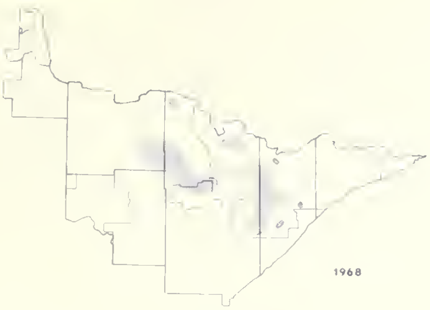

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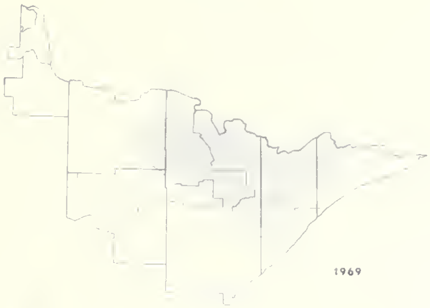

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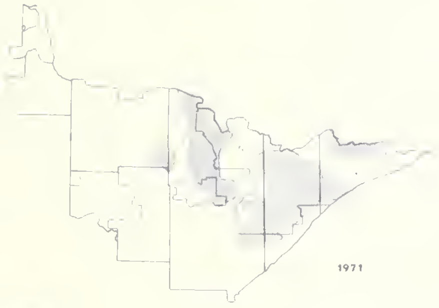

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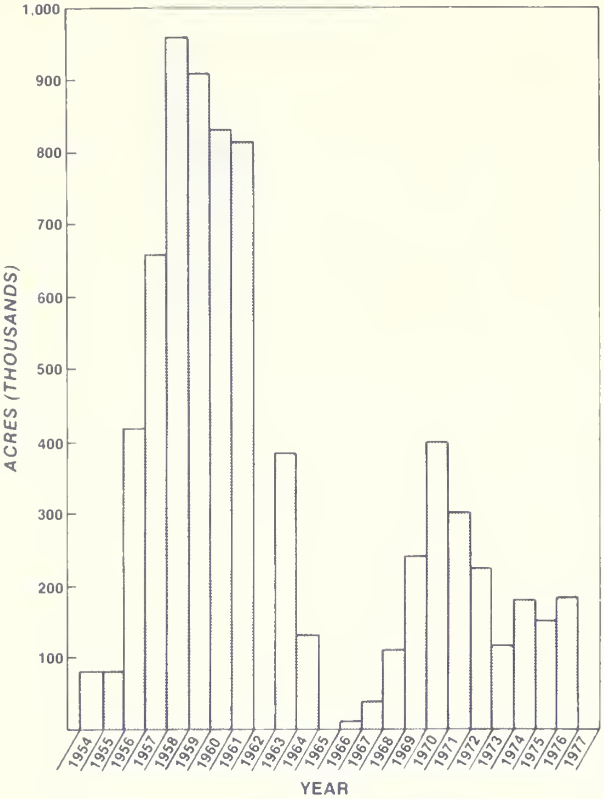

Figure 1.—*Acres of spruce-fir type defoliated by the spruce budworm in Minnesota, 1954 to 1977.*

During the period 1957-1963, about 85,000 Federally owned acres (mostly recreation) were treated with insecticides for budworm control (Fowler 1973).

The following maps are based on aerial and ground surveys conducted by the U.S. Forest Service (North Central Forest Experiment Station, Superior National Forest, and State and Private Forestry), the Minnesota Department of Agriculture (Division of Plant Industry), and Minnesota Department of Natural Resources. They show the yearly progress of budworm defoliation in Minnesota from 1954 through 1977.

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NORTH CENTRAL FOREST EXPERIMENT STATION
Research Note NC-244
1992 FOLWELL AVE. ST PAUL, MN 55108 FOREST SERVICE-U.S.D.A.
1978

DORMANCY AND ROOT REGENERATION OF BLACK WALNUT SEEDLINGS:

EFFECTS OF CHILLING

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Bedford, Indiana

ABSTRACT.—New root and shoot growth of black walnut seedlings were strongly dependent on the amount of time they were kept at a cold temperature. Physiological dormancy ended after approximately 3,100 hours at 3C, but growth responses continued to increase after 4,600 hours. Root regeneration was strongly correlated with shoot growth.

OXFORD: 181.36:161.9:176.1. KEY WORDS: *Juglans nigra*, cold storage, root regeneration potential.

Absorption of water and nutrients by black walnut (*Juglans nigra* L.) seedlings is primarily a function of new roots (Finn 1966). Slow regeneration of roots may be a possible cause for the slow top growth of walnut seedlings during the first growing season after they are transplanted. Root regeneration potential (RRP), a measure of seedling physiological quality, is the capacity of seedlings to initiate and elongate new roots rapidly after transplanting. High RRP has already been shown to be important to survival and subsequent growth for other species (Stone and Schubert 1959, Stone *et al.* 1962). This paper reports the seasonal pattern of RRP of freshly lifted and stored black walnut seedlings and its relation to chilling.

METHODS

Eleven liftings of 1-0 black walnut seedlings were made between October 6, 1976, and April 25, 1977, from the Vallonia Forest Nursery, near Brownstown, Indiana. Each lot of seedlings was graded to minimum stem caliper of 0.7 cm, root pruned to 22.0 cm, and then shipped to Carbondale, Illinois. Twelve seedlings were potted at each of the following dates: immediately, December 8, March 10, and May 12. The seedlings that were not potted immediately were stored at 3C until the time they were potted.

Root regeneration potential was determined by a method similar to that of Stone and Schubert (1959). Potted seedlings were placed in a greenhouse for 4 weeks. Air temperature in the greenhouse varied seasonally (minimum 16C), a photoperiod of 16 hours was maintained by supplemental lighting, and soil temperature was maintained at 24C.[1] At the end of the 4 weeks, the seedlings were unpotted and total shoot elongation, stem caliper 2.5 cm above root collar, ovendry weight of all new roots, and ovendry weight of the total root system were determined for each seedling. The length-of-storage-treatments were compared for significant differences by analysis of covariance—total root dry weight was the covariable for root growth response and stem caliper was the covariable for shoot growth response.

RESULTS AND DISCUSSION

All seedlings had to be subjected to cold temperatures for a minimum amount of time before any appreciable growth response appeared in RRP tests (figs. 1 and 2). During physiological dormancy, seedlings that were potted immediately could not be forced to grow during the 4 weeks in the greenhouse. In late February, an abrupt increase in growth response appeared in the seedlings that were potted immediately (fig. 1). Total shoot elongation and ovendry weight of new roots steadily increased with successive liftings during the early spring, and continued to increase beyond the time of flushing at the nursery. Seedlings lifted on April 25 had as much as 10 cm of new shoot growth at the time of lifting, but no new root growth. Existing new shoots died back during the RRP test but regrowth of shoots and regeneration of roots surpassed that of all previous lifting dates.[2] Thus, no peak in RRP was found, although it must have been imminent.

The pattern of response in stored seedlings was similar to that for seedlings overwintering in the nursery bed (fig. 2). Seedlings lifted prior to November 1 did not store well. The increase in root growth response was barely evident on March 10 for seedlings lifted on November 1, but an abrupt increase began

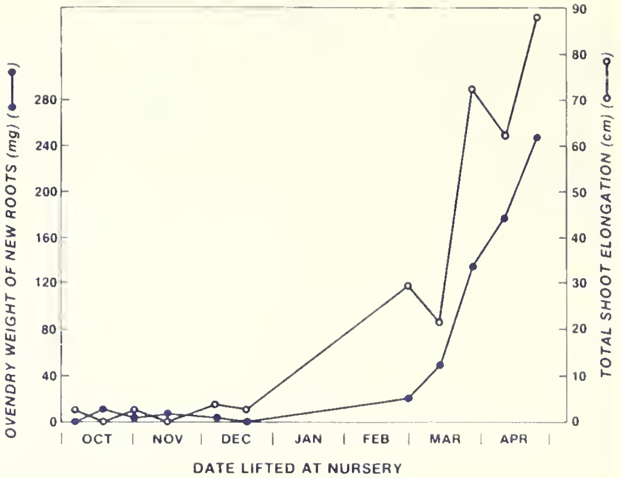

Figure 1.—*Total shoot elongation and ovendry weight of new roots for freshly lifted seedlings measured at the end of 4 weeks under forcing conditions in a greenhouse. The plotted values are the covariance-adjusted means of 12 seedlings.*

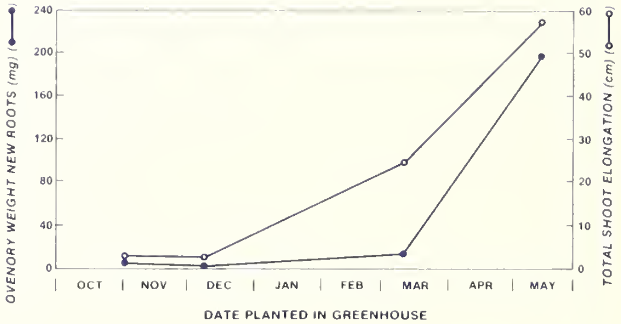

Figure 2.—*Total shoot elongation and ovendry weight of new roots for stored seedlings, measured at the end of 4 weeks after replanting. Seedlings were lifted on November 1 and then replanted on November 1, December 8, March 10, and May 12. Plotted values are the covariance-adjusted means of 12 seedlings.*

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[1] *Reported to be near optimum by Larson (1970).*

[2] *Note that this response occurred under favorable greenhouse conditions. In a field transplanting test, seedlings lifted after flushing grew poorly.*

later in March, which is similar to the response for seedlings that overwintered in the nursery. The pattern of RRP for black walnut seedlings in cold storage is similar to that reported for northern red oak (Farmer 1975), pin oak and scarlet oak (Lee *et al.* 1974), and sugar maple and white ash (Webb 1977).

Seedlings that overwintered outside ended physiological dormancy about two weeks earlier than the stored seedlings, and had consistently more top and root growth in subsequent RRP tests. The winter of 1976-1977 was abnormally cold, so outside seedlings were exposed to many more degree-hours of cold temperatures than stored seedlings. The slower rate of growth resumption of stored seedlings may be due to maintenance of deeper imposed dormancy in storage—the outside seedlings were exposed to warm, sunny weather beginning in late February.

Both ovendry weight of new roots and total shoot elongation were strongly correlated with chilling time, $r=+0.82$ ($P\leq 0.05$) and $+0.90$ ($P\leq 0.01$), respectively. Seedlings lifted on November 1 and stored until March 10 had been stored at 3C for 3,100 hours, excluding exposure to cool temperatures in the nursery bed prior to November 1. The longer these seedlings remained in cold storage, the more rapidly they resumed growth and the greater the growth response during the 4-week test period. By May 12, after 4,600 hours at 3C, the peak response had not yet been reached.

In the RRP tests, root growth was strongly correlated with shoot growth ($r=+0.95$, $P\leq 0.00001$); root regeneration increased with the degree of renewed shoot elongation. The major increase in RRP coincided with active shoot growth. However, the data do not depict which process began first.

Root regeneration for seedlings lifted on November 1 and potted on May 12 (198 mg) was lower than that for seedlings lifted and potted on April 25 (249 mg). This suggests that prolonged storage lowered the RRP and/or delayed the peak response.

Overwinter cold storage of fall-lifted black walnut seedlings offers a method of supplying planting stock in physiological condition conducive to resuming rapid growth as early as needed in the spring. Seedlings lifted when dormant and properly stored can be kept without any apparent detrimental effects at least until mid-May, which is normally beyond the time walnut seedlings are planted in the Central States.

Large, 1-0 black walnut stock, which has been kept under cold conditions a certain length of time and then transferred to favorable growing conditions, has the physiological capability for quickly growing new roots and vigorous new shoots. This study demonstrated that extended cold storage enhanced the rate at which growth of black walnut seedlings was resumed after transfer to environmental conditions favorable for growth. Future research should consider methods to accelerate chilling or enhance the chilling effect so that planting stock with peak RRP is available at planting time.

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1979

SHRUB NESTING OF THE RED-EYED VIREO IN RELATION TO STRUCTURE OF ASPEN FORESTS

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ABSTRACT.— Nests were built in five species of high shrubs in four trembling aspen forests of northern Minnesota. Nest densities ranged between 0.5 and 3.0 per acre and were positively related to the abundance of large (>1.2-cm diameter) shrub stems.

OXFORD: 156.1:228.0:148.2 (*Vireo olivaceous*). KEY WORDS: Breeding, nest density, forest structure, nesting habits.

Red-eyed vireos, *Vireo olivaceous* L., (REV) are among the commonest passerine species in the deciduous and mixed deciduous-coniferous forests of northern Minnesota. This note describes their nesting characteristics and nest densities in the shrub layer of four trembling aspen (*Populus tremuloides*) forests in relation to aspects of forest structure.

METHODS

I selected four study areas, each 25 acres, located in nearly pure stands of trembling aspen (35- to 45-year old) in extreme northern Minnesota, Koochiching County. Each study area was arbitrarily divided into four equal quadrats which were gridded into 64 blocks that were 1/10 acre large. I randomly selected five 1/10-acre plots from each quadrat (20/area) for counting nests which occurred from ground level to the bottom of the tree canopy (ca. 8 m). For each nest I recorded its height above ground, the species and stem diameter (5 cm above ground) of the shrub in which it was built, the basal area (basal area = cross-sectional area of tree trunks at 137 cm above ground) of overstory trees using a 10-factor prism, and whether the nest was active (with eggs or nestlings) or inactive.

Similar measurements were made on all other nests encountered between 1/10-acre sample plots within each study area but such nests were not used to estimate densities. The study was done between June 15 and 27, 1973, the period when birds were incubating eggs.

RESULTS AND DISCUSSION

Nesting Densities

Nests of the REV occurred in all four study areas (table 1). The number of active nests ranged from 0.0 to 1.0/acre, and the number of inactive nests ranged from 0.5 to 2.5/acre. Inactive nests were in various stages of deterioration because some were built the previous summer. These estimates are in accordance with observations by Southern (1958) and Rice (1978) which show that territory size of males ranges from 0.8 to 1.7 acres, thereby suggesting that nest densities should range between 0.6 and 1.2/acre if a habitat is fully packed and each male has acquired a mate.

Nest Locations in Relation to Shrub Species and Height

Nests of the REV occurred in five shrub species: hazel (*Corylus cornuta*), juneberry (*Amelanchier* spp), chokecherry (*Prunus virginiana*), tag alder (*Alnus rugosa*), and mountain maple (*Acer spicatum*) (table 2). These were basically the same species in which Lawrence (1953) found REV nests. In this study, nest heights ranged from 0.75 to 3.00 m, and averaged 1.55 m over all areas. In other studies where the tree canopy was also included along with shrubs, nest heights were predictably higher: Williamson (1971) (range: 0.6 to 21.4 m, average: 3.2), Southern (1958) (range: 0.4 to 7.9 m, average 2.3), and Lawrence (1953) (range: 1.0 to 16.7 m, average 2.9). In Lawrence's study, 73 percent of the nests occurred at heights less than 4.57 m. All studies reveal, though, that the REV preferentially nests low because in spite of wide ranges in nest heights the mean heights were invariably around 2 to 3 meters.

Table 1.— Nest densities of the red-eyed vireo (based on 20 1/10-acre sample plots per area) and aspects of community structure in four different aspen forests in northern Minnesota

	Shrubs/acre			Nests per acre		
Study area	Total stems	Tall shrub stems only[1]	Tree basal area/acre	Active	Inactive	Total
	Number		Ft^2		Number	
1	7,149	1,146	125	1.0	0.5	1.5
2	16,322	5,126	110	1.0	2.0	3.0
3	8,296	1,754	108	0.0	0.5	0.5
4	15,783	2,360	115	0.0	2.5	2.5

[1] Tall shrubs are defined as those having basal diameters >1.20 cm, the smallest stem used by red-eyed vireos for nesting.

Table 2.— Environmental variables (means + standard errors of shrub stem diameter, nest height, tree basal area) associated with red-eyed vireo nests in different shrubs in different study areas[1]

	Area 1— REV			Area 2— REV			Area 4— REV		
Shrub species	Shrub stem diameter	Nest height	Tree basal area	Shrub stem diameter	Nest height	Tree basal area	Shrub stem diameter	Nest height	Tree basal area
	cm		Ft^2/a	cm		Ft^2/a	cm		Ft^2/a
Acer spicatum	—	—	—	—	—	—	3.7±0.3	202±20	135±05±
Alnus rugosa	2.9±0.2	172±14	143±13	3.1±0.3	154±36	125±05	—	—	—
Amalanchier spp.	—	—	—	3.7±0.0	[2]300±00	120±00	—	—	—
Corylus cornuta	1.5±0.1	114±09	143±22	1.5±0.1	135±07	103±10	1.7±0.1	133±17	138±17
Prunus virginiana	2.9±0.3	177±17	157±03	2.9±0.0	175±00	100±00	—	—	—

[1] N or total number of nests observed per area is 13, 21, and 7 for areas 1, 2, and 4, respectively.

[2] Standard error of 0.0 means that n=1.

Nest Locations in Relation to Overstory

Tree cover around REV nests was usually very dense. For example, mean basal area in the immediate vicinity of individual REV nests averaged 125 feet^2 , although it ranged from 20 to 190 feet^2 /acre. In general, REV nests were located under tree cover that was equal to or denser than the average for the particular study areas. For example, mean basal areas around nests compared with the respective study area means were as follows: 146 vs 125 for area 1; 107 vs 110 for area 2; 140 vs 108 for area 3; and 137 vs 105 for area 4. According to Williamson (1971), the REV characteristically feeds where the canopy is abundant and the understory is moderate to dense. In such environments it has a cylindrical territory extending from the lower understory into the tree canopy.

Nesting Locations in Relation to Shrub Abundance

REV's apparently select shrubs based on their relative abundances providing all other things are equal. For example, the following tabulation compares the frequency distributions of nests among tall shrubs with frequencies of tall shrubs (>1.2-cm diameter, the smallest stems used by REVs) at area 1 (n = 13 nests) and area 2 (n = 21) where enough nests were found for such a comparison:

AREA 1

Nests:	Alder 54%	Cherry 23%	Hazel 23%	Black ash 0%
Shrubs	Alder 50%	Cherry 0%	Hazel 13%	Black ash 37%

AREA 2

Nests:	Hazel 80%	Alder 10%	Cherry 5%	Juneberry 5%	Misc. Species 0%
Shrubs:	Hazel 62%	Alder 20%	Cherry 3%	Juneberry 3%	Misc. Species 12%

Frequency distributions of shrubs were determined by counting and measuring all shrubs which occurred on 20 3 m^2 plots randomly placed within each stand. In spite of differences between frequencies of nests and shrubs, the data still suggest that REV's may distribute their nests in relation to the relative abundances of certain tall shrubs having the proper physical and other attributes. For some reason, REVs apparently avoided black ash at area 1 even though it was abundant and selected chokecherry in spite of its relative scarcity.

Moreover, the density of total nests per acre seems to increase with the density of large shrubs:

large stems/acre	5126	2360	1754	1146
total nests/acre	3.0	2.5	0.5	1.5

However, area 3 (1754 stems/acre) was anomalous, having the lowest nest density but not the lowest large shrub density. Since the REV nests across a wide spectrum of heights, it's possible that most REV nested in the canopy rather than in the shrub layer at area 3, thereby accounting for the paucity of nests. This explanation is probable because the tree canopy at area 3 was only 8 to 10 m above the ground, about 3 to 4 m lower than at other areas. In other words, the amount of airspace between the shrub and tree canopies could affect the vertical positioning of nests and the degree of nesting in the shrub layer.

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Aspen
Birch
Conifer

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SPACING AFFECTS KNOT SURFACE IN RED PINE PLANTATIONS

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ABSTRACT.— Quantifies the effect of spacing on branch diameter, number of branches, and knot surface in a red pine plantation.

OXFORD: 245.1:232.43:174.7 *Pinus resinosa.* KEY WORDS: *Pinus resinosa,* knot surface, poles, piling, branch diameter.

The spatial distribution of trees influences not only main stem diameter growth but also the growth of branches. Wide spacing in plantations results in greater diameter growth at breast height (4.5 feet) than close spacing but the large branches associated with wide spacing reduces tree quality. Close spacing results in smaller branches, but more of the branches die due to shading and produce loose knots. The purpose of this note is to quantify the effect of spacing on number of branches and branch diameter, both of which influence one tree quality characteristic — knot surface.

METHODS

The study area, located in Burnett County in northwestern Wisconsin, was planted in the spring of 1958 with 2-1 red pine (*Pinus resinosa Ait.*) nursery stock on soil described as Plainfield sand.[1] Seedlings were planted at spacings of 5- by 5-, 7- by 7-, 9- by 9-, and 11- by 11-feet. Site index is estimated at 70 feet. Mean height of dominant and codominant trees is 32 feet, and mean stand diameters for the four spacings are 4.3, 5.5, 6.5, and 7.3 inches, respectively. Total tree age is 23 years.

Six trees from each of the four spacings were sampled. Only dominant or codominant trees were selected because they represent potential crop trees. Diameter of all branches greater than 0.10 inch was measured in each whorl up to and including the third whorl below the terminal bud. Measurements were made 1.0 inch from the tree bole.

RESULTS

Branch Diameters

The 5- by 5- and 11- by 11-foot spacings are significantly[2] different in mean branch diameter from each other and the other spacings. Comparisons between the 7- by 7- and 9- by 9-foot spacings

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[1] Study maintained in cooperation with Burnett County and Wisconsin Department of Natural Resources.

[2] All statistical tests of significance were made at the 5 percent level.

showed barely nonsignificant differences, and except for one or two whorls, the 9- by 9-foot spacing consistently had larger diameter branches than the 7- by 7-foot spacing (table 1).

Branch diameter increased with height above ground to 3 feet for the 5 by 5 spacing and to 8 feet for the 11 by 11 spacing and remained constant to 17 feet for the 11 by 11 spacing and 24 feet for the 5 by 5 spacing. The other spacings were intermediate between these. Stiell (1964) observed this same relation. Wambach (1967) hypothesized this relation as total tree height increases faster than height to live crown at young ages. Thus, up to a certain age, each successive whorl lives slightly longer than the whorl below it. For this study, these ages are 5, 6, 7, and 8 years from planting for the 5- by 5-, 7- by 7-, 9- by 9-, and 11- by 11-foot spacings, rspectively.

The top whorl measured in this study was 3 years old. Within the last 5-year history of this stand, branch diameter growth decreased markedly for branches 4 years old regardless of spacing. Branch diameter growth virtually ceases at branch ages 5 to 7 years, progressing from the 5- by 5- to 11- by 11-foot spacings. Therefore, branch size in plantations 15 to 20 years old may be a good indication of branch size for red pine until the first thinning.

Number of Branches

Number of branches per whorl did not differ significantly between the four spacings (table 1). Similar results were observed by Stiell (1964) and Wambach (1967). Whorls above 3 feet averaged 6 branches per whorl (due to natural pruning, fewer branches remained below 3 feet). The number of branches was uniform from whorl to whorl — probability of having < 5 or > 7 branches is 0.07 and 0.14, respectively, and probability of having < 4 or > 8 is only < 0.03.

Knot Surface

Knot surface is defined as the sum of branch diameters and is a recognized standard of unsuitability for poles and piling. Eight inches of knot surface in any linear foot for branches greater than 0.49 inch is a common upper limit for product acceptance (Panshin *et al.* 1950). Trees in the 9- by 9- and 11- by 11-foot spacings either have exceeded or are rapidly approaching this 8-inch knot surface limit (table 1). This is particularly critical in the live crown because these branches will continue to grow after the first thinning.

The trees in this study have not attained the minimum top diameter and length for building poles, utility poles, natural taper piling, or standard piling. Currently, thinnings would yield

Table 1.—*Characteristics of dominant trees in a 20-year-old red pine plantation*[1]
(Site Index 70)

Characteristic	Spacing (feet) 5	7	9	11
Total height(ft.)	32	32	32	32
Height to live crown(ft.)	15	15	13	9
Live branches/tree(No.)	48	48	54	66
Dia. live branches 9 ft. to 17 ft.(in.)	.72	1.01	1.01	1.09
Live branches > 4 years old(No.)	24	24	30	42
Dia. live branches > 4 years old(in.)	.73	.93	1.01	1.07
Dead branches/tree(No.)	60	60	54	42
Dia. dead branches above 8 ft.(in.)	.73	.91	.93	1.13
Dia. dead branches below 8 ft.(in.)	.66	.76	.81	.86
Knot surface[2] below 17 ft.				
Mean(in.)	3.8	4.9	5.6	6.0
Maximum(in.)	6.5	8.1	9.2	10.6

[1] 2-1 trees planted; total tree age is 23 years.

[2] Measured 1 inch from bole.

pulpwood and posts, and knot surface is not a recognized standard of unsuitability for these products. Thinnings in 10 years will yield building poles, in 20 years will yield small utility poles plus a few natural taper piling, and in 30 years will yield some standard piling.

DISCUSSION

It is evident from this study, and implied by Stiell (1964) and Wambach (1967), that even at close spacings red pine retain most dead branches up to 20 years. Arend (1955) noted persistent dead branches to the ground in closely spaced red pine after 40 years. Thus, to produce an abundance of clear wood on rotations less than 100 years, pruning will be necessary regardless of spacing.

One advantage of wide spacing is to shorten the time to the first commercial thinning. However, this will necessitate pruning before the first thinning to minimize the size of the stem's "knotty" core and increase tree quality by allowing knots to be overgrown with strong clear wood. Crop trees in the 9- by 9-foot and wider spacings should be pruned before the first thinning, whereas pruning of crop trees in spacings closer than 9 by 9 feet could be delayed until the first thinning.

In the absence of pruning, plantation spacings 11 by 11 feet and wider would sharply curtail or eliminate the production of poles and piling.

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PULPWOOD PRODUCTION IN THE LAKE STATES, BY COUNTY, 1978

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ABSTRACT.-- Pulpwood production in the Lake States--Michigan, Minnesota, and Wisconsin--advanced from 4.74 million cords in 1977 to 4.91 million cords in 1978. Pulpwood production is shown by county and species group for these three States.

OXFORD: 861.0(77):792. KEY WORDS: Residue, Michigan, Minnesota, Wisconsin.

Lake States pulpwood production inched up to 4.91 million cords in 1978 from 4.74 million cords in 1977. By State, production was 1.89 million cords in Wisconsin (up 4 percent), 1.68 million cord in Michigan (up 5 percent), and 1.34 million cords in Minnesota (up 0.4 percent).

Nine out of 10 cords came from roundwood (including chips); the other cord came from mill residue such as slabs, edgings, veneer cores, and chips from those materials. Production from softwood and hardwood residue by State was:

State	Softwood	Hardwood
	(Hundred standard cords)	
Michigan	268	1,203
Minnesota	353	744
Wisconsin	404	1,835

Pine pulpwood output climbed to a record 820,000 cords, 88,000 cords ahead of 1977. Other moderate increases were in maple (77,000 cords), aspen (34,000 cords), and birch (24,000 cords). Elm pulpwood production fell 34,000 cords; several other species had nominal declines.

Harvesting rose substantially in the Western Upper Peninsula and Northern Lower Peninsula of Michigan and in Northwestern Wisconsin. No area had a significant harvest reduction.

Counties producing more than 100,000 cords were Iron, Marquette, and Dickinson in Michigan; St. Louis, Koochiching, and Itasca in Minnesota; and Oneida, Price, Marinette, and Forest in Wisconsin (table 1).

Pulpmills using Lake States timber in 1978 reported their pulpwood receipts by species group and State and county of origin. Their cooperation is gratefully acknowledged. Thanks are also due the Michigan Department of Natural Resources for collecting the data from pulpmills in Michigan.

Table 1.--*Lake States pulpwood production from roundwood by county and species, 1978*

(In hundred standard cords, roughwood basis)

MICHIGAN

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
E. UPPER PENINSULA												
ALGER	366	80	12	34	59	1	4	40	33	1	66	36
CHIPPEWA	322	150	35	40	10	2	2	43	15	X	13	12
DELTA	990	119	45	116	39	3	13	351	92	3	139	70
LUCE	547	278	44	54	52	1	2	34	19	1	32	30
MACKINAC	261	58	41	50	8	X	1	56	13	X	16	18
MENOMINEE	857	29	47	107	43	4	11	380	62	3	115	56
SCHOOLCRAFT	525	140	22	37	27	2	4	129	44	1	60	59
TOTAL	3868	854	246	438	238	13	37	1033	278	9	441	281
W. UPPER PENINSULA												
BARAGA	582	29	12	34	43	X	1	223	54	1	133	52
DICKINSON	1054	14	19	45	13	1	2	717	86	2	95	60
GOGEBIC	298	21	5	22	30	X	X	133	20	0	47	20
HOUGHTON	242	52	7	12	14	X	1	34	30	X	65	27
IRON	1186	108	76	158	42	2	6	450	85	1	181	77
KEWEENAW	15	1	1	1	7	0	0	X	1	0	3	1
MARQUETTE	1157	242	48	124	59	2	13	275	115	4	201	74
ONTONAGON	838	40	8	30	35	0	X	363	67	X	221	74
TOTAL	5372	507	176	426	243	5	23	2195	458	8	946	385
N. LOWER PENINSULA												
ALCONA	490	27	X	X	X	0	0	296	25	94	27	21
ALPENA	234	22	1	1	0	0	0	124	10	18	40	18
ANTRIM	1	1	0	0	0	0	0	0	0	0	0	0
ARENAC	1	0	0	0	0	0	0	1	0	0	X	0
BENZIE	103	0	0	0	0	0	0	68	4	6	22	3
CHARLEVOIX	10	0	0	0	0	0	0	2	0	1	6	1
CHEBOYGAN	205	47	X	1	X	0	0	90	9	4	38	16
CLARE	422	16	0	0	0	0	0	284	11	69	33	9
CRAWFORD	167	114	X	X	0	0	0	25	1	19	6	2
EMMET	X	0	0	0	0	0	0	X	0	0	0	0
GLADWIN	71	0	0	0	0	0	0	38	5	9	16	3
GRAND TRAVERS	61	20	0	0	0	0	0	28	1	2	8	2
IOSCO	156	109	X	0	0	0	0	14	1	28	3	1
ISABELLA	59	X	0	0	0	0	0	56	2	1	X	X
KALKASKA	67	23	0	0	0	0	0	22	5	3	13	1
LAKE	365	65	0	0	0	0	0	112	2	146	37	3
LEELANAU	1	1	0	0	0	0	0	0	0	0	0	0
MANISTEE	201	12	0	0	0	0	0	70	2	62	50	5
MASON	226	23	0	0	0	0	0	100	4	55	39	5
MECOSTA	135	29	0	0	0	0	0	83	X	12	8	3
MIDLAND	50	0	0	0	0	0	0	26	6	X	17	1
MISSAUKEE	67	9	0	0	0	0	0	31	3	8	11	5
MONTMORENCY	405	55	1	1	0	0	0	214	12	67	35	20
NEWAYGO	336	60	0	0	0	0	0	132	1	118	19	6
OCEANA	198	17	0	0	0	0	0	134	2	27	14	4
OGEMAW	110	34	0	0	0	0	0	36	3	24	10	3
OSCEOLA	270	31	0	0	0	0	0	135	5	33	59	7
OSCODA	341	129	X	1	X	0	0	124	6	55	18	8
OTSEGO	80	41	X	X	1	0	0	16	X	9	11	2
PRESQUE ISLE	206	38	X	4	1	0	0	102	34	3	16	8
ROSCOMMON	234	60	X	0	X	0	0	71	4	81	16	2
WEXFORD	472	229	X	1	1	0	0	134	4	41	57	5
TOTAL	5744	1212	2	9	3	0	0	2568	162	995	629	164
S. LOWER PENINSULA												
ALLEGAN	24	17	0	0	0	0	0	2	X	4	1	X
BARRY	8	7	0	0	0	0	0	1	0	0	0	0
CASS	X	X	0	0	0	0	0	0	0	0	0	0
GRATIOT	14	X	0	0	0	0	0	14	0	X	0	0
IONIA	2	2	0	0	0	0	0	0	0	0	0	0
KALAMAZOO	1	1	0	0	0	0	0	0	0	0	0	0
KENT	22	0	0	0	0	0	0	11	X	8	2	1
LIVINGSTON	X	0	0	0	0	0	0	0	0	X	X	0
MONTCALM	44	14	0	0	0	0	0	19	X	8	2	1
MUSKEGON	66	47	0	0	0	0	0	11	X	7	1	X
OAKLAND	X	X	0	0	0	0	0	0	0	0	0	0
OTTAWA	109	107	0	0	0	0	0	1	X	1	X	X
SHIAWASSEE	1	1	0	0	0	0	0	0	0	0	0	0
VAN BUREN	X	X	0	0	0	0	0	0	0	0	0	0
WASHTENAW	1	1	0	0	0	0	0	0	0	0	0	0
TOTAL	292	197	0	0	0	0	0	59	X	28	6	2
STATE TOTAL	15276	2770	424	873	484	18	60	5855	898	1040	2022	832

(CONTINUED ON NEXT PAGE)

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1978.
X=LESS THAN 50 CORDS.

MINNESOTA

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
NORTHERN ASPEN BIRCH												
CARLTON	257	32	31	22	0	1	0	168	2	0	1	0
COOK	255	60	115	50	0	0	0	30	0	0	0	0
KOOCHICHING	2574	163	661	263	0	157	0	1217	4	0	1	108
LAKE	680	200	180	48	0	0	0	247	5	0	X	0
ST.LOUIS	2974	436	275	206	0	21	0	1966	10	X	1	59
TOTAL	6740	891	1262	589	0	179	0	3628	21	X	3	167
NORTHERN PINE												
AITKIN	593	17	23	14	0	31	0	479	6	13	6	4
BECKER	23	18	0	0	0	0	0	5	0	0	0	0
BELTRAMI	818	163	97	107	0	17	0	426	6	0	1	1
CASS	749	178	7	13	0	9	0	525	8	3	1	5
CLEARWATER	174	24	14	12	0	18	0	106	X	0	X	0
CROW WING	169	78	X	X	0	0	0	91	0	0	0	0
HUBBARD	427	113	6	3	0	2	0	303	0	0	0	0
ITASCA	1473	74	107	215	0	23	0	972	29	3	6	44
LAKE OF THE W	236	71	85	3	0	4	0	73	0	0	0	X
MAHNOMEN	18	11	0	0	0	2	0	5	0	0	0	0
ROSEAU	155	65	38	1	0	X	0	51	0	0	0	0
WADENA	108	78	0	1	0	0	0	29	0	0	0	0
TOTAL	4943	890	377	369	0	106	0	3065	49	19	14	54
CENTRAL HARDWOOD												
BENTON	1	0	0	0	0	0	0	1	0	0	0	0
CHISAGO	2	0	0	0	0	0	0	2	0	0	0	0
HENNEPIN	29	0	0	0	0	0	0	0	0	0	0	29
ISANTI	15	15	0	0	0	0	0	0	0	0	0	0
KANABEC	63	6	0	0	0	0	0	37	4	12	4	0
MILLE LACS	162	0	0	0	0	0	0	101	12	37	12	0
MORRISON	101	18	X	0	0	0	0	63	4	12	4	0
OTTER TAIL	15	10	0	0	0	0	0	5	0	0	0	0
PINE	153	12	X	0	0	0	0	137	2	2	0	0
RAMSEY	20	0	0	0	0	0	0	0	0	0	0	20
SHERBURNE	X	0	X	0	0	0	0	0	0	0	0	0
TODD	17	15	0	0	0	0	0	2	0	0	0	0
TOTAL	578	76	X	0	0	0	0	348	22	63	20	49
PRAIRIE												
POLK	27	0	X	0	0	22	0	5	0	0	0	0
TOTAL	27	0	X	0	0	22	0	5	0	0	0	0
STATE TOTAL	12288	1857	1639	958	0	307	0	7046	92	82	37	270

(CONTINUED ON NEXT PAGE)

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1978.
X=LESS THAN 50 CORDS.

WISCONSIN

UNIT 1/ AND COUNTY	ALL SPECIES	PINE	SPRUCE	BALSAM FIR	HEM-LOCK	TAM-ARACK	CEDAR	ASPEN	BIRCH	OAK	MAPLE	OTHER HDWDS.
NORTHEASTERN												
FLORENCE	517	62	12	22	5	X	0	354	14	X	29	19
FOREST	1080	88	31	163	45	1	2	450	67	X	104	129
LANGLADE	527	19	2	25	8	4	0	175	37	5	134	118
LINCOLN	540	48	18	40	18	3	3	302	20	13	30	45
MARINETTE	1098	196	17	48	19	X	1	572	125	14	54	52
OCONTO	371	140	3	25	2	0	0	155	22	X	17	7
ONEIDA	1540	271	66	144	15	3	1	677	193	36	70	64
SHAWANO 2/	622	69	1	1	176	0	0	237	13	7	59	59
VILAS	762	88	16	60	16	1	X	386	125	3	45	22
TOTAL	7057	981	166	528	304	12	7	3308	616	78	542	515
NORTHWESTERN												
ASHLAND	845	53	9	76	17	X	2	459	67	21	72	69
BARRON	79	3	0	0	0	0	0	4	16	15	26	15
BAYFIELD	653	177	2	17	1	0	0	342	86	0	12	16
BURNETT	234	200	0	1	0	X	0	7	9	0	12	5
DOUGLAS	694	375	1	11	0	X	0	282	22	0	2	1
IRON	903	4	2	20	9	X	X	456	44	15	199	154
POLK	31	23	0	0	0	X	0	8	0	0	0	0
PRICE	1099	46	10	55	35	8	2	454	116	15	133	225
RUSK	229	5	X	1	1	X	0	120	31	7	35	29
SAWYER	992	66	1	12	105	X	1	392	99	17	155	144
TAYLOR	478	9	1	19	16	2	0	202	34	2	85	108
WASHBURN	540	255	1	X	0	X	0	273	5	0	4	2
TOTAL	6777	1216	27	212	184	10	5	2999	529	92	735	768
CENTRAL												
ADAMS	358	277	0	0	0	0	0	2	3	66	6	4
CHIPPEWA	188	11	0	1	2	X	0	88	20	11	31	24
CLARK	225	32	0	1	4	0	0	44	6	92	29	17
EAU CLAIRE	102	34	0	0	0	0	0	4	7	36	14	7
JACKSON	161	135	0	0	0	X	0	1	3	12	6	4
JUNEAU	293	221	0	0	0	0	0	7	3	52	6	4
MARATHON	471	28	X	10	29	X	0	117	9	10	155	113
MARQUETTE	89	47	0	0	0	2	0	2	1	3	29	5
MONROE	83	68	0	0	0	0	0	X	2	2	7	4
PORTAGE	158	90	X	X	2	X	0	25	1	25	12	3
WAUPACA	141	68	0	X	0	1	0	46	3	2	9	12
WAUSHARA	87	78	0	0	0	0	0	3	1	2	2	1
WOOD	245	126	2	0	0	X	0	26	2	59	24	6
TOTAL	2601	1215	2	12	37	3	0	365	61	372	330	204
SOUTHWESTERN												
BUFFALO	4	4	0	0	0	0	0	0	0	0	0	0
CRAWFORD	17	0	0	0	0	0	0	3	X	12	1	1
DUNN	40	40	0	0	0	0	0	0	0	0	0	0
GRANT	53	0	0	0	0	0	0	8	1	36	4	4
IOWA	11	2	0	0	0	0	0	1	X	6	1	1
LACROSSE	13	13	0	0	0	0	0	0	0	0	0	0
LAFAYETTE	9	0	0	0	0	0	0	1	X	6	1	1
PEPIN	1	1	0	0	0	0	0	0	0	0	0	0
PIERCE	X	X	0	0	0	0	0	0	0	0	0	0
SAUK	24	18	0	0	0	0	0	0	2	X	3	1
TREMPEALEAU	30	30	0	0	0	0	0	X	0	0	0	0
VERNON	X	0	0	0	0	0	0	0	0	0	X	X
TOTAL	202	108	0	0	0	0	0	13	3	60	10	8
SOUTHEASTERN												
BROWN	5	3	0	0	0	0	0	2	0	0	0	0
COLUMBIA	39	27	0	0	0	0	0	0	X	1	9	2
DOOR	3	3	0	0	0	0	0	0	0	0	0	0
GREEN	3	3	0	0	0	0	0	0	0	0	0	0
GREEN LAKE	X	X	0	0	0	0	0	0	0	0	0	0
JEFFERSON	X	X	0	0	0	0	0	0	0	0	0	0
KENOSHA	X	0	0	0	0	0	0	X	0	0	0	0
MANITOWOC	X	0	0	0	0	0	0	X	0	0	0	0
OUTAGAMIE	4	1	0	1	0	0	0	X	1	0	1	X
WAUKESHA	15	15	0	0	0	0	0	0	X	0	X	X
TOTAL	69	52	0	1	0	0	0	2	1	1	10	2
STATE TOTAL	16706	3572	195	753	525	25	12	6687	1210	603	1627	1497

1/ INCLUDES ONLY THOSE COUNTIES THAT SUPPLIED PULPWOOD IN 1978.
2/ INCLUDES MENOMINEE COUNTY.
X=LESS THAN 50 CORDS.

NORTH CENTRAL FOREST EXPERIMENT STATION
Research Note NC-248
1992 FOLWELL AVE [illegible] MN 55108 FOREST SERVICE-U.S.D.A.
1979

FEEDING PREFERENCE OF PENNED WHITE-TAILED DEER FOR HYBRID POPLAR CLONES

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ABSTRACT.— Five hybrid poplar clones were presented to 16 penned white-tailed deer on a feeding board over a 3-day period in September, 1978. A definite order of preference was observed over a 3-hour period for each of 3 trials. Over a longer period (8-24 hours), all 5 clones were completely consumed.

OXFORD: 151.3—149.6 CER. KEY WORDS: browse, intensive culture, plantations.

Knowing how palatable hybrid poplar clones are to white-tailed deer (*Odocoileus virgineanus*) is important if plantations of these clones are to be established. Certain genotypes may be preferred over others even though gross physical characteristics are very similar[1]. The objective of this study was to determine feeding preference by white-tailed deer for various hybrid poplar clones that are being used in intensive culture studies at the Forestry Sciences Laboratory in Rhinelander, Wisconsin.

MATERIALS AND METHODS

Five hybrid poplar clones were presented to 16 penned white-tailed deer on a feeding board over a 3-day period in September 1978.

Leafy twigs of the 5 clones were harvested from experimental plots at the Forestry Sciences Laboratory on September 12, 1978 (table 1). The twigs were placed in plastic bags, packed with crushed ice in styrofoam containers and delivered for testing to Ashland, Wisconsin. All the vegetation, even that used 3 days after delivery, appeared to be in good condition. The careful packing preserved the color and turgor of the leaves.

In preparation for the feeding trials, each twig was trimmed to 12 inches with 10 leaves left on each twig. In each feeding trial, 10 twigs of each clone were tied together in a bundle and secured to a feeding board 10 feet long and 4 inches wide. The feeding board was attached to 2 trees so that the tops of the clone bundles were 4 feet from the ground. Clonal order on the board was randomized.

The number of leaves in each bundle was counted at half-hour intervals for 3 hours, and again after the material had been in the deer yard at least 8 hours. Three separate feeding trials were run.

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[1] *Dimock, E. J., II, R. R. Silen, and E. V. Allen. 1976. Resistance in Douglas-fir to damage by snowshoe hare and black-tailed deer. For. Sci. 22:106-121.*

Table 1.—*Parentage of clones used in September, 1978 penned deer studies*

Clone number	Clone and/or parentage	Received from— and number
5260	P. 'Tristis #1', (P. tristis × P. balsamifera)	Indian Head, Sask.
5262	P. cv. Candicans × P. cv. Berolinensis	Upper Darby, PA. NE-385
5272	P. nigra × P. laurifolia	Upper Darby, PA. NE-1
5325	P. × euramericana cv. Ostia	Maple, Ontario DN-28
5332	P. cv. Betulifolia × P. trichocarpa	Upper Darby, PA. NE-98

The penned deer are normally fed by park personnel in the early afternoon. Food consists primarily of hay and grain. In addition, residents of the area often visit the deer yard and bring bread, apples and other foods.

RESULTS AND DISCUSSION

The time of presenting the clones to the animals influenced how quickly the vegetation was consumed. The deer appeared most interested in the poplars when hay and grain were not available. However, time of presentation had no apparent effect on clonal preference.

In trial #1 (table 2), the deer had not been fed by park personnel for almost 24 hours, but evidence of other feeding was prominent. The clones were immediately investigated by several animals and some browsing took place on all five clones. Three animals (two does and a buck) browsed on clones 5325 and 5272. They repeatedly wandered away but returned each time to the same two clones. The remaining animals (13) showed little interest in the material after their initial examination.

The other two trials showed that the same clones were preferred but the time required to consume all leaves was different (table 3). Over a longer period (8-24 hours) the leaves from all 5 clones were completely consumed. In some instances even the twigs were eaten. In trial #3 all 16 animals actively investigated and browsed on the clonal material.

Table 3.—*Clonal preference based on three feeding trials with penned deer*

Clone number	Trial 1	Trial 2	Trial 3
5325	1	1	1
5272	2	2	2
5332	3	3	3
5260	4	4	5
5262	5	5	4

Care must be taken in interpreting the results of this study since the natural browse in the 5-acre deer yard has long been depleted. It is possible that browse material consumed in this study might be ignored in the field.

Table 2.— *Leaves remaining after various periods of elapsed time in deer pen*

Clone number	Leaves remaining																				
	Trial 1 September 14, 1978 11:00 AM							Trial 2 September 15, 1978 4:00 PM							Trial 3 September 16, 1978 7:00 AM						
	Hours elapsed							Hours elapsed							Hours elapsed						
	½	1	1½	2	2½	3	24	½	1	1½	2	2½	3	15	½	1	1½	2	2½	3	8
	Number							*Number*							*Number*						
5260	82	71	71	56	41	37	0	84	80	80	61	53	53	0	33	27	11	11	Traces	0	0
5262	91	80	51	51	51	46	0	98	98	98	94	94	94	0	50	21	0	0	0	0	0
5272	46	31	11	0	0	0	0	98	71	71	43	43	10	0	Eaten in 11 minutes						0
5325	20	7	0	0	0	0	0	18	Traces		Traces		Traces	0	Eaten in 6 minutes						0
5332	84	70	64	31	31	31	0	90	86	86	67	51	46	0	10	0	0	0	0	0	0

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ORTH CENTRAL FOREST
XPERIMENT STATION 1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.
Research Note NC-249
1979

SOIL STRUCTURE AND MYCORRHIZAE ENCOURAGE BLACK WALNUT GROWTH ON OLD FIELDS

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Carbondale, Illinois

ABSTRACT.—Examination of black walnut seedlings grown in forest and field soils showed all root systems were infected with mycorrhizae; the amount of infection was influenced by treatments. Mean height and dry weight of tops and roots were greater for seedlings grown in forest than field soil. Seedling height growth was not increased by disturbing either soil; but, root dry weight was significantly increased by disturbing the field soil.

OXFORD: 114.14:181.351:176.1 *Juglans nigra*. KEY WORDS: Endomycorrhizal fungi, bulk density sampling, soil sterilization.

Black walnut trees (*Juglans nigra* L.) planted on abandoned fields often grow much less than trees planted on cleared forest sites or on old fields reverted to tree cover (Carmean *et al*. 1976). Good soil structure, valuable for promoting plant growth and microorganisms, is less common in old fields than in the undisturbed soils under continuous forest cover.

Black walnut is known to form vesicular-arbuscular (VA) mycorrhizae. Mazur and Semahanova (1965) reported that mycorrhizae developed best on *J. regia* L. at 40 to 50 percent moisture content, and seedling development (foliation, height, stem diameter, and root system) was positively related to the amount of mycorrhizae formation.

This report describes the influence of disturbed and undisturbed soils from both forested and abandoned field sites, and the effects of inoculation with VA endomycorrhizal fungi on the growth of black walnut seedlings under greenhouse conditions.

METHODS

In the spring of 1978, soils of the Wellston series (fine-silty, mixed, mesic-Ultic Hapludalfs) were collected from a forest and an abandoned field on the Kaskaskia Experimental Forest in Hardin County, Illinois. This silt loam soil is well-drained and was formed in loess and underlying material weathered from sandstone or shale bedrock. Topsoil thickness averaged 12 cm in the forest and 8 cm in the abandoned field. Subsoil thickness averaged nearly 1 m to sandstone bedrock in both soils. The abandoned field (last cultivated in early 1960's) was dominated with broomsedge (*Andropogon virginicus* L.), and had been sparsely invaded by white ash (*Fraxinus americana* L.), green ash (*F. pennsylvanica* var. *subintegerrima* (Vahl.) Fern.), yellow-poplar (*Liriodendron tulipifera* L.), sassafras (*Sassafras albidum* Nutt.), and flowering dogwood (*Cornus florida* L.). The forest area is adjacent to the field and has sawtimber-size white oak (*Quercus alba* L.), white ash, yellow-poplar, and several large diameter black walnut (*Juglans nigra* L.) trees.

Using a newly designed soil sampler and cast acrylic resin tubes, relatively undisturbed soil cores 20 cm in diameter were obtained from the upper 36 cm of both forest and field. Sections of burlap were fastened over the bottom ends of the tubes to retain soil. Soils for the disturbed treatment were also collected from the upper 36 cm of the forest and field. This soil was thoroughly disturbed by the use of a mechanical shredder and equal amounts (by weight) were put into epoxy painted (inside and outside) galvanized steel containers the same size as the acrylic containers and secured with burlap.

Sixty containers each of the forest and field soils were prepared. Treatments included undisturbed (U), disturbed (D) undistrubed autoclaved (UA), disturbed autoclaved (DA), undisturbed, autoclaved, and inoculated (UAI), and disturbed, autoclaved, and inoculated (DAI). Each treatment was replicated 10 times for each of the two soils. All containers were randomly placed in a shaded greenhouse in mid-May 1978. The acrylic containers were covered with aluminum foil to prevent roots from being affected by sunlight.

Autoclaved soils were treated at 122C and pressure of 1.5 kg/cm^2 in containers for two 2-hour periods separated by 24 hours. Autoclaved and inoculated soils were inoculated by forcing a 10 mm sterilized glass tube into the soil to a depth of 10 cm in each container at three equi-distant locations, removing a plug of soil, and inserting a sterilized glass tube of nonautoclaved forest soil into the hole. An additional 10 g of nonautoclaved forest soil was broadcast over the surface to complete inoculation.

One pregerminated black walnut seed that had been surface-sterilized with sodium hypochlorite was planted in each container. Seedlings were watered with distilled water as needed throughout the growth period.

After 12 weeks of growth, seedlings were harvested and stem height and diameter (2.54 cm above root collar) were recorded. Roots were separated from tops and rinsed thoroughly in tap water. Six 10-cm lengths per treatment were randomly removed and examined microscopically at 100X for the presence of VA mycorrhizal infection after clearing and staining according to the method of Phillips and Hayman (1970). The root was scored mycorrhizal if hyphae, arbuscules, or vesicles were present separately or together in any part of the root segment. The density of the infection was not measured. The remaining roots and tops were ovendried for 24 hours at 65C and weighed.

RESULTS AND DISCUSSION

Mycorrhizae

Roots of seedlings grown in all treatments of the undisturbed and disturbed forested and field soils were mycorrhizal, but the amount of infection was influenced by treatments (figs. 1D and H). Autoclaving undisturbed forest soil cores (UA) reduced mycorrhizal infection to 40 percent, but autoclaving undisturbed field soil cores reduced mycorrhizal infection only to 80 percent. When undisturbed and autoclaved forest soil cores (UA) were inoculated (UAI) the mycorrhizal infection increased from 40 to 60 percent and in the case of the field soil (UAI), roots were 100 percent infected as were seedlings in the undisturbed field cores. Thus, it can be concluded that autoclaving undisturbed soils at 122C reduces mycorrhizal infection but does not completely eliminate infection.

Results were similar for seedlings grown in disturbed and autoclaved cores for both forest and field soils (fig. 1D and H). Autoclaving disturbed forest and field soils (DA) reduced mycorrhizal infection much more than autoclaving undisturbed soils (UA), and when these disturbed and autoclaved soils were inoculated (DAI) mycorrhizal infection was greatly improved. The percent infection increased from 20 to 100 in roots of seedlings grown in field soil cores but only from 20 to 60 for seedlings in forest soil cores. Thus, it can be concluded that inoculation of both forest and field soils that have been autoclaved improved mycorrhizal infection. Also, the inoculum and the method used for inoculation, although improving infection, did not usually result in the 100 percent infection observed in soils that were not autoclaved.

Seedling growth

Comparison of mean height and dry weight of roots and tops shows that seedlings grown in containers of forest soil were superior to those in the field soil (fig. 1A,B,C,E,F,G). Much of the greater height, and top and root dry weights of

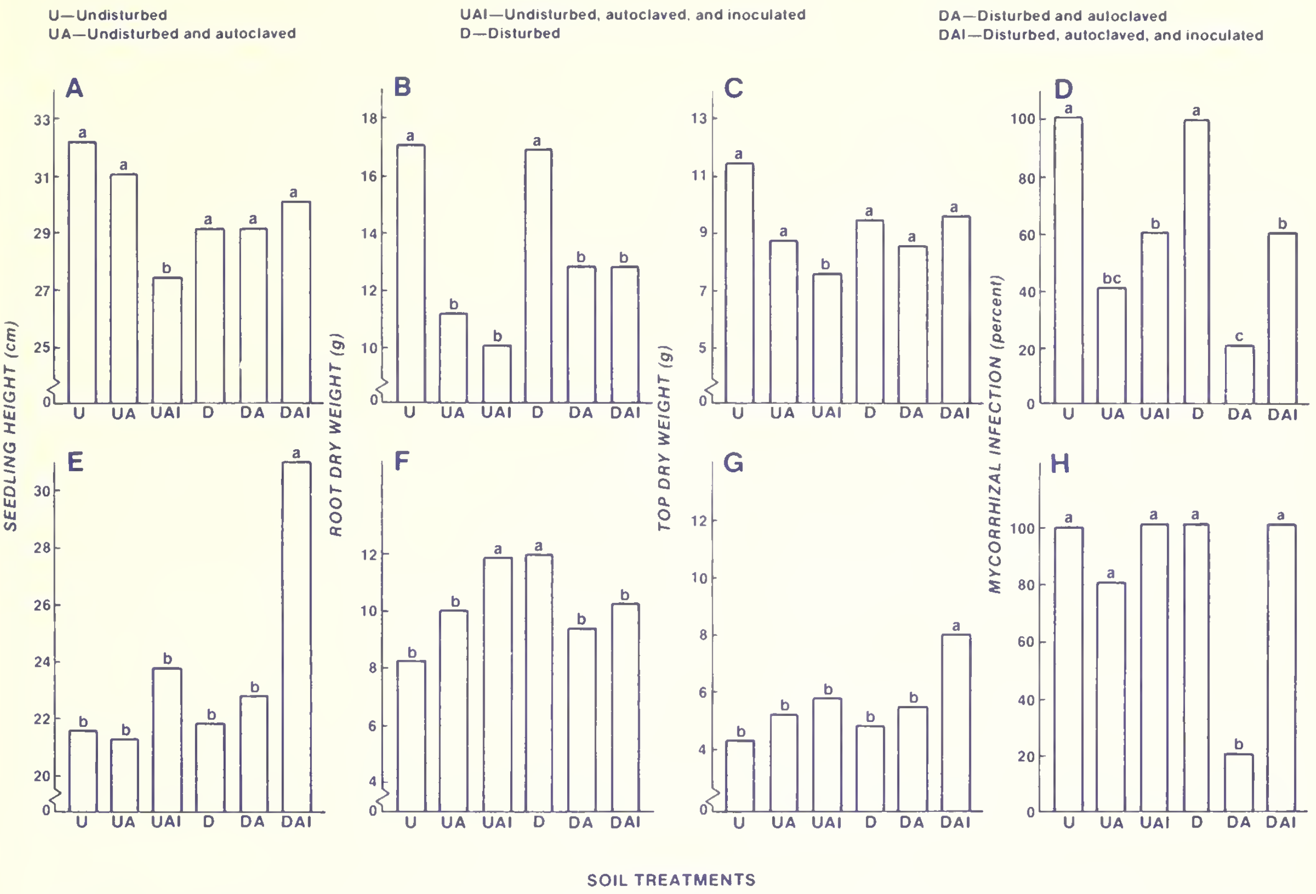

Figure 1.—*Effects of soil treatments on seedling height, root dry weight, top dry weight, and mycorrhizal infection in forest soils, A through D respectively; and field soils, E through H respectively. (Bars with the same letters are not significantly different at the 0.05 level. Means of 10 plants.)*

seedlings grown in forest soil may be attributed to its lower bulk density, and greater nutrient and organic matter content compared to field soil (table 1). Height growth of seedlings was not increased by disturbing the forest soil (D). Clark (1964) showed that yellow-poplar seedlings grown in undisturbed forest soil had greater height and dry weight than seedlings grown in disturbed forest soil.

The root dry weight of seedlings grown in disturbed field soil was significantly increased over seedlings grown in undisturbed field soil. Undisturbed field soils are dense (1.40 g/cm^3,table 1); disturbing these soils reduced bulk density to 1.18 g/cm^3. Thorough loosening of the soil may not always be desirable, as some plants require rather dense soil for best root-soil contact and growth. Evidently loosening the field soil in this study improved soil aeration and favored root penetration, proliferation, and growth. An increase in root mass in response to lowering the soil bulk density might lead to improved top growth differences in old field plantings years later.

Lack of mycorrhizae is likely not a problem in the growth of black walnut on abandoned field sites. However, the more dense, and less aerated condition of undisturbed field soils might have diminished VA mycorrhizal activity and thus reduced the ability of seedlings to absorb nutrients and moisture. We did not determine whether the mycorrhizae in forest and field soils are the same organisms. If they are different and some are more effective in promoting growth than others, infection alone may not mean much (Marx *et al.* 1971).

Table 1.—*Average soil properties before and after treatments*

Soil	pH[1]	Bulk density[2]	Organic matter[3]	Nutrients[4]				
				N	P	K	Ca	Mg
		g/cm³	*Percent*			*Ppm*		
Before								
Forest	6.1	1.29	.88	27.6	7.5	42	928	75
Field	5.3	1.40	0.94	3.6	5.4	33	395	120
After								
Forest	6.0	1.15	1.56	25.2	6.4	43	1404	75
Field	5.4	1.18	0.78	6.0	6.6	35	508	112

[1] pH by glass electrode in 1:1 soil solution.

[2] Bulk density according to the formula ovendry weight/volume of sample.

[3] Organic matter by titration after oxidation with 1N $K_2Cr_2O_7$ and concentrated H_2SO_4.

[4] N colorimetrically after extraction with $Ca(OH)_2$; P colorimetrically after extraction with 0.002N H_2SO_4; K, Ca, and Mg by atomic absorption after extraction with 0.075N acid mixture (0.5N HCl + 0.25N H_2SO_4).

Both broomsedge and sassafras in the abondoned field vegetation contain allelopathic compounds that have been known to inhibit the growth of several competing plant species (Rice 1972); others inhibit nitrogen fixing and nitrifying bacteria (Rice 1964, Gant and Clebsch 1975). Carmean *et al.* (1976) suggested that allelopathic compounds produced by broomsedge and sassafras may reduce the growth of planted hardwoods. In most cases reduced plant growth has been attributed to low soil nitrogen. There may be a connection between low soil nitrogen and allelopathy that is not yet completely understood (Rice 1977).

CONCLUSION

Black walnut seedlings grown in both forest and field soils were mycorrhizal to some degree. Forest soil had the best growth of all treatments, and seedlings were well infected with endomycorrhizae. Good seedling growth is apparently dependent on high mycorrhizal infection rates—rates that could not be achieved by autoclaving and then inoculating previously undisturbed forest soil. Disturbing field soils reduced bulk density and increased average root dry weight of seedlings. Even though establishment of mycorrhizal infection is no problem in old fields, soil structure may restrict optimal mycorrhizal development. We conclude that both mycorrhizae and soil structure are important in black walnut seedling growth.

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RABBITS AND GRASSHOPPERS: VECTORS OF ENDOMYCORRHIZAL FUNGI ON NEW COAL MINE SPOIL

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ABSTRACT.— Rabbit droppings and grasshoppers were collected on recently graded coal mine spoil to determine if they were vectors of endomycorrhizal fungi. After 6 weeks of growth, roots of rye grass and sudan grass grown in mixtures of sterilized sand containing either unsterilized rabbit droppings or grasshoppers were endomycorrhizal, while the roots of plants grown in sterilized mixtures of these were not.

KEY WORDS: Mycorrhizae, spoil banks, animal vectors, revegetation, insect vectors.

Coal strip mine operations alter the natural soil strata, producing a mixture of rock fragments, clays, coal fragments, and the original soil. The site condition of this heterogeneous mixture is varied, and commonly referred to as "spoil".

Microflora investigations of plants growing on spoils have shown plants to be infected with vesicular arbuscular (VA) endomycorrhizae. Daft *et al.* (1975) found endomycorrhizae on roots of grasses and other herbaceous plants colonizing anthracite and bituminous coal spoils in Pennsylvania and bituminous coal spoils in Scotland. Marx (1975) reported that grasses, trees, and herbaceous plants on both artificially and naturally revegetated coal spoils in Kentucky and Virginia were endomycorrhizal infected to some degree. Endomycorrhizal fungi are thought to spread slowly— mainly by water, soil movement, and possibly mammals and insects. Recently, Trappe and Maser (1976) found spores of *Glomus macrocarpus* Tul. & Tul. to be viable after passing through the digestive tract of rodents. The purpose of the present study was to determine if the mammals or insects that frequented a recently graded spoil could be vectors of endomycorrhizal fungi.

METHODS

In mid-summer 1978, rabbit droppings and live grasshoppers were randomly collected at the Sahara Coal Mine Company near Carrier Mills, Illinois on a spoil graded in the fall of 1977. (According to the 1971 Illinois Surface-Mined Land Conservation and Reclamation Act, top soil need not be replaced.) The rabbit droppings and grasshoppers were divided into two portions. One portion, along with several containers of builders sand, was sterilized by autoclaving at 122C and 17 psi for two 2-hour periods; the second period was 24 hours after the first. The second portion of the droppings and grasshoppers were dried for 72 hours at 30C in an oven, crushed and mixed separately with autoclaved sand in separate lots. Similarly sterilized rabbit droppings and grasshoppers were crushed and mixed with sterilized sand. Four replications each of rye grass (*Lolium perenne* L.) and sudan grass *(Sorghum sudanense)* were planted in 1-gallon containers with the mixtures. Both a sterilized and unsterilized sand control were also planted. All plants were grown for 6 weeks under greenhouse conditions.

Plant roots were examined for VA endomycorrhizal presence with a compound microscope at 100X after clearing and staining the roots according to the method of Phillips and Hayman (1970).

RESULTS AND DISCUSSION

Careful examination of plants growing in sterilized sand mixed with either unsterilized rabbit droppings or grasshoppers showed some of them to be endomycorrhizal. As shown in the following tabulation, after 6 weeks of growth, plants were 20 and 31 percent infected when grown in sterilized sand containing unsterilized rabbit droppings, and in sterilized sand and grasshoppers, respectively. Plants grown in sterilized sand containing either sterilized rabbit droppings or sterilized grasshoppers had no infection.

Treatment	**Rye grass**	**Sudan grass**
	Percent[1]	
Unsterilized sand	7	8
Sterilized sand	0	0
Sterilized sand + sterilized rabbit droppings	0	0
Sterilized sand + unsterilized rabbit droppings	20	28
Sterilized sand + sterilized grasshoppers	0	0
Sterilized sand + grasshoppers	22	31

Gerdemann and Trappe (1974) found mature *Endogone* spores that had passed through the digestive tracts of mammals without morphological changes. However, no viability tests were done on spores. Taylor, Vorhies, and Lister (1935) state that jack rabbits (*Lepus californicus melanotis*) regularly defecate as they feed, or very soon afterwards. Therefore, it is probable that many fungal propagules could pass through a rabbit's digestive tract unharmed.

Hansen and Ueckert (1970) reported ingestion of fungi by crickets and grasshoppers. According to Gerdemann and Trappe (1974), some of this fungal material was later identified as spores of Endogonaceae.

Although droppings of rodents were not investigated in this study as a means of endomycorrhizal dispersal, rodents such as field mice are known to feed upon a variety of endomycorrhizal fungi (Bakerspigel 1958). Near the study area, 33 mice were trapped in one night using the line transect method (Dennis Harmon, personal communication).

Fumigated nursery soil and other areas treated to preclude micro-organisms may be reinfected by rabbits and grasshoppers or other vectors that feed or come in contact with such fungi. South (1977) states that both inoculated and uninoculated soil that had previously been fumigated with methyl bromide produce seedlings having the same amount of infection.

SUMMARY AND CONCLUSION

Rabbit droppings and live grasshoppers were collected from a recently graded coal mine spoil. A portion of both along with builders sand was sterilized while the remaining portion was not. These were mixed separately with sterilized sand and planted with rye grass and sudan grass. After 6 weeks, a number of roots growing in both the unsterilized rabbit droppings and grasshoppers and sterilized sand mixtures were endomycorrhizal, while the roots of plants in either mixture containing sterilized rabbit droppings and sterilized grasshoppers and sterilized sand were not. Results from this study show that both rabbits and grasshoppers are vectors of endomycorrhizal fungi. Further research is needed to determine how important small mammals and insects such as rabbits and grasshoppers are in the dispersal of endomycorrhizae.

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[1] *Based on 100 plants.*

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WOOD SPECIFIC GRAVITY OF PLANTATION RED PINE LITTLE AFFECTED BY SPACING

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ABSTRACT.—Shows stocking density has little effect on wood specific gravity of red pine.

KEY WORDS: *Pinus resinosa,* wood quality, wood strength.

Red pine (*Pinus resinosa* Ait.) covers more than one million acres in Michigan, Minnesota, and Wisconsin. A large percentage of this acreage is plantations. Early thinnings of these plantations will yield pulpwood, posts, and some poles. And, specific gravity of this wood is an important quality factor affecting fiber yield, working and finishing qualities, and strength. The purpose of this note is to quantify the effect of spacing on wood specific gravity for red pine grown on a good site.

METHODS

The study area, located in Burnett County in northwestern Wisconsin, was planted in the spring of 1958 with 2-1 red pine nursery stock on soil described as Plainfield sand.[1] Seedlings were planted at spacings of 5- by 5-feet, 7- by 7-feet, 9- by 9-feet, and 11- by 11-feet. Mean height of dominant and codominant trees is 32 feet, and mean stand diameters for the four spacings are 4.3, 5.5, 6.5, and 7.3 inches, respectively. Total tree age is 23 years. Site index is estimated at 70 feet.

Six trees from each of the four spacings were sampled. Only dominant and codominant trees were selected because they represent the effect of spacing on specific gravity without the additional effect of suppression on specific gravity that would be present in intermediate and suppressed trees. A disc was cut at 4.5 feet and between each whorl from the base of the tree up to and including the current year's growth. The bark was removed and the green discs soaked in water for 48 hours, weighed to the nearest 0.5 gram, and immersed and weighed again to determine volume by the displacement method. Discs were ovendried (70C) for 48 hours and weighed a third time. Specific gravity was determined by:

$$\text{Specific gravity} = \frac{\text{ovendry weight}}{\text{weight (wet, air)} - \text{weight (wet, immersed)}}$$

RESULTS

Specific gravity at 4.5 feet increased as the number of trees per acre increased (table 1). However, the

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[1] *Study maintained in cooperation with Burnett County and Wisconsin Department of Natural Resources.*

Table 1.—*Specific gravity of dominant trees in a 20-year-old plantation*[1]

Height (feet)	**Spacing (feet)**			
	5	**7**	**9**	**11**
2	.3511	.3379	.3337	.3388
4.5	.3495	.3337	.3325	.3315
6	.3494	.3308	.3297	.3284
8	.3447	.3274	.3263	.3276
12	.3430	.3276	.3257	.3231
14	.3412	.3271	.3272	.3214

[1] 2-1 trees planted, total tree age is 23 years.

only difference of any magnitude occurred between the trees in the 5- by 5-foot spacing and those in the other three spacings. The same relation was exhibited at other heights above ground (table 1).

In a similar study, Wambach[2] (1967) investigated the relation between specific gravity and spacing in red pine plantations over a wide range of sites. He determined specific gravity from increment cores taken at 4.5 feet and produced an equation to predict specific gravity as a function of site index and number of trees per acre. Our estimate of specific gravity for 889 (7- by 7-foot), 538 (9- by 9-foot), and 360 (11- by 11-foot) trees per acre are close to his estimates (+ 1.3 to 1.8 percent). However, our estimate of specific gravity for 1,742 (5-by 5-foot) trees per acre deviates from his by +4.6 percent and equals his estimate of specific gravity for 1,600 trees per acre at site index 57.

We hypothesize that on good sites with narrow spacing, competition occurs early and diameter growth parallels that of plantations with fewer trees per acre but on poorer sites. If this is true, the mean stand diameter of 1,600 trees per acre, site index 57, should be approximately the same as our mean stand diameter. Because there is a 1- or 2-year difference in reaching 4.5 feet in height, the number of growth rings at 4.5 feet for 25-year-old trees, site index 57, should not differ by more than one from 23-year-old trees, site index 70. From Wambach,[2] the mean stand diameter for 25-year-old trees, site index 57, with 1,600 trees per acre is 4.3 inches, the same as our plantation with 1,742 trees per acre.

The combination of age, site index, and 5- by 5-foot spacing of our plantation is on the periphery of the 85 plantations in Wambach's data set. And, perhaps, his data set could not capture this trend. Although our estimate of specific gravity for very narrow spacing and good site differs from Wambach's, for practical purposes it is probably unimportant because this combination of site index and spacing represents a small percentage of existing plantations.

DISCUSSION

The spatial distribution of trees has a large effect on main stem diameter growth[2] and size of branches[3] but has little effect on the specific gravity of wood. Spacing of trees from 7 to 11 feet did not change specific gravity more than 2 percent and the closest spacing of 5 feet increased specific gravity about 5 percent. The use of narrow spacing in red pine plantations is not a practical method to increase specific gravity, and little concern should be given to small decreases in specific gravity of red pine at very wide spacings.

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[2] *Wambach, Robert F. 1967. A silvicultural and economic appraisal of initial spacing in red pine. 282 p. Ph.D. Thesis, University of Minnesota.*

[3] *Laidly, Paul R., and Robert G. Barse. 1979. Spacing affects knot surface in red pine plantations. U.S. Department of Agriculture Forest Service, Research Note NC-246, 3 p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.*

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FULL-TREE SKIDDING FAVORS BLACK SPRUCE REPRODUCTION UNDER CERTAIN PEATLAND CONDITIONS

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ABSTRACT.—Two trials on different sites indicate that clearcut black spruce reproduces well after full-tree skidding only on nonbrushy sites that have fairly abundant sphagnum seedbeds and adequate natural seeding.

OXFORD: 231.3:375.4:174.7(776) *Picea mariana*. KEY WORDS: *Picea mariana*, mechanized harvesting, site preparation, natural seeding, broadcast burning, Minnesota.

Because of increased mechanization, full-tree skidding has become a popular way to harvest black spruce (*Picea mariana* (Mill.) B. S. P.) on the extensive peatlands of north-central Minnesota. However, compared with broadcast burning, little is known about full-tree skidding as a method of site preparation for reproducing clearcut black spruce by natural seeding. Findings have been reported for only one trial 2 years after skidding (Johnston 1975), plus two other studies where piling of slash simulated full-tree skidding by keeping seedbeds exposed (Johnston 1971, Verry and Elling 1978). Further, this research was done only on **nonbrushy** sites that had **abundant** sphagnum moss (*Sphagnum* spp.)—a good seedbed. So even though actual or simulated skidding resulted in satisfactory reproduction under these conditions, no findings have been reported to guide forest managers dealing with other conditions.

However, 2-year results are now available from a trial of full-tree skidding on a **brushy** site that had **sparse** sphagnum seedbeds. And 7-year results are available from the previous skidding trial mentioned above. The overall results from these two trials indicate that at present full-tree skidding is reliable for reproducing black spruce only on nonbrushy sites that have fairly abundant sphagnum seedbeds and adequate natural seeding.

PROCEDURE

The trials were made in mature stands of black spruce on separate peatlands near Big Falls in north-central Minnesota.[1] The **brushy** site, which apparently receives nutrient-enriched soil water from an adjacent upland, represents good site quality for black spruce growing on organic soil. The stand was low density (at least partly because of wind-caused mortality), had trees such as balsam fir (*Abies balsamea* (L.) Mill.) and paper birch (*Betula papyrifera* Marsh.), tall shrubs such as speckled alder (*Alnus rugosa* (Du Roi) Spreng.), and sparse sphagnum seedbeds. The **nonbrushy** site, which represents medium site quality, had a dense stand of pure black spruce, no tall shrubs, and abundant sphagnum seedbeds.

Harvesting was done in winter when the ground was frozen. The brushy site was harvested the same way as the nonbrushy site (Johnston 1975): trees 2

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[1] *The cooperation of the Minnesota Department of Natural Resources, Division of Forestry, is gratefully acknowledged.*

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inches d.b.h. and larger were felled; those 3 inches d.b.h. and larger were pulled to a landing as whole trees by a rubber-tired skidder, and then processed. Felling and skidding were done with reasonable care to minimize breaking off branches and tops. The harvest averaged 16 and 26 cords of conifer pulpwood per acre on the brushy site and nonbrushy site, respectively.

Natural seeding was provided by a mature stand of black spruce that bordered the brushy site (230 by 730 feet) on the long, windward side and the nonbrushy site (330 by 530 feet) on three sides. Although the brushy site's seed source averaged only 40 square feet of basal area per acre for spruce trees more than 3.5 inches d.b.h., seeding was considered adequate because a similar site nearby with a similar seed source reproduced satisfactorily after broadcast burning. The brushy site was sampled the same way as the nonbrushy site (Johnston 1975): tree reproduction was counted on a ¼-milacre subplot in 100 well-distributed milacre plots 2 years after skidding; if black spruce was absent on the subplot, its presence was checked on the whole plot to determine milacre stocking. Also, seedbeds were recorded by cover class on the 100 ¼-milacre subplots to help explain reproduction results.

The nonbrushy site, which continued to receive natural seeding, was resampled 7 years after skidding to find out if the reproduction had changed substantially since 2 years after skidding. Data were obtained from the previously established 100 subplots and plots as described above. In addition, the height of the tallest black spruce and quaking aspen (*Populus tremuloides* Michx.) was measured on these subplots to determine to what extent spruce was overtopped by the aspen that seeded in.

RESULTS AND DISCUSSION

Black spruce seedlings averaged 800 per acre and 39 percent milacre stocking on the brushy site 2 years after full-tree skidding. These values are very low compared with the several thousand seedlings per acre and more than 80 or 90 percent stocking reported earlier for the nonbrushy site 2 years after skidding and for brushy and nonbrushy sites 2 to 4 years after broadcast burning (table 1). Probably the main reason black spruce reproduced poorly on the brushy site after skidding is because sphagnum moss, which usually remains moist after exposure, was sparse. Sphagnum seedbeds covered more than one-fourth of the ground on only 2 percent of the ¼-milacre subplots on the brushy site compared with 64 percent on the nonbrushy site.

Because little snow covered the brushy site during skidding, a substantial amount of scarified and compacted seedbeds resulted. At first it appeared these nonsphagnum seedbeds would compensate for the shortage of sphagnum seedbeds, but the results show they did not. A long dry period the first summer probably caused considerable seedling mortality, especially on these nonsphagnum seedbeds. However, initial establishment should have been good the second summer had sphagnum seedbeds been abundant.

Associated reproduction was composed mainly of quaking aspen and paper birch on the brushy site 2 years after full-tree skidding, as on the nonbrushy site. However, these two species plus black ash (*Fraxinus nigra* Marsh.) and balsam fir were considerably more abundant on the brushy site (table 2). Further, whereas all stems on the nonbrushy site were new seedlings and less than 2 feet tall, on the brushy site 39 percent of the birch and nearly all of the ash were

Table 1.—*Black spruce seedlings after full-tree skidding or broadcast burning on brushy and nonbrushy sites receiving natural seeding*[1]

Treatment	Site	Time after treatment	Seedlings[2]		Basis: areas sampled
			Stems per acre	Milacre stocking	
		Years	*Number*	*Percent*	*Number*
Full-tree skidding	Brushy	2	800	39	1
	Nonbrushy	2	22,600	92	1
		7	22,800	96	
Broadcast burning	Brushy	2-3	8,100	84	2
	Nonbrushy	2-4	17,600	98	2

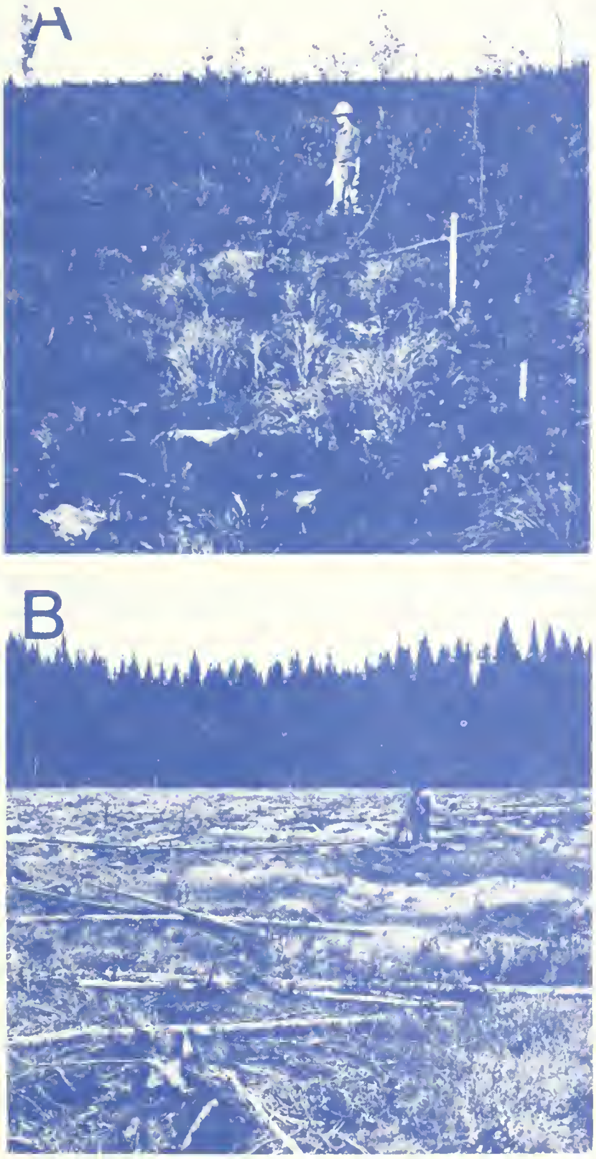
[1] Values in second row from Johnston 1975; those in last two rows adapted from Johnston 1971.

[2] Advance growth almost nil, so excluded.

Table 2.—*Associated reproduction after full-tree skidding on the brushy site and nonbrushy site*

Site	Time after treatment	Species			
		Quaking aspen	Paper birch	Black ash	Balsam fir
	Years	*Number of stems per acre*			
Brushy	2	17,900	6,600	900	700
Nonbrushy	2	4,900	800	0	<100
	7	4,300	5,400	0	200

sprouts, 58 percent of the fir were advance seedlings, and 1,100 stems per acre— mainly birch—were 2 to 7 feet tall. Finally, other vegetation such as grasses, sedges, and shrubs was much denser on the brushy site than nonbrushy site 2 years after skidding (fig. 1, A and B).



Thus black spruce seedlings were not only relatively scarce on the brushy site 2 years after full-tree skidding, but they also had much more vegetation to compete with than on the nonbrushy site. In addition, this vegetation produced a large amount of leaf litter—a poor seedbed. Leaf litter seedbeds covered more than one-fourth of the ground on about 80 percent of the ¼-milacre subplots on the brushy site compared with only 1 percent on the nonbrushy site. So even with continued natural seeding, satisfactory reproduction of black spruce—at least 60 percent milacre stocking of **established** seedlings (Johnston 1977)—either will not be obtained on the brushy site or will require several more years.

Black spruce reproduction on the nonbrushy site 7 years after full-tree skidding was almost identical to that reported earlier for 2 years—about 23,000 seedlings per acre and more than 90 percent milacre stocking (table 1). The number of quaking aspen and balsam fir seedlings also changed little, whereas paper birch seedlings were much more abundant at 7

Figure 1.—*Trial areas after full-tree skidding: brushy site at 2 years (A), nonbrushy site at 2 years (B) and 7 years (C).*

years than at 2 years (table 2). Although birch may have increased some from further seeding, most stems were likely present at 2 years but too small to be readily identified. Practically no more reproduction became established on the nonbrushy site despite 5 more years of natural seeding because the high number of black spruce and associated seedlings 2 years after skidding probably already occupied the good seedbeds.

The tallest black spruces on the nonbrushy site 7 years after skidding averaged less than half the height of the tallest quaking aspens—2.4 vs. 5.2 feet. However, spruce was generally growing well and many stems were not overtopped by aspen or birch (fig. 1, C). Thus release probably will not increase the growth of black spruce much on this medium quality site, but a trial is under way.

MANAGEMENT IMPLICATIONS

Sound information is still limited on using full-tree skidding as a method of site preparation for reproducing clearcut black spruce by natural seeding. However, research and experience to date indicate that spruce seedlings will have the following relative stocking about 5 years after skidding under the peatland conditions shown:

	Sphagnum seedbeds	
Site	**Abundant**	**Sparse**
Nonbrushy	Good to overstocked	Understocked to poor
Brushy	Poor to moderate	Understocked to poor

The two trials reported in this note represent two of the conditions in the above tabulation. The nonbrushy site with abundant sphagnum had good seedbeds plus little competing vegetation, and so was overstocked—more than 10,000 spruce seedlings per acre (Johnston 1977). In contrast, the brushy site with sparse sphagnum had poor seedbeds plus much competing vegetation, and so was understocked—less than 60 percent milacre stocking.

Full-tree skidding has not been tried under the other two conditions in the preceding tabulation. Nevertheless, brushy sites with abundant sphagnum should have ample black spruce seedlings initially because of good seedbeds, but much competing vegetation is expected. So unless these seedlings are released, their stocking will likely be poor to moderate after a few years. Full-tree skidding on nonbrushy sites with sparse sphagnum probably will result in poor stocking at best. This is because other mosses, particularly the feather mosses, usually dry up after clearcutting and become poor seedbeds (Johnston 1971, 1977).

Therefore, until further information is available, full-tree skidding is recommended for reproducing black spruce only on nonbrushy sites that have fairly abundant sphagnum seedbeds and adequate natural seeding. Exposed patches of sphagnum should have a milacre stocking of 60 percent or more, and seed should be provided by a mature spruce stand within 130 to 260 feet of the skidded area (Johnston 1977).

Broadcast burning of slash is still recommended for most other peatland conditions (Johnston 1977). In fact, severe burning is the only reliable practice at present to initially control competing vegetation on brushy sites and to improve nonsphagnum seedbeds. However, the popularity of full-tree skidding black spruce means few loggers are any longer willing to remove just the pulpwood and leave the slash evenly distributed for burning. Hence alternative practices such as planting or mechanical preparation of seedbeds need to be developed for those conditions where skidding alone will not result in satisfactory reproduction.

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THE INFLUENCE OF CONTAINER TYPE AND POTTING MEDIUM ON GROWTH OF BLACK WALNUT SEEDLINGS

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ABSTRACT.—Container size and shape, potting medium, and genotype interacted to influence the growth of black walnut (*Juglans nigra* L.) seedlings. Larger containers tended to produce larger trees. In tall, narrow, vent-pipe containers, different proportions of peat and sand in potting media had no effect on total weight; a higher proportion of peat than of very fine sand in the potting media reduced the shoot/root ratio. In conventionally shaped pots, seedlings averaged 123 percent heavier when grown in a soil mix containing 75 percent peat and 25 percent sand than when grown in pure sand.

KEY WORDS: *Juglans nigra*, peat, sand, genotype, planting.

Continuing interest in intensive culture of black walnut (*Juglans nigra* L.) has prompted us to study techniques of growing black walnut seedlings in containers, not only for use as experimental plants, but also as trees potentially suitable for bench grafting or field planting in seed orchards or in special forest situations such as dry sites. We describe here the effects of pot volume, pot shape, and media containing different proportions of peat and sand on growth of black walnut seedlings raised from seed of 2 parent trees (Celmer 1970).

MATERIALS AND METHODS

Seed was collected from 2 southern Illinois parent trees, one each in Jackson and Randolph Counties, cleaned and stratified in polyethylene bags for 6 months at 2C, germinated in peat-filled flats, and transplanted to pots in early June.

Seedlings were grown in 6 container types, including all combinations of 3 volumes and 2 shapes, as follows:

Code	Approximate volume cm^3	Conventional shape	Cylindrical shape	Code
L	10,350	10-inch tarpaper pot	6 × 24-inch galvanized vent pipe	LL
M	3,450	8-inch plastic pot	4 × 24-inch galvanized vent pine	ML
S	1,150	5-inch plastic pot	1 quart milk carton	SL

The texture of the inner surface of pots may influence root development (Boden *et al.* 1969, Harris 1968) so the tarpaper pots were lined with 4-mil polyethylene to provide a smooth inner surface similar to plastic containers; holes were punched to allow drainage.

The media contained 4 proportions of very fine sand and shredded Canadian sphagnum peat as prescribed by Matkin and Chandler (1957): A—100 percent very fine sand; B—75 percent sand, 25 percent peat; C—50 percent sand, 50 percent peat; D—25 percent sand, 75 percent peat. At the time of mixing, 3.6 kg of dolomitic lime, 1.8 kg of 45 percent superphosphate, 0.3 kg of $MgSO_4$ and 37 g of fritted trace elements were incorporated in each m^3 of soil mix. Liquid 20-20-20 fertilizer was added weekly during the growing season and all pots were thoroughly watered 2 or 3 times each week. The seedlings were grown under 55 percent shade screens in a greenhouse with cooling that usually held day temperatures at a level not exceeding outdoor temperatures by more than 3C.

Treatments were replicated 3 times in a randomized complete block design. The containers were spaced sufficiently far apart to avoid crowding or shading of short pots by taller ones. After 6 weeks the blocks were interchanged and pots randomly rearranged within each block to reduce variation related to location in the greenhouse.

After 12 weeks, when the seedlings had dropped nearly all their leaves, total height of each seedling was measured to the nearest 0.5 cm and the plants were removed from the pots. Roots were washed free of potting medium and severed at the root collar. Shoots and roots were dried in an oven for 5 days at 48-50C, and weighed to the nearest 0.1 g.

Height, total weight, and shoot and root weights were analyzed following a conventional 3-way analysis of variance format (Celmer 1970).

RESULTS

The black walnut seedlings responded to all the pot type, soil mix and genotype treatments (table 1). Seedlings from the Randolph County parent (fig. 1) grew taller than did those from the Jackson County parent in all pot types and in all soil mixes. Genetic growth differences were most pronounced in the 2 smaller pot sizes in which the Randolph County trees were not only taller but also averaged more than 40 percent heavier (table 2). The taller Randolph County seedlings probably represent a seed-size effect; the nuts were about 1.7 times as large as those from Jackson County.

The Randolph County seedlings weighed slightly less than those from Jackson County, especially in the 6-inch vent-pipe containers (LL) (table 2). The Randolph County trees tended to be heavier with increasing peat content of the potting medium in the L, M, and ML pots. These trends may be related to differences in root form between the 2 seedling families in that 15 percent of the Jackson County seedlings were found to have developed multiple taproots

Table 1.—*Significance of pot type, soil mix, genotype, and interaction of these treatments on growth of black walnut seedlings as determined by analysis of variance*

Source of variation	Dependent variable			
	Height	Dry weight		
		Tops	Roots	Total
	cm	----------	*grams*	----------
Pot type (P)	**[1]	**	**	**
Soil mix (S)	**	**	**	**
Genotype (G)	**	NS[2]	NS	NS
PS	**	**	**	**
PG	NS	NS	**	**
SG	NS	NS	NS	NS
PSG	**	**	**	**

[1] Significant at the 1 percent level.

[2] NS = nonsignificant.

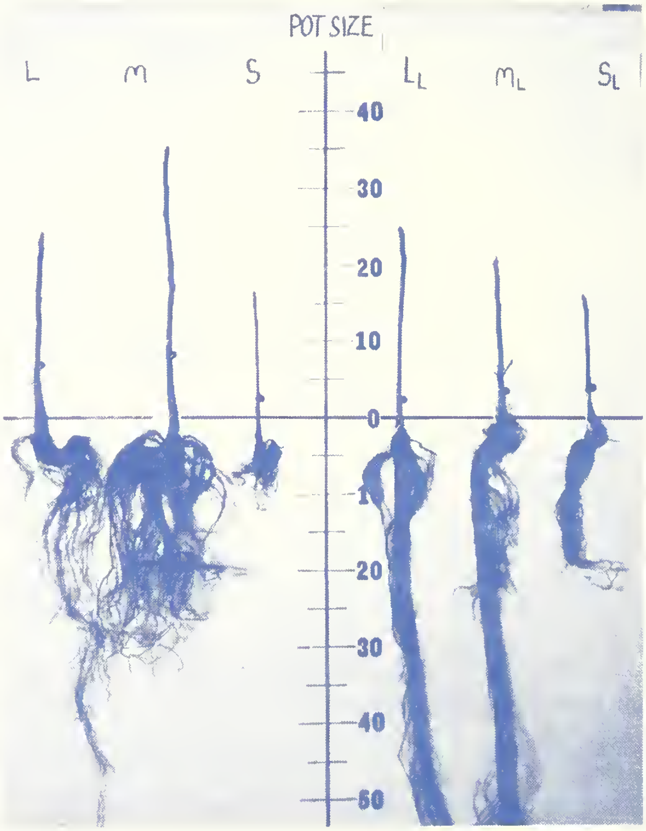

Figure 1.—*Walnut seedling height (cm) in relation to container size and shape, soil mix C. Seedlings from Randolph County tree.*

Table 2.—*Ovendry weight of black walnut seedlings (grams) grown in different containers and media*[1]

Pot	Jackson County seed tree				Randolph County seed tree				Mean
	Soil mix				Soil mix				
type	A	B	C	D	A	B	C	D	
L	6.6	3.4	18.1	28.2	2.5	3.7	16.6	32.7	14.0
M	22.6	18.5	20.7	30.4	17.7	17.9	26.1	32.8	23.3
S	7.6	6.6	9.3	14.0	11.4	8.6	12.9	14.4	10.6
LL	37.4	30.7	34.9	34.1	22.6	21.1	19.1	27.6	28.4
ML	14.3	21.0	16.6	14.9	12.9	13.0	23.0	17.0	16.6
SL	8.5	1.4	4.5	6.3	4.9	13.4	9.2	7.4	7.0
Mean	16.2	13.6	17.3	21.3	12.0	12.9	17.8	22.0	16.7

[1] Standard error of difference values: between any 2 individual treatment combinations—16.1 g; between any 2 pot-type means—5.7 g; between any 2 soil mix means—6.6 g.

while all but 2 percent of those grown from Randolph County seed possessed the single heavy taproot typical of most black walnut seedlings. These differences were not apparent at the time of transplanting. It may be that seedlings with multiple taproots are better adapted to growing in potting media with relatively high sand content.

Pot type and soil mix influenced seedling height and weight, jointly as well as separately. The trend toward larger plants in larger pots was obvious, except in the large tarpaper (L) pots (table 2). This deviation was not anticipated, because in a previous study (Funk 1971) mean weights of black walnut seedlings were nearly the same for plants grown in L and LL pots in soil mixes B and C (mixes A and D were not tested). The tarpaper pots (L) used in the earlier study were not lined with polyethylene, and we hypothesize that in this study growth was much poorer in the soil mixes with greater sand content because aeration was insufficient (Long 1932). A similar pattern of heavier seedlings associated with greater peat content is apparent for all 3 sizes of conventionally shaped pots but potting media had no influence on weights of plants in the cylindrical containers (fig. 2).

Occasional small seedlings had unusually high shoot/root ratios and, when these ratios were averaged for treatment means, some extreme values appeared. Thus, it was more realistic to sum the shoot and root weights for the seedlings in the 3 replications of each treatment and then calculate ratios based on these sums; the 2 seedling families were also pooled (table 3) because there was little difference between their ratios. These ratios of sums are no longer additive and the suitability of analysis of variance is thus limited.

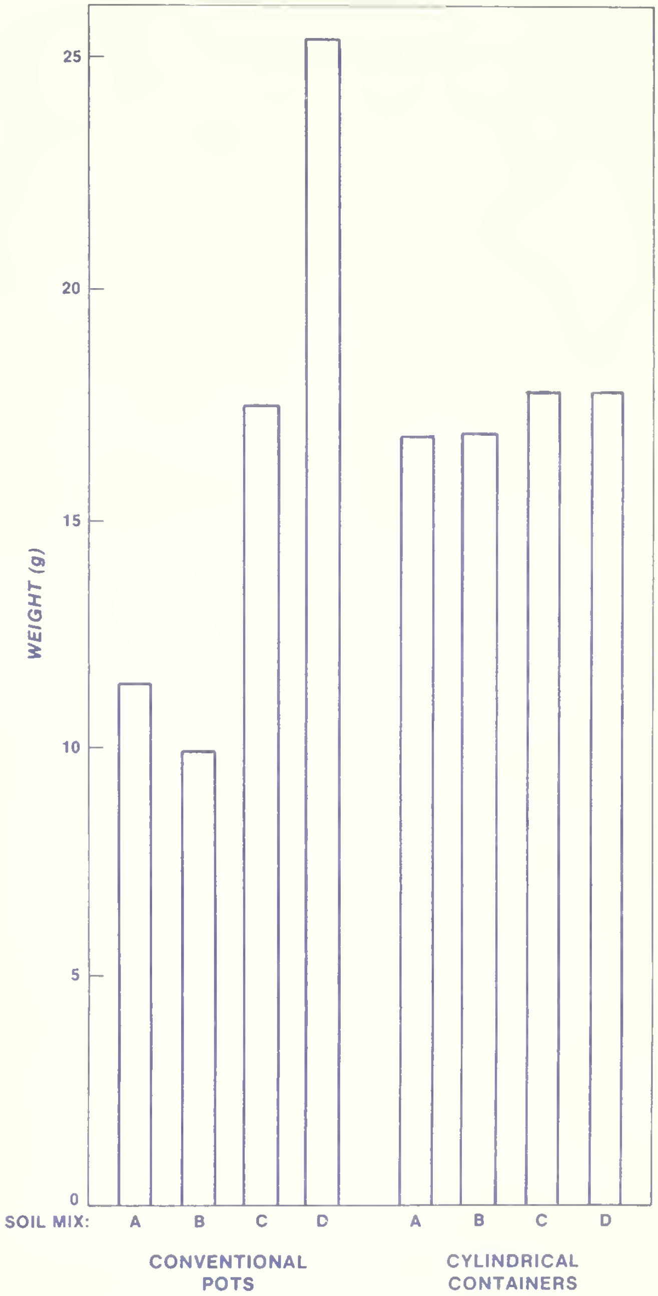

Figure 2.—*Weight of black walnut seedlings in relation to soil mix and container shape (3 container sizes and 2 genotypes pooled).*

DISCUSSION

Heavier seedlings generally had lower shoot/root ratios (tables 2 and 3); the correlation between shoot/root ratio and total weight was –.69. Other workers have suggested that the shoot/root ratio varies with plant weight, although not necessarily in the same fashion for herbs, conifers, and broad-leaved trees (Jones 1968, Ledig and Perry 1966). Farmer

Table 3.—*Shoot/root ratio (dry weight basis) of black walnut seedlings grown in different containers and media*

Container type	**Soil mix**				
	A	**B**	**C**	**D**	**Mean[1]**
L	0.251	0.250	0.163	0.127	0.155
M	.158	.137	.184	.150	.157
S	.245	.246	.172	.175	.202
LL	.145	.148	.108	.112	.128
ML	.150	.137	.128	.117	.132
SL	.297	.227	.324	.165	.248
Mean	.175	.163	.156	.135	.154

[1] Mean ratios were calculated from shoot and root sums for each treatment, not by averaging ratios in the body of the table.

(1970), studying larger plants of eastern cottonwood (*Populus deltoides* Bartr.) grown in loam with 2 soil moisture regimes, found that shoot/root ratio was related to plant weight. In a favorable soil moisture situation the correlation between plant weight and shoot/root ratio was negative while in a stressful situation the correlation was positive.

In an earlier pot study with black walnut seedlings, Funk (1971) proposed that changes in shoot/root ratio are not necessarily related to total plant weight, so we looked for sets of treatments in which total plant weight was relatively constant to see if any ratio differences were evident. Apparently total weight of walnut seedlings is not much affected by soil mix in cylindrical containers (fig. 2). Considering the 2 genotypes together, weight is especially stable in vent-pipe containers (LL and ML) (table 2). But shoot/root ratio of seedlings grown in soil mix D in vent pipes is about 29 percent lower than for those grown in the soil mix A (table 3). Acknowledging that analysis of variance of these ratios is not completely appropriate, we made such an analysis based on the 4 soil mixes, 2 sizes of vent pipes, and 2 seedling families. The effect of soil mix on shoot/root ratio was significant; a subsequent covariance analysis determined that the effect was not related to differences in total weight.

In the vent-pipe containers the proportions of peat and sand in the potting media influences shoot/root ratio of seedlings, and this effect was independent of weight. But we doubt that any of these soil mixes (except perhaps mix A, 100 percent sand) constituted "drastic treatments" (Ledig and Perry 1966) although Farmer (1970) suggests that the stress regime that led to a positive correlation between shoot/root ratio and weight of cottonwood seedlings could be considered as drastic.

Soil mix D produced relatively heavy and well balanced seedlings for most pot-type and genotype combinations, but it is also relatively expensive because of its high proportion of peat. It is not commonly used for growing container stock, but has excellent aeration and moisture-holding properties and has been suggested for pots and beds (Matkin and Chandler 1957). Our results suggest that media containing high proportions of peat or perhaps other organic materials (Klett *et al.* 1972) are desirable for growing walnut seedling in conventional pots and should be considered for producing planting stock in nursery beds. Peat-sand proportions of potting media should be less important when seedlings are grown in tall, narrow containers, unless field studies indicate that differences in shoot/root ratio are related to plantation performance.

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1980

SOIL PROPERTIES RELATED TO CONIFEROUS SEEDLING HEIGHT GROWTH IN NORTHERN WISCONSIN[1]

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ABSTRACT.—Soil properties (organic matter content, pH, texture, and microclimate) were related to early height growth of jack pine (*Pinus banksiana,* Lamb.), red pine (*Pinus resinosa,* Ait.), white spruce (*Picea glauca,* (Moench) Voss), and hybrid larch (*Larix leptolepis* x *Larix decidua*) planted in northern Wisconsin. Based on 2-year height growth, jack pine and hybrid larch performed best on these silty soils.

KEY WORDS: Organic matter, soil pH, jack pine, red pine, white spruce, hybrid larch.

Seedling early growth and survival are important aspects of forest management to ensure a quick economic return to the landowner. The optimization of tree growth by matching tree species to the most suitable soil is one management technique that shows promise in achieving that goal. Yet in order to do this, a clear understanding of the most influential soil factors is essential.

The importance and need for soil evaluation in relation to timber production has been emphasized in many reports. Stevens and Wertz (1971) estimated that the Nicolet area of Wisconsin has the potential for a 60 percent increase in sawtimber production by matching species to the soils. Therefore, we tested jack pine, red pine, white spruce, and hybrid larch in this area of northern Wisconsin to determine which soil properties were best related to early height growth of seedlings.

METHODS

The experimental site is on the Nicolet National Forest in northern Wisconsin. The soil is Padus silt loam, an Alfic Haplorthod, of the coarse-loamy, mixed, frigid family, and consists of well-drained loamy sediments over sands and gravels on outwash plains, terraces, and pitted outwash.

The 1.0-ha site was cleared and disked in 1974 and hand planted with containerized seedlings in August, 1974. The site was divided into four blocks so each species occupied its own 0.25-ha block. Each species block (0.25 ha) contains 4 replications in a

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[1] *A research study performed in cooperation with the Rhinelander Forestry Sciences Laboratory, USDA Forest Service, North Central Forest Experiment Station, and the University of Wisconsin, Stevens Point, under Cooperative Agreement No. 13-544.*

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randomized complete block design with 16 plots in each replication and 16 seedlings planted in each plot at a 2 meter spacing. In the fall of 1976, soil samples were extracted from the surface 15 centimeters (6 inches) of 60 randomly selected plots—17 from jack pine, 13 from red pine, 16 from hybrid larch, and 14 from white spruce. The average plot height growth was determined from those surviving from the original 16 seedlings planted in the plot.

Soil organic matter content was determined by the Walkley-Black method (Black 1965), soil texture by hydrometer, soil pH by potentiometer, and soil buffering with SMP buffer and potentiometer (Shoemaker *et al.*1961). Soil data were then regressed with normalized height growth data.

It was hypothesized that microrelief variations could have affected seedling performance. To test for this, the site was stratified into high and low microsites for all species except larch, and an analysis of variance test was run on soil and growth data.

RESULTS AND DISCUSSION

Higher soil organic matter was related to increased growth of jack pine, but not the other three species (fig. 1). This may suggest a greater growth potential for jack pine on soils with more organic matter. If a site is to be prepared for jack pine, methods that incorporate surface organic layers may be more desirable. The other three species grew well over the range of organic matter contents and may be advantageous for planting on soils whose surface organic layers have been depleted or completely removed.

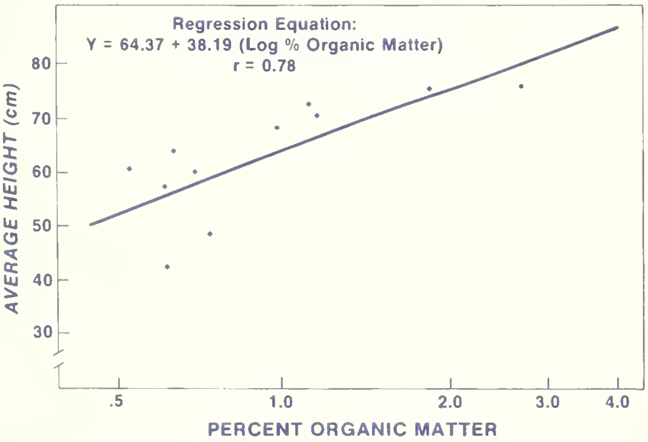

Figure 1.—*Relation of amount of soil organic matter to jack pine height growth.*

Soil pH was significantly negatively correlated to red pine and white spruce growth (fig. 2). Both species grew better in the strongly acid (pH = 5.1 – 5.5) range. Jack pine and hybrid larch grew well over the range of pH's from 5.0 to 6.0.

White spruce and jack pine grew better on the coarser soil textures (fig. 3). Hybrid larch, however, grew better on the finer textures of the site (fig. 4). Other soil textural effects, such as surface runoff, soil compaction, infiltration, frost heaving, and aeration may have also had some effect on seedling growth.

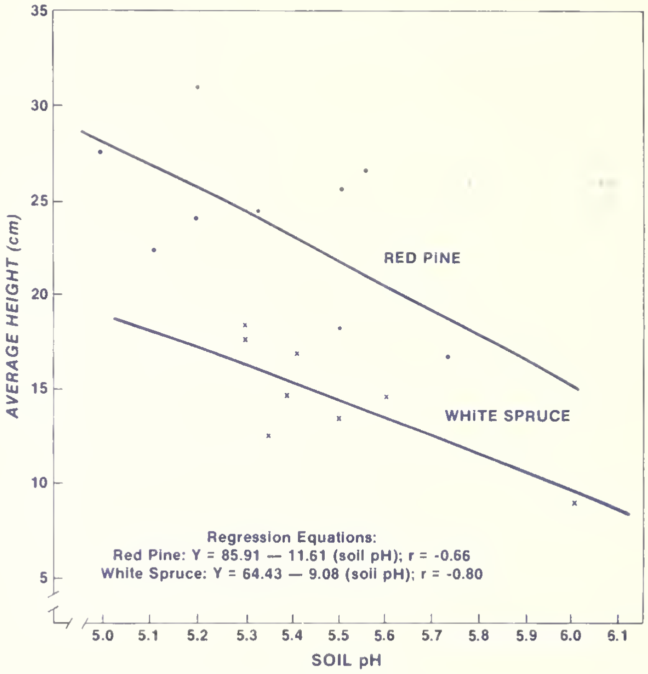

Figure 2.—*Relation of soil pH to red pine and white spruce height growth.*

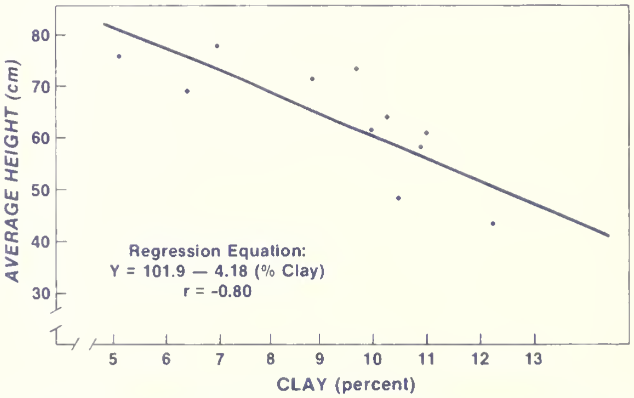

Figure 3.—*Relation of amount of clay in soil to jack pine height growth.*

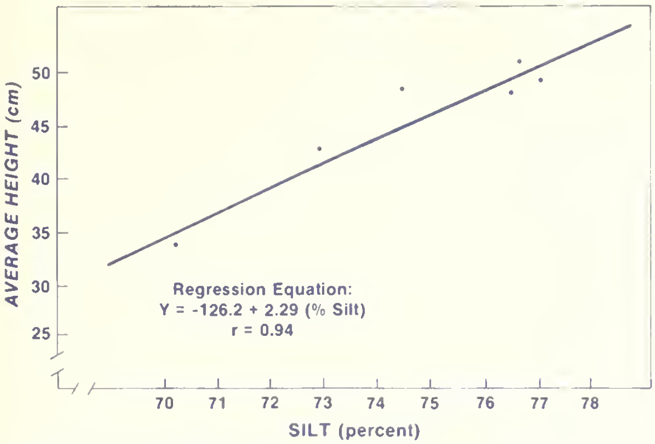

Figure 4.—*Relation of amount of silt in soil to larch height growth.*

Height growth was significantly different between high and low microsites for jack and red pine. This might imply that microclimate differences, such as humidity, radiation, or temperature may have affected seedling growth. However, because soil properties were also significantly different, no specific conclusion could be drawn.

Jack pine and hybrid larch have better early growth and survival on these soils than red pine and white spruce. From the soil and growth relations, hybrid larch growth was not related to organic matter and had better growth in the loamier textures of the site. Jack pine was related positively to organic matter and negatively to percent clay, but nevertheless, good growth and survival were apparent.

Recent research has shown that red pine eventually outproduces jack pine on similar soils throughout the Lake States due to its greater basal area (Alban 1978). However, another recent study has shown great potential for intensively cultured jack pine (Zavitkovski and Dawson 1978). In this study, jack pine biomass production was two to several times higher in intensively cultured silvicultural systems than in jack pine plantations grown under traditional silvicultural systems.

Site preparation methods appeared to cause considerable soil variation between plots. An evaluation of soil variation and stratification prior to planting may be advantageous in future tree planting experiments. By doing this, the experimental design could be adapted to anticipated growth differences.

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MINNESOTA LAND OWNERSHIP TRENDS, 1962-1977

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ABSTRACT.—The distribution of Minnesota's commercial forest land among ownership classes has remained stable between 1962 and 1977. This note summarizes commercial forest ownership data by Forest Survey Unit for 1962 and 1977 and presents more detailed area statistics for Minnesota's 17 northern counties.

KEY WORDS: commercial forest area, commercial forest ownership.

Although the area of commercial forest land in Minnesota declined 11 percent between 1962[1] and 1977, the distribution of the land among ownership classes remained stable. In 1977, 54 percent of the State's commercial forest land was publicly owned; 46 percent was privately owned. 1962 area statistics showed the same distribution.

The largest public owner of commercial forest land in 1977 was the State of Minnesota, with 2.7 million acres. Commercial forest land in State ownership decreased 34.7 thousand acres between 1962 and 1977. This decrease is the result of the State acquiring less commercial forest land than it lost through sales, expansion of the Boundary Waters Canoe Area (BWCA), creation of the Voyageurs National Park, and transfers to State Parks. The only ownership class to show an increase in commercial forest area was forest industry; forest industry commercial forest land holdings increased from 715.7 thousand acres in 1962 to 772.0 thousand acres in 1977.

All other ownership classes showed a decline in commercial forest area. The farmer and miscellaneous private ownership class lost the most acreage, 915.0 thousand acres, but national forests showed the largest percent decline, 20 percent. Most of the decline in national forest ownership is the result of commercial forest land in the Superior National Forest being transferred to the BWCA, where it is classified as productive-reserved.

Eighty-two percent of Minnesota's commercial forest land is located in the 17 northern counties that make up the Aspen-Birch and Northern Pine Forest Survey Units (fig. 1). Commercial forests account for 57 percent of the total land area in northern Minnesota. The 11.2 million acres of commercial forest land reported here in 1977 was 1.1 million acres less than that found in 1962. St. Louis County, the largest county in the region, accounted for the largest portion of the loss. Most of the decline in commercial forest land in St. Louis County was due to the expansion of the BWCA.

The majority of commercial forest land in the region is publicly owned. State and county and municipal ownership classes equally control approximately 41 percent of the commercial forest land in the region (4.6 million acres). The Superior and Chippewa National Forests contain 1.7 million acres of commercial

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[1] *Previously published 1962 statistics have been adjusted to be comparable with 1977 data. Adjustments were necessary because Survey Unit boundaries changed between surveys. Further adjustments were required because definitions have changed between surveys and survey procedures have improved. Improvements in survey procedures include better ground control during the selection of sample points from aerial photos and improved methods for determining unproductive forest land.*

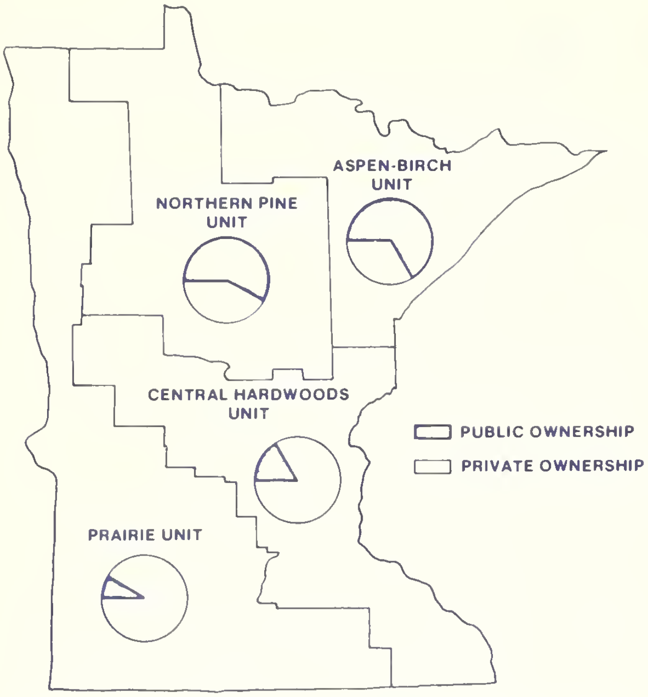

Figure 1.— *Percent of commercial forest area in public ownership by Forest Survey Unit, Minnesota, 1977.*

forest land, concentrated in six counties— St. Louis, Lake, Cook, Itasca, Cass, and Beltrami. The area of commercial forest land in the national forests declined in every county between 1962 and 1977 with the exception of Beltrami County. St. Louis and Lake Counties showed the largest decline in national forest area (161.7 thousand acres and 143.0 thousand acres, respectively). The Bureau of Indian Affairs, Bureau of Land Management, Fish and Wildlife Service, and other federal agencies administer the remaining 587.5 thousand acres of publicly owned land in the region.

Farmer and miscellaneous private owners control 3.5 million acres of commercial forest land in the region, 31 percent of the total. In northern Minnesota, commercial forest land accounts for 45 percent of the total land in this ownership category. Farmer and miscellaneous private commercial forest land declined 380.9 thousand acres between 1962 and 1977.

Forest industries own commercial forest land in most counties in the region, the exceptions being Mahnomen and Roseau Counties. Ninety-five per-

Table 1.— *Area of commercial forest land[1] by Survey Unit and ownership classes, Minnesota, 1962 and 1977*
(In thousand acres)

ASPEN-BIRCH

Year	All owners	National forest[2]	Other federal[3]	State[4]	County and municipal[5]	Forest industry[6]	Farmer and misc. private[7]
1977	5,451.4	1,152.8	126.3	1,132.1	1,185.9	534.7	1,319.6
1962	6,244.0	1,572.3	158.7	1,190.1	1,289.3	549.5	1,484.1
Change	(–)792.6	(–)419.5	(–)32.4	(–)58.0	(–)103.4	(–)14.8	(–)164.5
NORTHERN PINE UNIT							
1977	5,758.4	562.3	461.2	1,228.7	1,096.7	233.8	2,175.7
1962	6,025.0	569.7	457.9	1,208.4	1,233.6	163.3	2,392.1
Change	(–)266.6	(–)7.4	(+)3.3	(+)20.3	(–)136.9	(+)70.5	(–)216.4
CENTRAL HARDWOODS UNIT							
1977	1,951.1	—	24.7	244.7	59.0	0.5	1,622.2
1962	2,360.3	—	45.2	241.5	134.2	2.9	1,936.5
Change	(–)409.2	—	(–)20.5	(+) 3.2	(–)75.2	(–)2.4	(–)314.3
PRAIRIE UNIT							
1977	534.2	—	9.1	45.0	—	3.0	477.1
1962	782.5	—	14.3	45.2	26.1	—	696.9
Change	(–)248.3	—	(–)5.2	(–)0.2	(–)26.1	(+)3.0	(–)219.8
ALL UNITS							
1977	13,695.1	1,715.1	621.3	2,650.5	2,341.6	772.0	5,594.6
1962	15,411.8	2,142.0	676.1	2,685.2	2,683.2	715.7	6,509.6
Change	(–)1,716.7	(–)426.9	(–)54.8	(–)34.7	(–)341.6	(+)56.3	(–)915.0

[1] Forest land that is producing or is capable of producing crops of industrial wood and that is not withdrawn from timber utilization by statute or administrative regulation

[2] Federal land that has been designated by executive order or statute as national forest or purchase units, and other land under the administration of the USDA Forest Service

[3] Federal lands other than national forests.

[4] Land owned by states, or land leased by them for more than 50 years

[5] Land owned by counties, or local public agencies, or land leased by them for more than 50 years

[6] Land owned by companies or individuals operating primary wood-using plants

[7] Land privately owned by other than forest industry

Table 2.— *Area of commercial forest land*[1] *by county and ownership, seventeen northern counties, Minnesota, 1962 and 1977*
(In thousand acres)

County and year	All owners	National forest [2]	Other public [3]	Forest industry[4]	Farmer and misc. private[5]
Aitkin					
1977	672.5	—	405.7	4.2	262.6
1962	687.5	—	414.4	3.0	270.1
Change	(–)15.0	—	(–)8.7	(+)1.2	(–)7.5
Becker					
1977	313.9	—	128.0	2.6	183.3
1962	326.1	—	138.3	9.8	178.0
Change	(–)12.2	—	(–)10.3	(–)7.2	(+)5.3
Beltrami					
1977	794.6	54.7	556.5	2.5	180.9
1962	833.3	54.4	569.5	6.4	203.0
Change	(–)38.7	(+)0.3	(–)13.0	(–)3.9	(–)22.1
Carlton					
1977	312.8	—	109.1	27.1	176.6
1962	336.2	—	140.7	10.9	184.6
Change	(–)23.4	—	(–)31.6	(+)16.2	(–)8.0
Cass					
1977	858.6	242.7	343.5	28.1	244.3
1962	909.9	249.6	356.6	24.5	279.2
Change	(–)51.3	(–)6.9	(–)13.1	(+)3.6	(–)34.9
Clearwater					
1977	301.7	—	146.2	5.5	150.0
1962	322.5	—	165.7	5.6	151.2
Change	(–)20.8	—	(–)19.5	(–)0.1	(–)1.2
Cook					
1977	538.8	335.9	112.2	37.7	53.0
1962	685.7	449.3	129.6	48.5	58.3
Change	(–)146.9	(–)113.4	(–)17.4	(–)10.8	(–)5.3
Crow Wing					
1977	371.9	—	91.2	18.3	262.4
1962	375.7	—	96.8	17.9	261.0
Change	(–)3.8	—	(–)5.6	(+)0.4	(+)1.4
Hubbard					
1977	398.0	—	194.2	20.9	182.9
1962	405.2	—	202.0	22.0	181.2
Change	(–)7.2	—	(–)7.8	(–)1.1	(+)1.7
Itasca					
1977	1,281.0	264.9	471.0	131.3	413.8
1962	1,319.3	265.7	546.9	55.3	451.4
Change	(–)38.3	(–)0.8	(–)75.9	(+)76.0	(–)37.6
Koochiching					
1977	1,278.9	—	913.8	227.6	137.5
1962	1,341.4	1.4	980.7	204.0	155.3
Change	(–)62.5	(–)1.4	(–)66.9	(+)23.6	(–)17.8
Lake					
1977	855.3	370.6	250.1	97.5	137.1
1962	1,018.2	513.6	240.6	126.0	138.0
Change	(–)162.9	(–)143.0	(+)9.5	(–)28.5	(–)0.9
Lake of the Woods					
1977	360.6	—	272.3	1.6	86.7
1962	380.9	—	243.8	4.7	132.4
Change	(–)20.3	—	(+)28.5	(–)3.1	(–)45.7
Mahnomen					
1977	106.4	—	54.2	—	52.2
1962	126.6	—	61.6	0.4	64.6
Change	(–)20.2	—	(–)7.4	(–)0.4	(–)12.4
Roseau					
1977	191.9	—	106.6	—	85.3
1962	229.2	—	85.1	0.4	143.7
Change	(–)37.3	—	(+)21.5	(–)0.4	(–)58.4
St. Louis					
1977	2,465.6	446.3	1,059.1	144.8	815.4
1962	2,862.5	608.0	1,146.5	160.1	947.9
Change	(–)396.9	(–)161.7	(–)87.4	(–)15.3	(–)132.5
Wadena					
1977	107.3	—	17.2	18.8	71.3
1962	108.8	—	19.2	13.3	76.3
Change	(–)1.5	—	(–)2.0	(+)5.5	(–)5.0
Total					
1977	11,209.8	1,715.1	5,230.9	768.5	3,495.3
1962	12,269.0	2,142.0	5,538.0	712.8	3,876.2
Change	(–)1,059.2	(–)426.9	(–)307.1	(+)55.7	(–)380.9
Percent					
1977	100.0	15.3	46.7	6.8	31.2
1962	100.0	17.5	45.1	5.8	31.6

[1] Forest land that is producing or is capable of producing crops of industrial wood and that is not withdrawn from timber utilization by statute or administrative regulation.

[2] Federal land that has been designated by executive order or statute as national forest or purchase units, and other land under administration of the USDA Forest Service.

[3] Public land other than national forest land, including land administered by federal, state, or local public agencies.

[4] Land owned by companies or individuals operating primary wood-using plants.

[5] Land privately owned by other than forest industry.

cent of forest industry land is classified as commercial forest. Forest industries were the only ownership class in the region to show an increase in commercial forest land between 1962 and 1977. The increase was especially notable in Itasca County.

The sampling error for commercial forest areas from this survey is less than 1.5 percent (at one standard deviation) per million acres.

Table 3.—*Total land areas*[1] *by county and ownership, seventeen northern counties, Minnesota, 1962*[2] *and 1977*[3]
(In thousand acres)

County and year	All owners	National forest[4]	Other public[5]	Forest industry[6]	Farmer and misc. private[7]
Aitkin					
1977	1,169.7	—	632.6	5.8	531.3
1962	1,167.4	—	723.3	4.4	439.7
Change	(+)2.3	—	(–)90.7	(+)1.4	(+)91.6
Becker					
1977	830.0	—	169.2	2.6	658.2
1962	841.6	—	180.0	10.2	651.4
Change	(–)11.6	—	(+)10.8	(–)7.6	(+)6.8
Beltrami					
1977	1,604.2	61.6	1,032.3	3.0	507.3
1962	1,610.9	59.7	1,065.7	7.5	478.0
Change	(–)6.7	(+)1.9	(–)33.4	(–)4.5	(+)29.3
Carlton					
1977	551.8	—	157.2	28.8	365.8
1962	550.4	—	201.5	12.0	336.9
Change	(+)1.4	—	(–)44.3	(+)16.8	(+)28.9
Cass					
1977	1,278.8	285.3	476.9	28.1	488.5
1962	1,313.9	281.7	492.1	28.7	511.4
Change	(–)35.1	(+)3.6	(–)15.2	(–)0.6	(–)22.9
Clearwater					
1977	639.9	—	279.2	5.5	355.2
1962	643.2	—	291.2	7.4	344.6
Change	(–)3.3	—	(–)12.0	(–)1.9	(+)10.6
Cook					
1977	861.4	630.4	127.0	37.8	66.2
1962	897.9	630.0	183.7	48.6	35.6
Change	(–)36.5	(+).4	(–)56.7	(–)10.8	(+)30.6
Crow Wing					
1977	636.5	—	126.2	20.7	489.6
1962	639.4	—	142.2	20.2	477.0
Change	(–)2.9	—	(–)16.0	(+).5	(+)12.6
Hubbard					
1977	596.2	—	222.8	22.4	351.0
1962	596.5	—	233.6	24.8	338.1
Change	(–)0.3	—	(–)10.8	(–)2.4	(+)12.9
Itasca					
1977	1,685.3	297.9	660.5	141.5	585.4
1962	1,704.3	298.1	765.2	58.8	582.2
Change	(–)19.0	(–)0.2	(–)104.7	(+)82.7	(+)3.2
Koochiching					
1977	2,001.3	—	1,471.9	237.7	291.7
1962	2,002.6	1.6	1,496.9	212.7	291.4
Change	(–)1.3	(–)1.6	(–)25.0	(+)25.0	(+)0.3
Lake					
1977	1,319.8	737.0	323.8	100.4	158.6
1962	1,364.5	725.4	335.4	129.7	174.0
Change	(–)44.7	(+)11.6	(–)11.6	(–)29.3	(–)15.4
Lake of the Woods					
1977	838.8	—	644.6	1.6	192.6
1962	837.1	—	586.1	4.8	246.2
Change	(+)1.7	—	(+)58.5	(–)3.2	(–)53.6
Mahnomen					
1977	360.2	—	80.9	—	279.3
1962	367.4	—	87.1	0.7	279.6
Change	(–)7.2	—	(–)6.2	(–)0.7	(–)0.3
Roseau					
1977	1,072.8	—	305.1	—	767.7
1962	1,072.6	—	361.1	0.9	710.6
Change	(+)0.2	—	(–)56.0	(–)0.9	(+)57.1
St. Louis					
1977	3,899.1	766.6	1,549.4	150.9	1,432.2
1962	4,019.8	767.8	1,633.3	172.4	1,446.3
Change	(–)120.7	(–)1.2	(–)83.9	(–)21.5	(–)14.1
Wadena					
1977	342.7	—	29.2	21.3	292.2
1962	343.0	—	34.9	17.9	290.2
Change	(–)0.3	—	(–)5.7	(+)3.4	(+)2.0
Total					
1977	19,688.5	2,778.8	8,288.8	808.1	7,812.8
1962	19,972.5	2,764.3	8,813.3	761.7	7,633.2
Change	(–)284.0	(+)14.5	(–)524.5	(+)46.4	(+)179.6
Percent					
1977	100.0	14.1	42.1	4.1	39.7
1962	100.0	13.9	44.1	3.8	38.2

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[1] The area of dry land and land temporarily or partially covered by water such as marshes, swamps, and river flood plains; streams, sloughs, estuaries, and canals less than one-eighth of a statute mile in width; and lakes, reservoirs, and ponds less than 40 acres in area Total land in all ownership by county is based on U S. Bureau Census data

[2] U S Bureau of the Census, 1960.

[3] U S Bureau of the Census, 1970

[4] Federal land that has been designated by executive order or statute as national forest or purchase units, and other land under administration of the USDA Forest Service

[5] Public land other than national forest land, including land admininstered by federal, State, or local public agencies.

[6] Land owned by companies or individuals operating primary wood-using plants.

[7] Land privately owned by other than forest industry.

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KILN SIZE AFFECTS ENERGY REQUIRED TO DRY LUMBER

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ABSTRACT.—Energy requirements for lumber drying kilns can depend on kiln size and range from 18,000 Btu/lb water evaporated for a 10 board foot capacity kiln to 1,600 Btu/lb water evaporated for a 100,000 board foot capacity kiln.

The rising cost of fossil fuels is triggering a big push to conserve energy in the manufacture of wood products, so the lumber industry is taking a closer look at the energy consumption of wood-drying kilns. Wood moisture content and species, drying schedule, ambient conditions, leaks in the kiln, and kiln size all affect the amount of energy needed to dry the wood but many people are not aware of the great effect that kiln size has on the energy required to dry wood.

The energy used in a lumber dry kiln can be divided into the heat required to:

1. Raise the temperature of wood substance and water in the wood.
2. Evaporate the moisture (includes the energy to overcome the hygroscopic forces).
3. Raise the temperature of air and water vapor for venting.
4. Raise the temperature of the kiln.
5. Compensate for losses by conduction, radiation, and leaks through the walls, doors, and roof.

The magnitude of each category may vary somewhat depending on drying conditions, kiln type, and wood type, but usually the heat required to evaporate the moisture consumes the most energy.

To demonstrate the effect of kiln size on energy requirements, we theoretically calculated the heat required to dry wood in kilns of different capacity while keeping all operating conditions and kiln construction details the same. We assumed that southern pine of 0.48 green specific gravity dried from 105 to 10 percent moisture content at 190 °F in 82 hours. Ambient temperature was 70 °F and overall heat transfer coefficients were 0.15 Btu/hr ft^2 °F for the walls and roof and 0.80 Btu/hr ft^2 °F for the floor. The heat required to dry the lumber ranged from 1,600 Btu/lb of water evaporated in a 100,000 board foot kiln to almost 18,000 Btu/lb of water evaporated in a 10 board foot kiln (fig. 1).

As shown below for a 25,000 board foot kiln drying southern pine from 105 to 10 percent moisture content by a standard schedule, most of the energy was needed to evaporate moisture from the wood.

Energy needed to:	Total energy (Percent)
Heat wet wood	8
Evaporate moisture	64
Heat air and water vapor	8
Heat kiln	3
Compensate for heat losses	17

As kiln size changed, the energy to heat the wet wood, evaporate the moisture, and heat the air and water vapor per board foot of lumber remained nearly constant. Conversely, the energy required to heat the

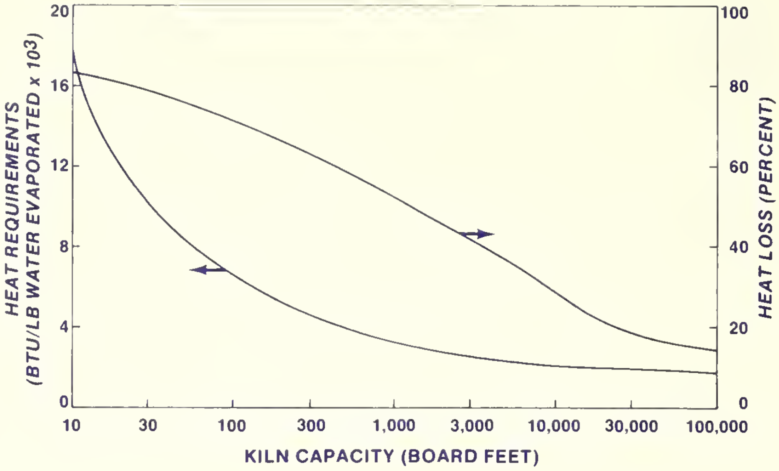

Figure 1.—*Heat loss and heat required to dry 2-inch thick southern pine at 190°F in kilns of different capacity.*

kiln and to compensate for heat losses changed significantly as kiln size changed. As kiln capacity decreased, heat loss increased. Heat losses accounted for more than 70 percent of the energy required to dry the lumber in kilns of 100 board feet or lower. Thus, energy requirements in Btu/lb water evaporated increased as kiln size decreased.

The energy required to heat the kiln and to compensate for losses is proportional to the surface area of the kiln, whereas the remaining heat requirements are proportional to the volume of the kiln. Thus, the ratio of the volume to surface area of the kiln affects energy requirements. Larger kilns have a greater volume/surface area than smaller kilns.

Experimental values of energy requirements obtained from the literature for high temperature drying of southern pine are consistent with the previous theoretical calculations (table 1).

Table 1.—*Energy required to high temperature dry southern pine in different sized kilns—experimental data*

Kiln size	Volume per surface area	Btu/lb water evaporated	References
120,000	3.0	1,630	Taylor
120	1.3	6,770	Koch
3	0.3	10,600	Rosen

The implications of the effect of kiln size on energy consumption are important when comparing different kilns or drying techniques to find which is the most energy efficient. When comparing different sized kilns for energy efficiency, make sure that kiln size is not the overriding influence for energy requirements. Also, specific statements on the effect of kiln conditions on energy requirements of small experimental kilns (1,000 board feet or less) may not apply to the larger commercial kilns (20,000 board feet or more).

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ENERGY VALUES OF NINE *POPULUS* CLONES

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ABSTRACT.— Compares calorific values for components of nine *Populus* clones. The components include stem wood, stem bark, and branches. Also compares calorific values for clones of balsam poplar and black cottonwood parentages.

KEY WORDS: Calorific values, calorimetry, tree components, parentage

INTRODUCTION

Because of its rapid growth, *Populus* may be a desirable genus to grow for energy in short rotation intensively cultured plantations (Zavitkovski *et al.* 1976). Inadequate information is available on energy values for *Populus* clones selected for this study or the individual tree components of *Populus* clones. Parr and Davidson (1922), Peterson *et al.* (1970), Reiners (1972), and James and Smith (1978) reported calorific values for different components of native *Populus*. Holt and Murphey (1978) determined calorific values for *Populus* clone NE-388 and recently Bowersox *et al.* (1979) reported calorific values for seven hybrid poplars.

METHODS

One sample tree was randomly selected from each of nine, 4-year-old Populus clones grown at Rhinelander, Wisconsin. Each tree was divided into upper stem, lower stem, and branches. The bark was removed from the stem sections. All components were dried and ground in a Wiley mill to pass a 60-mesh screen. Ground samples were dried again at 70° C for at least 48 hours and pressed into pellets.

The calorific value (also called heat of combustion) of the samples was determined in an adiabatic oxygen bomb calorimeter using the standardized techniques of the manufacturer (Parr Instrument Company 1969[1]). Correction for fuse wire burn and heat of formation of nitric acid were deducted from the gross heat of combustion.

Analyses of variance and t-tests were used to test differences among clones and components. All tests were done at the 95 percent confidence level.

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[1] *Mention of trade names of the product does not constitute endorsement by the USDA Forest Service.*

RESULTS

As shown below, mean calorific values of the *Populus* clones ranged from 4,636 to 4,755 cal/gm.

Clone[2]	Parentage	Mean cal/gm
5377	*P.* x *euramericana* cv. Wisconsin #5	4,636
5326	*P.* x *euramericana* cv. Eugenii	4,663
5331	*P. betulifolia* x *P.* trichocarpa, NE-229	4,680
5262	*P. candicans* x *P.* berolinensis, NE-383	4,688
5332	*P. betulifolia* x *P.* trichocarpa, NE-98	4,710
5263	*P. candicans* x *P.* berolinensis, NE-386	4,711
5272	*P. nigra* x *P.* laurifolia, NE-1	4,726
5260	*P. tristis* x *P. balsamifera*	4,730
5258	Unknown	4,755

Although significant differences cannot be tested, balsam poplar clones (5262, 5263, 5272, and 5260) tend to have higher unweighted mean calorific values than black cottonwood clones (5377, 5326, 5331, and 5332).

Mean values of individual tree components are shown in the following tabulation.

Component	Mean cal/gm
Lower stem bark	4,604a[3]
Lower stem wood	4,618a
Upper stem wood	4,703b
Upper stem bark	4,760bc
Branches	4,813c

The clones were separated into two groups, each having at least one identical parent and their calorific values were tested for significant differences using a t-test.

Component	Black poplar Cal/gm	Balsam poplar Cal/gm
Lower stem bark	4,572	4,604
Lower stem wood	4,628	4,612
Upper stem wood	4,709	4,693
Upper stem bark	4,674	4,825[4]
Branches	4,779	4,833[4]

Clone 5258 was excluded from this test because its parentage is unknown. Clones with balsam poplar as one parent had significantly higher calorific values than black poplar clones in the upper stem bark and branches. Although clones do not differ significantly, balsam poplars tend to have a higher calorific value than black poplars. One possible reason could be the higher extractive content in balsam poplar's buds and bark. Upper and lower stem wood and lower stem bark were not significantly different between the two groups.

DISCUSSION

Calorific values for stem wood in this study are similar to those presented by Holt and Murphey (1978) for bole wood of *Populus* clone NE-388, which ranged from 4,563 to 4,607 cal/gm, and to Bowersox *et al.* (1979) for composite wood and bark samples which averaged 4,659 cal/gm for seven *Populus* clones. Similarly, Peterson *et al.* (1970) reported calorific values of 4,591 cal/gm for trunk wood and bark of a *P. tremuloides* clone in Alberta. However, Parr and Davidson (1922) and Reiners (1972) found somewhat higher calorific values for bole wood—4,800 cal/gm for unspecified poplar wood, and 4,760 cal/gm for *P. grandidentata*, respectively.

Reiners (1972) also measured a mean calorific value of 4,800 cal/gm for branches, which agrees with the average for clones in this study. James and Smith (1978) separated twigs into bark and wood. The calorific value for twig wood was 4,550 cal/gm and that for twig bark was 5,040 cal/gm. The twig wood value is similar to my data for upper stem wood, but the twig bark value is higher than my value for upper stem bark.

In this study calorific values increased up the stem; branch calorific values were always higher than those of other components. This trend is substantiated by Madgwick (1970) and Hughes (1971).

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[2] *North Central Forest Experiment Station clone number.*

[3] *Means followed by the same letter are not significantly different at the 5 percent probability level.*

[4] *Significantly different at the 5 percent level.*

I found that calorific values of wood samples did not differ significantly among clones. This agrees with Bowersox *et al.* (1979). Because stem wood is the largest component of the total tree (about 50 percent of the total weight), plantations at wider spacings may show differences due to their larger proportion of branches.

Calorific values of upper stem bark and of branches of clones with one balsam poplar parent were significantly higher than those of other components. Contradictory evidence was reported by Bowersox *et al.* (1979) for clone NE-388 whose one parent belongs to the balsam poplar group. However, the comparison was between a composite sample of bark from the total stem and wood, which would lower the calorific value for bark because bark from lower stem has a lower calorific value than bark from upper stem.

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FOREST AREA IN MINNESOTA, 1977[1]

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ABSTRACT.— Presents statistics on Minnesota's forest land area by county for 1977.

KEY WORDS: Commercial forest land, noncommercial forest land.

One out of every 3 acres in Minnesota is forested. These forested acres total 16.7 million acres in the State, almost 85 percent of which occur in a 17 county area in northern Minnesota encompassing the Aspen-Birch and Northern Pine Survey Units (fig. 1, table 4).

Forest land declines across Minnesota from 87 percent of all land in the northeast (Aspen-Birch Unit) to 3 percent of all land in the southwest (Prairie Unit). Cook County in northeast Minnesota is 99 percent forest, the most heavily forested county in the State.

Forest land, Statewide, declined 1.7 million acres or 9.4 percent between 1962 and 1977. A comparison of areas from the two inventories by geographical regions in the State shows that even more significant changes took place in certain sections of the State. The greatest reductions in forest area occurred in the Prairie and Central Hardwoods Units where the losses were 37 and 22 percent, respectively (table 1).

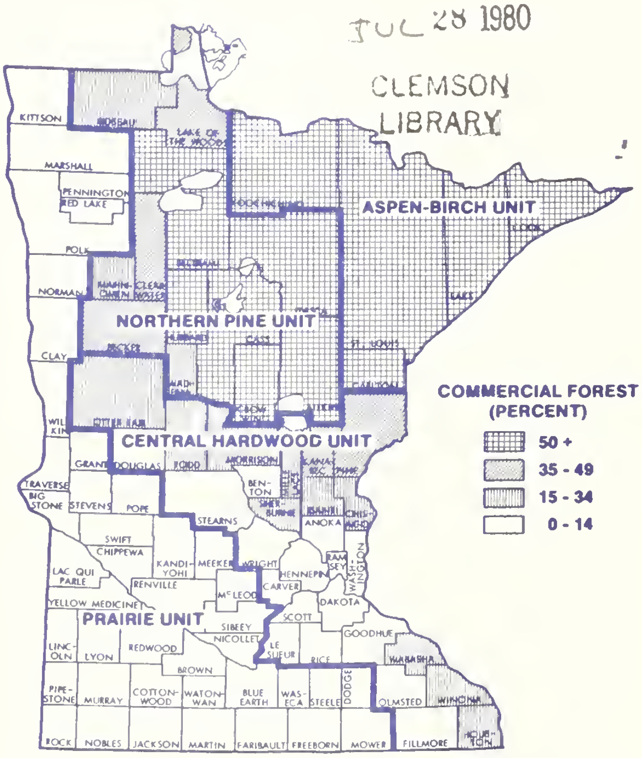

Figure 1.— *Commercial forest area as a percent of land area by county, Minnesota, 1977.*

Commercial forests (land suitable for growing industrial timber products and not reserved from this use) now occupy 13.7 million acres or 82 percent of Minnesota's forest land. Since the previous inventory in 1962, commercial forests have declined 1.7 million acres or 11 percent (table 2).

The patterns of change by geographical area follow those of total forest land except for the Aspen-Birch Unit. In this Unit, almost 500 thousand acres of forest land that formerly was classified as commercial

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[1] *The sampling error of area for this survey was ± 0.39 percent for the 13.7 million acres of commercial forest land. The fourth forest inventory of Minnesota was conducted by the North Central Forest Experiment Station and the Minnesota Department of Natural Resources.*

Table 1.— *Area of total forest land by Forest Survey Unit for 1962 and 1977, Minnesota*

Unit	**Survey year**		**Change since**	
	1962[1]	**1977**	**1962**	
	Thousand acres			*Percent*
Aspen-Birch	7,771	7,472	–299	–3.8
Northern Pine	7,004	6,512	–492	–7.0
Central Hardwood	2,748	2,144	–604	–22.0
Prairie	922	581	–341	–37.0
State total	18,445	16,709	–1,736	–9.4

[1] 1962 areas have been adjusted to conform to 1977 statistics because of changes in procedures and definitions between surveys.

Table 2.— *Area of commercial forest land by Forest Survey Unit for 1962 and 1977, Minnesota*

Unit	**Survey year**		**Change since**	
	1962[1]	**1977**	**1962**	
	Thousand acres			*Percent*
Aspen-Birch	6,244	5,451	–793	–12.7
Northern Pine	6,025	5,759	–266	–4.4
Central Hardwood	2,360	1,951	–409	–17.3
Prairie	783	534	–249	–31.8
State total	15,412	13,695	–1,717	–11.1

[1] 1962 areas have been adjusted to conform to 1977 statistics because of changes in procedures and definitions between surveys.

has been reclassified productive-reserved. This is due to the creation of the Voyageurs National Park and the addition of the Portal Zone to the reserved section of the Boundary Waters Canoe Area of the Superior National Forest.

Noncommercial forest land totaled 3 million acres in 1977 (table 3). Of this amount, 1.8 million acres is forest land too poor to grow timber products suitable for industrial use. The remaining 1.2 million acres are productive but reserved for uses other than timber production, such as parks and other reserved recreation areas. The decline in noncommercial forest land between inventories can be attributed to a drop in unproductive forest acres.

Table 3.— *Area of noncommercial forest land by Forest Survey Unit for 1962 and 1977, Minnesota*

Unit	**Survey year**		**Change since**	
	1962[1]	**1977**	**1962**	
	Thousand acres			*Percent*
Aspen-Birch	1,526	2,020	+494	+32.4
Northern Pine	979	754	–225	–23.0
Central Hardwood	388	193	–195	–50.3
Prairie	140	47	–93	–66.4
State Total	3,033	3,014	–19	–.6

[1] 1962 areas have been adjusted to conform to 1977 statistics because of changes in procedures and definitions between surveys.

Table 4.—Area of land and forest land by county, Minnesota, 1977

ASPEN-BIRCH UNIT

County	All land[1]	Forest Land[2]			Commercial forest as a percent of land area	All forest as a percent of land area
		All forest	Non-commercial[3]	Commercial[4]		
	Thousand acres				Percent	
Carlton	551.8	336.1	23.3	312.8	57	61
Cook	861.4	852.9	314.1	538.8	63	99
Koochiching	2,001.3	1,794.3	515.4	1,278.9	64	90
Lake	1,319.8	1,257.1	401.8	855.3	65	95
St. Louis	3,899.1	3,231.4	765.8	2,465.6	63	83
Total	8,633.4	7,471.8	2,020.4	5,451.4	63	87
NORTHERN PINE UNIT						
Aitkin	1,169.7	762.6	90.1	672.5	58	65
Becker	830.0	322.8	8.9	313.9	38	39
Beltrami	1,604.2	1,044.0	249.4	794.6	50	65
Cass	1,278.8	883.4	24.8	858.6	67	69
Clearwater	639.9	333.7	32.0	301.7	47	52
Crow Wing	636.5	380.7	8.8	371.9	58	60
Hubbard	596.2	403.2	5.2	398.0	67	68
Itasca	1,685.3	1,331.6	50.6	1,281.0	76	79
Lake of the Woods	838.8	596.1	235.5	360.6	43	71
Mahnomen	360.2	107.8	1.4	106.4	30	30
Roseau	1,072.8	232.6	40.7	191.9	18	22
Wadena	342.7	113.7	6.4	107.3	31	33
Total	11,055.1	6,512.2	753.8	5,758.4	52	59
CENTRAL HARDWOOD UNIT						
Anoka	271.0	42.9	6.3	36.6	14	16
Benton	257.4	28.3	2.2	26.1	10	11
Carver	229.9	12.3	1.9	10.4	5	5
Chisago	268.1	55.7	5.5	50.2	19	21
Dakota	368.4	19.5	3.0	16.5	5	5
Douglas	413.9	20.4	1.9	18.5	5	5
Fillmore	549.8	72.9	7.6	65.3	12	13
Goodhue	482.1	60.7	4.3	56.4	12	13
Hennepin	363.1	11.4	3.6	7.8	2	3
Houston	361.7	119.6	8.1	111.5	31	33
Isanti	280.6	54.1	7.2	46.9	17	19
Kanabec	335.1	134.5	5.5	129.0	39	40
LeSueur	281.6	11.4	1.4	10.0	4	4
Mille Lacs	365.6	136.2	13.4	122.8	34	37
Morrison	721.4	161.3	12.6	148.7	21	22
Olmsted	419.6	35.3	3.3	32.0	8	8
Otter Tail	1,255.9	200.5	14.2	186.3	15	16
Pine	904.7	477.6	52.0	425.6	47	53
Ramsey	99.0	.1	.1	—	—	—
Rice	317.6	14.1	2.0	12.1	4	4
Scott	225.7	16.3	2.7	13.6	6	7
Sherburne	275.8	62.3	5.4	56.9	21	23
Stearns	858.9	60.3	4.3	56.0	7	7
Todd	602.6	111.1	6.6	104.5	17	18
Wabasha	334.1	62.1	4.7	57.4	17	19
Washington	246.9	12.1	1.9	10.2	4	5
Winona	397.1	114.9	8.6	106.3	27	29
Wright	431.6	35.8	2.3	33.5	8	8
Total	11,919.2	2,143.7	192.6	1,951.1	16	18

(Table 4 continued on next page)

(Table 4, continued)

PRAIRIE UNIT

County	All land[1]	Forest Land[2]			Commercial forest as a percent of land area	All forest as a percent of land area
		All forest	Non-commercial[3]	Commercial[4]		
	Thousand acres				*Percent*	
Big Stone	313.8	2.7	.3	2.4	1	1
Blue Earth	471.3	23.6	2.2	21.4	5	5
Brown	390.3	10.7	1.6	9.1	2	3
Chippewa	372.2	4.0	.1	3.9	1	1
Clay	669.1	11.2	.9	10.3	1	2
Cottonwood	407.0	2.6	.1	2.5	1	1
Dodge	278.4	7.4	1.0	6.4	2	3
Faribault	455.1	6.5	.3	6.2	1	1
Freeborn	448.4	5.7	.9	4.8	1	1
Grant	349.6	3.0	.1	2.9	1	1
Jackson	445.5	2.3	.2	2.1	1	1
Kandiyohi	501.2	12.4	2.5	9.9	2	3
Kittson	719.0	71.9	4.4	67.5	9	10
Lac qui Parle	491.6	5.2	.6	4.6	1	1
Lincoln	339.8	2.2	.2	2.0	1	1
Lyon	453.5	5.3	.9	4.4	1	1
McLeod	312.3	6.1	.3	5.8	2	2
Marshall	1,145.1	142.7	14.2	128.5	11	13
Martin	450.1	3.8	.2	3.6	1	1
Meeker	396.3	12.0	1.2	10.8	3	3
Mower	449.9	6.1	.9	5.2	1	1
Murray	449.9	1.4	.3	1.1	—	—
Nicollet	276.7	13.7	1.4	12.3	4	5
Nobles	455.5	.7	—	.7	—	—
Norman	566.4	23.1	.9	22.2	4	4
Pennington	398.0	32.0	1.3	30.7	8	8
Pipestone	297.0	.4	—	.4	—	—
Polk	1,288.1	71.3	3.3	68.0	5	6
Pope	428.3	7.8	.9	6.9	2	2
Red Lake	276.5	28.9	1.7	27.2	10	11
Redwood	559.4	6.7	.5	6.2	1	1
Renville	626.3	8.0	.8	7.2	1	1
Rock	310.4	.5	—	.5	—	—
Sibley	373.2	11.9	1.0	10.9	3	3
Steele	272.3	5.6	.6	5.0	2	2
Stevens	357.2	1.0	—	1.0	—	—
Swift	473.2	5.0	.3	4.7	1	1
Traverse	363.7	.9	—	.9	—	—
Waseca	265.3	5.0	.4	4.6	2	2
Watonwan	276.9	1.1	—	1.1	—	—
Wilkin	481.1	.5	—	.5	—	—
Yellow Medicine	482.2	8.6	.8	7.8	2	2
Total	19,137.1	581.5	47.3	534.2	3	3
STATE TOTAL	50,744.8	16,709.2	3,014.1	13,695.1	27	33

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[1] 1970 Bureau of the Census estimates.

[2] Land at least 16.7 percent stocked by forest trees of any size, or formerly having such tree cover; excludes land currently developed for nonforest use such as urban or heavily settled residential or resort area, city parks, orchards, improved roads, or improved pasture land. The minimum forest area classified was 1 acre. Roadside, streamside, and shelterbelt strips of timber with a crown width of at least 120 feet and unimproved roads and trails, streams, and clearings in forested areas if less than 120 feet in width were classified as forest.

[3] Unproductive forest land incapable of yielding crops of industrial wood because of adverse site conditions, and productive public forest land withdrawn from commercial timber production through statute or administrative regulation.

[4] Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation.

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PULPWOOD PRODUCTION[1] IN THE LAKE STATES, BY COUNTY, 1979

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ABSTRACT.--Pulpwood production in the Lake States--Michigan, Minnesota, and Wisconsin--climbed to 5.55 million cords in 1979. Pulpwood production is shown by county and species group for these three States.

KEY WORDS: Residue, Michigan, Minnesota, Wisconsin.

Lake States pulpwood production advanced to 5.55 million cords in 1979. For the first time, logs, bolts, and wood residue used in manufacturing particleboard and waferboard are included in this annual report series. Wisconsin produced 2.11 million cords, Michigan 1.98 million cords, and Minnesota 1.46 million cords.

Ninety percent of the total output came from roundwood (including chips); the remainder came from mill residue such as slabs, edgings, veneer cores, and chips from those materials. Production from softwood and hardwood residue by State was:

State	Softwood	Hardwood
	(Hundred standard cords, unpeeled)	
Michigan	153	1,625
Minnesota	427	752
Wisconsin	485	2,107

Leading species harvested were aspen (2,298,000 cords), pine (870,000 cords), maple (443,000 cords), balsam fir (287,000 cords), and birch (266,000 cords).

Wisconsin continued to import large quantities of wood--516,000 cords from Michigan, 169,000 cords from Minnesota, 266,000 cords from other (primarily western) States, and 92,000 cords from Canada. Total exports from Wisconsin were only 85,000 cords.

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[1] Includes logs, bolts, and wood residue used in manufacturing particleboard and waferboard.

Counties producing more than 100,000 cords were Iron and Marquette in Michigan; St. Louis, Koochiching, and Itasca in Minnesota; and Oneida, Marinette, Price, Forest, and Sawyer in Wisconsin (table 1). These counties supplied one-third of the pulpwood produced in the Lake States from roundwood in 1979.

Table 1.--*Lake States pulpwood production by county and species, 1979*

(In hundred standard cords, unpeeled)

MICHIGAN

Unit[1] and county	All species	Pine	Spruce	Balsam fir	Hemlock	Tamarack	Cedar	Aspen	Birch	Oak	Maple	Other hdwds.
E. UPPER PENINSULA												
Alger	621	107	18	51	69	2	9	105	81	1	101	77
Chippewa	492	295	36	50	12	2	4	47	15	X	21	10
Delta	923	90	34	107	42	3	12	333	86	2	132	82
Luce	559	331	34	30	57	1	2	41	17	X	29	17
Mackinac	396	49	43	49	12	1	5	128	31	X	46	32
Menominee	938	29	36	93	46	3	5	462	66	5	124	69
Schoolcraft	636	285	12	47	26	1	4	131	49	1	34	46
Total	4565	1186	213	427	264	13	41	1247	345	9	487	333
W. UPPER PENINSULA												
Baraga	657	27	10	41	24	2	8	132	114	1	247	51
Dickinson	710	15	34	40	7	X	2	406	62	2	99	43
Gogebic	663	42	14	38	51	2	7	215	38	2	150	104
Houghton	218	62	4	17	9	X	1	36	23	X	46	20
Iron	1355	105	65	176	38	3	9	581	101	1	196	80
Keweenaw	7	X[2]	1	2	3	X	0	0	X	0	1	X
Marquette	1345	228	36	94	48	4	13	312	150	12	373	75
Ontonagon	655	5	3	5	5	X	1	366	37	1	152	80
Total	5610	484	167	413	185	11	41	2048	525	19	1264	453
N. LOWER PENINSULA												
Alcona	463	47	0	0	0	0	0	260	11	106	23	16
Alpena	296	44	0	0	0	0	0	148	17	42	30	15
Antrim	17	X	0	0	0	0	0	10	X	1	3	3
Arenac	51	3	0	0	0	0	0	20	3	18	5	2
Bay	1	X	0	0	0	0	0	1	X	0	0	0
Benzie	119	2	0	0	0	0	0	61	2	9	29	16
Charlevoix	X	0	0	0	0	0	0	X	0	0	0	0
Cheboygan	482	62	1	4	0	0	0	315	38	2	43	17
Clare	413	16	0	0	0	0	0	293	9	37	53	5
Crawford	247	157	2	1	0	0	0	27	1	31	27	1
Emmet	44	X	0	0	0	0	0	37	2	1	4	0
Gladwin	85	X	0	0	0	0	0	65	4	4	10	2
Grand Traverse	110	37	0	0	0	0	0	37	1	12	19	4
Iosco	100	87	0	0	0	0	0	12	0	0	1	X
Isabella	61	2	0	0	0	0	0	59	0	X	X	X
Kalkaska	148	40	0	0	0	0	0	83	2	10	10	3
Lake	601	143	0	0	0	0	0	154	2	184	100	18
Leelanau	37	4	0	0	0	0	0	3	0	6	10	14
Manistee	223	4	0	0	0	0	0	97	4	79	26	13
Mason	221	22	0	0	0	0	0	89	5	46	48	11
Mecosta	161	32	0	0	0	0	0	101	X	22	5	1
Midland	34	1	0	0	0	0	0	30	2	0	1	0
Missaukee	134	15	2	1	0	0	0	97	2	6	9	2
Montmorency	537	116	0	X	0	0	0	307	23	49	32	10
Newaygo	382	157	0	0	0	0	0	114	1	89	17	4
Oceana	206	12	0	0	0	0	0	114	2	37	30	11
Ogemaw	262	60	0	0	0	0	0	149	3	24	23	3
Osceola	195	33	0	0	0	0	0	113	3	25	18	3
Oscoda	675	266	0	0	0	0	0	269	26	80	27	7
Otsego	389	75	0	0	0	0	0	255	19	7	32	1
Presque Isle	313	26	3	4	0	0	0	170	27	14	52	17
Roscommon	207	27	2	1	0	0	0	150	2	20	4	1
Wexford	375	170	0	0	0	0	0	111	2	21	54	17
Total	7589	1660	10	11	0	0	0	3751	213	982	745	217
S. LOWER PENINSULA												
Allegan	35	15	0	0	0	0	0	10	0	9	1	X
Barry	4	3	0	0	0	0	0	1	0	X	0	0
Gratiot	2	0	0	0	0	0	0	2	0	X	X	X
Ionia	X	X	0	0	0	0	0	0	0	0	0	0
Kalamazoo	1	1	0	0	0	0	0	0	0	0	0	0
Kent	7	5	0	0	0	0	0	1	0	1	X	X
Livingston	1	1	0	0	0	0	0	0	0	0	0	0
Montcalm	38	5	0	0	0	0	0	24	X	8	1	X
Muskegon	57	36	0	0	0	0	0	3	X	16	2	X
Ottawa	112	93	0	0	0	0	0	5	X	12	2	X
Saginaw	1	0	0	0	0	0	0	1	0	0	0	0
Shiawassee	1	1	0	0	0	0	0	0	0	0	0	0
Tuscola	2	2	0	0	0	0	0	0	0	0	0	0
Van Buren	6	5	0	0	0	0	0	X	0	1	X	0
Washtenaw	5	5	0	0	0	0	0	0	0	0	0	0
Total	272	172	0	0	0	0	0	47	X	47	6	X
State total	18036	3502	390	851	449	24	82	7093	1083	1057	2502	1003

(Table 1 continued on next page)

(Table 1 continued)

MINNESOTA

Unit and county	All species	Pine	Spruce	Balsam fir	Hem-lock	Tam-arack	Cedar	Aspen	Birch	Oak	Maple	Other hdwds.
ASPEN-BIRCH												
Carlton	165	28	19	13	0	6	0	94	X	0	X	5
Cook	544	48	112	78	0	0	0	296	3	0	0	7
Koochiching	2633	139	589	330	0	154	0	1333	3	0	3	82
Lake	569	133	172	24	0	2	0	223	10	0	X	5
St. Louis	3046	399	294	268	0	21	0	1972	9	X	1	82
Total	6957	747	1186	713	0	183	0	3918	25	X	4	181
NORTHERN PINE												
Aitkin	536	11	10	8	0	9	0	493	1	1	1	2
Becker	32	10	0	0	0	0	0	22	0	0	0	0
Beltrami	966	130	79	113	0	63	0	547	3	4	4	23
Cass	690	135	4	12	0	9	0	516	2	1	X	11
Clearwater	299	32	22	16	0	20	0	209	0	0	0	0
Crow Wing	137	55	1	X	0	0	0	81	0	0	0	0
Hubbard	487	124	6	22	0	4	0	331	0	0	0	0
Itasca	2047	52	84	262	0	30	0	1581	4	X	2	32
Lake of the Woods	386	82	104	26	0	13	0	152	0	0	0	9
Mahnomen	33	10	0	0	0	2	0	21	0	0	0	0
Roseau	159	52	31	2	0	3	0	71	0	0	0	0
Wadena	78	61	2	0	0	0	0	15	0	0	0	0
Total	5850	754	343	461	0	153	0	4039	10	6	7	77
CENTRAL HARDWOOD												
Chisago	6	3	0	0	0	0	0	3	0	0	0	0
Hennepin	6	0	0	0	0	0	0	0	0	0	0	6
Isanti	22	17	0	0	0	0	0	5	0	0	0	0
Kanabec	61	6	0	0	0	0	0	50	2	1	X	2
Mille Lacs	228	0	0	0	0	0	0	189	15	8	4	12
Morrison	56	10	X	X	0	0	0	41	2	1	X	2
Otter Tail	22	10	0	0	0	2	0	10	0	0	0	0
Pine	138	13	X	0	0	0	0	112	13	0	0	0
Ramsey	1	0	0	0	0	0	0	0	0	0	0	1
Sherburne	16	16	0	0	0	0	0	0	0	0	0	0
Todd	10	9	0	0	0	0	0	1	0	0	0	0
Total	566	84	X	X	0	2	0	411	32	10	4	23
PRAIRIE												
Polk	28	0	0	0	0	20	0	8	0	0	0	0
Total	28	0	0	0	0	20	0	8	0	0	0	0
State total	13401	1585	1529	1174	0	358	0	8376	67	16	15	281

(Table 1 continued on next page)

(Table 1 continued)

WISCONSIN

Unit and county	All species	Pine	Spruce	Balsam fir	Hem-lock	Tam-arack	Cedar	Aspen	Birch	Oak	Maple	Other hdwds.
NORTHEASTERN												
Florence	587	47	7	14	2	X	X	384	35	3	54	41
Forest	1079	63	42	187	38	1	1	409	99	5	129	105
Langlade	674	36	3	25	3	X	0	242	67	8	184	106
Lincoln	628	33	8	41	13	2	X	327	39	12	76	77
Marinette	1369	284	14	31	18	X	X	794	109	12	61	46
Oconto	379	154	4	36	3	X	0	151	16	X	10	5
Oneida	1611	201	51	199	45	2	1	625	214	53	144	76
Shawano[3]	588	60	0	2	126	0	0	258	13	7	58	64
Vilas	944	67	13	69	10	X	X	453	170	26	92	44
Total	7859	945	142	604	258	5	2	3643	762	126	808	564
NORTHWESTERN												
Ashland	765	62	9	77	4	X	X	359	108	9	86	51
Barron	104	3	0	0	0	0	0	6	21	23	35	16
Bayfield	859	195	2	20	1	0	X	503	111	6	11	10
Burnett	220	177	0	X	0	0	0	38	3	0	2	X
Douglas	841	428	1	5	0	0	0	384	20	0	1	2
Iron	521	16	2	15	4	X	X	264	30	3	88	99
Polk	6	3	0	0	0	0	0	3	0	0	0	0
Price	1280	29	16	60	25	6	1	506	130	24	197	286
Rusk	312	3	0	1	2	X	0	166	38	11	47	44
Sawyer	1044	102	2	25	75	X	X	419	124	28	161	108
Taylor	670	12	5	23	15	X	0	271	46	16	116	166
Washburn	382	103	3	1	0	0	0	263	5	1	3	3
Total	7004	1133	40	227	126	6	1	3182	636	121	747	785
CENTRAL												
Adams	340	243	X	0	0	0	0	4	3	81	4	5
Chippewa	206	19	0	X	1	X	0	93	20	21	25	27
Clark	306	44	0	X	4	0	0	118	18	71	25	26
Eau Claire	151	53	0	0	0	0	0	10	8	53	17	10
Jackson	175	127	0	0	0	X	0	13	4	22	4	5
Juneau	288	193	0	0	0	0	0	20	8	53	6	8
Marathon	847	51	X	12	7	0	0	200	29	50	236	262
Marquette	122	67	1	0	0	0	0	2	4	40	4	4
Monroe	83	63	0	0	0	0	0	2	2	12	2	2
Portage	175	101	0	X	1	X	0	36	4	26	6	1
Waupaca	136	49	0	X	X	0	0	67	2	6	4	8
Waushara	127	111	0	0	0	0	0	1	X	13	1	1
Wood	311	149	X	0	X	0	0	89	7	45	10	11
Total	3267	1270	1	12	13	X	0	655	109	493	344	370
SOUTHWESTERN												
Buffalo	15	15	0	0	0	0	0	0	0	0	0	0
Crawford	14	0	0	0	0	0	0	4	1	5	2	2
Dunn	93	93	0	0	0	0	0	0	X	X	X	X
Grant	31	0	0	0	0	0	0	8	1	14	4	4
Iowa	3	0	0	0	0	0	0	1	X	2	X	X
La Crosse	16	16	0	0	0	0	0	0	X	0	X	X
Lafayette	3	0	0	0	0	0	0	1	X	2	X	X
Pepin	16	16	0	0	0	0	0	0	0	0	0	0
Pierce	X	0	0	0	0	0	0	X	0	0	X	X
Richland	X	X	0	0	0	0	0	0	0	0	0	0
Sauk	30	28	0	0	0	0	0	0	X	1	1	X
Trempealeau	31	31	0	0	0	0	0	X	0	0	X	X
Vernon	1	1	0	0	0	0	0	X	0	0	0	0
Total	253	200	0	0	0	0	0	14	2	24	7	6
SOUTHEASTERN												
Brown	14	4	6	0	0	0	0	4	0	0	0	0
Columbia	59	43	0	0	0	0	0	1	2	8	3	2
Dodge	3	0	0	0	0	0	0	0	3	0	0	0
Door	X	X	0	0	0	0	0	0	0	0	0	0
Green	2	2	0	0	0	0	0	0	0	0	0	0
Green Lake	2	1	X	0	0	0	0	0	X	0	X	1
Outagamie	10	1	0	0	0	0	0	8	X	0	1	X
Waukesha	13	13	0	0	0	0	0	0	0	0	0	0
Total	103	64	6	0	0	0	0	13	5	8	4	3
State total	18486	3612	189	843	397	11	3	7507	1514	772	1910	1728

[1] Includes only those counties that supplied pulpwood in 1979.

[2] X = Less than 50 cords.

[3] Includes Menominee County.

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MENSURATIONAL AND BIOMASS RELATIONS FOR POPULUS 'TRISTIS #1' UNDER INTENSIVE CULTURE[1]

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ABSTRACT.— Tree measurement data from plantations established in 1970 and 1973 and grown under intensive culture were used to establish various dimensional relations and biomass equations for *Populus 'Tristis #1'*. These equations subsequently have been used to estimate yields on study plots and for projections of future yields. They are presented here for others working with this hybrid and as a guide to model forms which might be utilized for other species.

KEY WORDS: tree measurement, plantations, hybrids, yield analysis.

Short rotation intensive culture (SRIC) studies begun in 1970 at the Hugo Sauer Nursery in Rhinelander, Wisconsin, have involved considerable growth and yield analysis. The principal variety used for studies of intensive cultural practices (fertilization, irrigation, etc.) to date has been *Populus 'Tristis #1'*. Dawson (1976) reviewed previous work on this variety. Ek and Dawson (1976) described earlier tree biomass equations developed for plantings established in 1970. The intent of this paper is to update that work by presenting equations developed from incorporating more recent data. Some of these data and the equations described here were used in yield analyses by Meldahl (1979). The new data are from the same nursery site and fertilization and irrigation treatments described in these earlier papers.

DESCRIPTION OF YIELD DATA

As the SRIC plantations have grown in number and tree sizes have increased, stem and branch analyses have evolved to consider more detailed stand and tree sampling techniques in developing biomass data. The earlier Ek and Dawson paper developed individual tree dry weight yield equations for stem wood, stem bark, branch wood, branch bark, branch tips, and leaves. The equations developed in that study were based on essentially complete analysis of small sample stems from three plots with square spacings of 0.2286, 0.3048, and 0.6096 m. Plots had sides measuring 5.0, 5.2, and 5.5 m. Sample trees were drawn from the interior of each plot each year. This led to 235 observations of tree dimensions and associated stem wood and bark weight. (There were fewer observations for other tree weight components.) Over 80 percent of these data were obtained at ages 1 and 2 years. The remaining 20 percent came from trees at ages 3 and 4 years. In addition to recording total tree height and basal diameter (2.5 cm above the base of the root collar), the trees were separated into the six above mentioned components. Harvesting was done in late summer at the time of maximal leaf biomass.[2] These components were then oven dried at 70 C and weighed to the nearest 0.01 g.

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[2] *A small but undetermined number of leaves were lost prior to harvest.*

These data subsequently are referred to as those from the 1970 plantings.

Additional larger plantings were established in June 1973 with square spacings of 0.3048, 0.6096, 1.2192, and 2.4384 m. These plots were 8 to 16 rows wide and had 24 to 36 trees per row. As in 1970, 20-cm cuttings were planted. Trees subsequently were selected and harvested or otherwise observed on these plots at ages 3 and 4 years to augment the data from the 1970 plantings. Additionally, two of the larger trees from the 1970 plantings were harvested in the fall of 1976 to augment information on larger stems. Together, these data subsequently are referred to as those from 1973 plantings. This data set included 20 to 34 trees, depending on the variable of interest.

The 1973 data were developed by selecting and harvesting three trees from the 0.3048, 0.6096, and 1.2192 m spacings near the peak of the third growing season (9 trees), and one more stem from each spacing at the end of that season (3 trees). In addition, two trees were drawn from each spacing at the end of the fourth growing season (6 trees). Also, two trees drawn from the 1970 plantings at the end of the seventh growing season were included in this data set. Except for the two trees from the 1970 plantings, the selected stems were a stratified sample, with stratification based on diameter outside bark at breast height (D). Equal numbers of stems were selected randomly from each of three D classes within each spacing. To minimize the influence on remaining stems, however, this harvesting was concentrated at one end of each plot, excluding border trees. The two trees from the 1970 plantings were purposively selected from among the largest stems from the plots established in that year. These stems were obtained from the interior of the 0.3048 and 0.6096m spacings. These 20 stems are grouped together here because of their similar analysis as described below.

Laboratory analysis of the stems then was conducted using four or more systematically located 150-mm sections along the stem, beginning at 25 mm above the ground. Section measurements included green diameters inside and outside bark at each end, oven dry (70 C) weight of wood and bark, and the height of each section base above ground. Total stem height (H), D, and diameters outside bark every 30 cm up the stem also were determined. Section volumes for specific gravity determinations were developed using Smalians formula for frustrums of paraboloids.

Branch observations included measurement of the diameter (at 25 mm from stem base) of all branches and the height of the branch base above ground. Long and short branches then were selected randomly from each of the above stem sections for length, specific gravity, and dry weight of wood and bark determinations. Total branch wood plus bark dry weights were observed directly, but dry weight of wood and bark components were estimated, using the total branch weights multiplied by wood and bark specific gravities determined on sections. Section size and location procedure was similar to those used for the main stem. Leaf dry weight determinations were made only for the nine trees measured at the peak of the third growing season and only for the selected long and short branches on those stems.

An additional 14 trees were purposively selected from the 1973 plantings to cover the range of tree sizes present. These were observed only for height and basal diameter (2.5 cm above ground) and inside and outside bark diameters at breast height at the end of the third growing season.

Another data set, referred to as 1974 observations, involved determining diameters outside bark at six to eight systematically located positions along the stems of 30 trees. These trees were selected at random in the spring of 1974 from the 1970 plantings. Observations on these stems included basal diameter (2.5 cm above ground), diameter at 0.15 m, 0.30 m, 1.37 m, and at approximately 1.0 m intervals to the tip, and total height. Diameters at 0.15 m from the tip also were recorded. These data originally were intended for development of a stem taper equation, but even when combined with the 1973 data, extrapolation to larger tree sizes via the various equations tested was tenuous. Consequently, the development of taper equations was postponed and the 1974 data were used only to aid quantification of stem biomass.

ANALYSIS

The above yield data were analyzed by nonlinear regression analysis to develop two types of equations. The first set, primarily mensurational, was used to convert the 1970 data to a form compatible with the 1973 data (this involved estimating breast height diameter from basal diameter), and to develop tree component weights for the 1973 and 1974 data sets from the various subsample information on these trees. The second type of equations given describe tree dry weight or biomass components as a function of tree D and total height H. These equations are described in tables 1 and 2.

Computing stem weight for wood and bark components for the 1973 and 1974 data involved applying the diameter inside bark and specific gravity equations (table 1, equations b, c, and d) to the periodic diameter outside bark data available for these stems. The section volumes were obtained using Smalians formula.

Tree branch wood, branch bark, and leaf weights were obtained using equations developed from the branch data to express weight as a function of branch and tree characteristics. The model form used was:

$$w = b_1 d^{b_2} (H-h)^{b_3} (H/D)^{b_4} + b_5$$

where:

w = branch component weight,

d = branch diameter outside bark at 25 mm from base,

h = height to base of branch and the b_i are constants

Summing predictions over all branches on the stem provided the total branch component weight used for these trees. Details of developing these equations are given by Ek (1979). Only average specific gravities of branch wood and bark are given in table 1, as these characteristics were not well correlated with with branch and/or tree dimensions.

The use of the biomass equations given in table 2 is recommended for trees 0.5 to 9.1 cm D. For smaller trees, the equations based on basal diameter and total height given by Ek and Dawson (1976) are recommended. With those equations, branch wood plus tip weight is analogous to the branch wood term estimated in this report. For extrapolation to trees larger than 9.1 cm, the equations given here based on D should provide useful approximations. Use of table 2 equation (a) for stem wood weight together with the stem specific gravity equation (g) for larger tree sizes leads to total stem volume values comparable to those given in table 3 of Gevorkiantz and Olsen (1955). The fact that table 3 is known to fit a wide range of species suggests the feasibility of extrapolation via equations given in table 2.

The model form used for tree biomass in table 2 is:

$$w = b_1 D^{b_2} H^{b_3} \qquad (1)$$

This model is an extension of the common allometric model. It has a long history of use in forest yield analyses (Husch, *et al.* 1972). The use of weighting procedures here produced a slight improvement in fits for the smaller tree sizes. Other models were tested but this form consistently performed best. An attempt to introduce a spacing term via the model form:

$$w = b_1 D^{b_2} H^{b_3} S^{b_4}$$

where S was the initial stand spacing in m produced negligible improvement in fits.

From a physical standpoint, model (1) also may be rewritten as:

$$\begin{aligned} w &= b_1 D^{b_2 - 2} H^{b_3 - 1} (D^2 H) \\ &= F (D^2 H) \qquad (2) \end{aligned}$$

In this form, the first term on the right hand side (F) of (2) may be viewed as a combination of basic constants, stem form, and specific gravity factors applied to the dimensions of a cylinder of height = H and diameter = D Barring sharp changes in stem form and specific gravity not associated with tree size, this formulation suggests considerable extrapolative potential. Extrapolation is not encouraged, but may be necessary for some yield projections until more data are available. Of the equations in table 2, the one for leaf weight, because of its limited data base in terms of stand age, is perhaps least suitable for extrapolation.

The equations in table 2 also may be used with slight adjustment, to approximate yields above a 0.15 m stump. The total stem biomass for the higher stump for 20 trees from the 1973 plantings ranged from 90 to 98 percent of that for the 0.03 m stump. Percentage differences in yields for the two stump heights also decreased with increasing tree size. Percentage differences in biomass for branch components between the two stump heights were negligible.

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Table 1.—*Mensurational relations used to develop tree biomass information for* Populus 'Tristis *#1*'

Equation[1]	Dependent variable				Observations	
	SE	[2]R^2	Mean	Range	Number	Source
(a) Diameter outside bark at breast height (1.37 m) $D = 0.2309 + 0.3221\ D_s^{0.72609}\ H^{0.63856}$	0.203	0.98	3.13	0.82-9.20	53	1970, 1973
(b) Stem diameter inside bark[3] $dib = /B\ 0.5247/(-\ 0.5247 + dob^{0.20305}) + 0.9488\ dob$	0.760	0.99	26.59	1.75-112.95	349	1970, 1973 (29 trees)
(c) Specific gravity of stem wood $S_{gsw} = 0.3944\ (1.0 - 0.7438e^{B1.97469\ dib})$	0.032	0.68	0.36	0.12-0.45	156	1973 (20 trees)
(d) Specific gravity of stem bark $S_{gsb}\ 0.3621\ (1.0 - 0.2711e^{-0\ 65811\ dib})$	0.045	0.25	0.33	0.15-0.53	156	1973 (20 trees)
(e) Specific gravity of branch wood $S_{gbw} = 0.4088$	0.060	—			93	1973 (20 trees)
(f) Specific gravity of branchbark $S_{gbb} = 0.3298$	0.046	—			93	1973 (20 trees)

[1] Definition of terms: D_s = stem basal diameter (2.5 cm above base) in cm; H = total tree height (m); dob = stem diameter outside bark (cm); dib = stem diameter inside bark (cm)

[2] Uncorrected R^2 values were all higher than those given and in no cases less than 0.98

[3] Diameters in this equation are in mm.

Table 2.— *Biomass Relations for* Populus 'Tristis *#1*'

Equation[1]	Standard error[2]	[3]R^2	Basis No. of observations	Dependent variable[4] mean
(a) Stem wood weight $w_1 = 43.1256\ D^{2.23921}\ H^{0.29812}$	10.80	0.98	247	471.60
(b) Stem bark weight $w_2 = 21.6690\ D^{1.76075}\ H^{0\ 19632}$	5.38	0.92	217	94.81
(c) Branch wood weight $w_3 = 91.7349\ D^{4\ 18068}\ H^{-2.37816}$	17.97	0.65	215	118.49
(d) Branch bark weight $w_4 = 38.4169\ D^{3.35658}\ H^{-1.51204}$	8.53	0.74	215	71.04
(e) Leaf weight $w_5 = 205.7909\ D^{3\ 55347}\ H^{-2.48585}$	13.48	0.71	217	96.67
(f) Total tree weight $w_6 = \sum_{i=1}^{5} w_i$ or $w_6 = 274.3524\ D^{2.90672}\ H^{-0.91102}$	37.16	0.94	215	793.94
(g) Stem wood specific gravity $S_g = 0.3928\ (1.0 - 0.5909e^{-1.65546\ D})$	0.0021	0.99	40 (1973 data)	0.3813

[1] Definition of terms: w_i = component dry weight in grams above a 0.03 m stump, D = tree diameter at breast height (1.37 m) in cm, H = total tree height in m.

[2] Fit statistics for equations (a)-(f) were based on weighted nonlinear regression with weights = $1/(D^2H)$.

[3] Corrected R^2 values.

[4] Range in tree D was 0.5-9.1 cm.

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CUTTING DIAMETER INFLUENCES EARLY SURVIVAL AND GROWTH OF SEVERAL *POPULUS* CLONES

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ABSTRACT.—The effects of cutting diameter on early survival and growth of several *Populus* clones were studied in field tests in Wisconsin and Michigan. Generally, large diameter cuttings survived and grew better than small diameter cuttings. Response differences among clones were evident.

KEY WORDS: vegetative propagation; tree plantations; dormant hardwood cuttings.

Plantations of fast-growing clones of *Populus* hybrids and selections in the sections of Aigeiros and Tacamahaca are most efficiently established by planting dormant cuttings from 1-year-old stems. These clones possess preformed root primordia that enable them to root and grow when planted on favorable sites (Shapiro 1958, Smith and Wareing 1974). However, to obtain best survival and growth it is necessary to select the most vigorous cutting material. Because the factors responsible for cutting vigor are not well defined or understood, the propagator or nursery manager must rely on a variety of criteria such as stem age, collection time, overall appearance, and dimensions to collect the best material.

The possible correlation between cutting diameter and establishment success has been investigated only to a limited extent in *Populus*. Generally, it has been found that small diameter cuttings obtained from the tip portions of shoots have fewer preformed root primordia (Smith and Wareing 1974) and do not root or grow as well as those from basal portions (Bloomberg 1959, 1963, Hartmann and Kester 1975, Ying and Bagley 1977). However, overall results of this kind of research seem to have been inconsistent.

To determine the importance of cutting diameter on early field performance of some promising *Populus* clones, we studied the effect of a range of diameter classes on first-year survival and shoot growth at two locations in the Lake States.

MATERIALS AND METHODS

Two separate studies were begun in 1978— one in northern Wisconsin at the North Central Forest Experiment Station's Harshaw Experimental Farm near Rhinelander, Wisconsin, and the other in East Lansing, Michigan, at the Michigan State University Tree Research Center.

Data from both experiments were subjected to analysis of variance. Means from the Rhinelander study were compared using the method of Newman and Keuls and means from the East Lansing study were compared using the Least Significant Difference method (Snedecor and Cochran 1967).

Rhinelander Study

The three clones selected for the Rhinelander study were *Populus* cv. 'Betulifolia' x *P. trichocarpa* Torr. & Gray (NE 299);[1] *Populus nigra* L. x *P. laurifolia* Ledeb. (NE 1), and *Populus tristis* Fisch. x *P. balsamifera* L. cv. 'Tristis #1' (NC 5260). One-year-old coppice shoots of each clone were collected in January and cut into 20 cm lengths. The cuttings were then sorted into diameter classes of <6, 6, and 9 to 16 mm (measured in the middle of the cutting), sealed in heavy polyethylene bags, and stored at 2.8°C until planting.

On June 20, the cuttings were hand planted about 15 cm deep in a fertile, sandy loam soil in an area prepared by discing. Cuttings were planted 0.3 m apart within the row; rows were 0.6 m apart. The design was a randomized complete block design with 20 cuttings of a diameter class in each of 3 replications. Plots were hand weeded and irrigated as needed. Survival and shoot height were recorded for the various treatments at the end of the first growing season on September 21.

East Lansing Study

The three clones selected for the East Lansing study were *Populus* cv. 'rasumowskyana' x *P.* cv. 'incrassata' (NE 58); *Populus* x *euramericana* (Dode) Guinier cv. 'I45/51' (NC 5328), and *Populus deltoides* Bartr. x *P.* cv. 'caudina' (NE 353). Hardwood cuttings 25 cm long were harvested from 1-year-old coppice shoots in March and stored in polyethylene bags with moist sphagnum moss at 2°C. Cuttings were sorted into small-end diameter classes just before planting as follows: <6, 6 to 10, 10 to 13, 13 to 16, and 16 to 19 mm.

Cuttings were hand planted about 23 cm deep in nursery beds on June 30 and July 3. The sandy loam soil was rototilled several times before planting. Cuttings were planted at 0.3 by 0.6 m spacing in a split plot, randomized block design with eight cuttings per plot and four replications. Plots were hand weeded and irrigated as needed. Three weeks after growth began, each cutting was pruned to just one shoot. Plants were sprayed once with the insecticide Sevin in mid-August to control the cottonwood leaf beetle (*Crysomela scripta*). Height and survival of shoots were measured every 2 weeks beginning on July 21. On September 25, shoots of two trees from each treatment combination were randomly selected, harvested, oven-dried at 70°C, and weighed.

RESULTS AND DISCUSSION

In both the Rhinelander and East Lansing studies, cutting survival and shoot length growth were significantly influenced by cutting diameter (tables 1 and 2). In general, large diameter cuttings survived better and produced taller shoots than small diameter cuttings. Large diameter cuttings also produced shoots with a greater dry weight than small diameter cuttings in the East Lansing study (table 2).

Clones differed distinctly in their response to cutting diameter. For example, clone NC 5328 showed 100 percent survival regardless of the size of cuttings, whereas clone NC 5260 showed only 38 percent survival of small diameter cuttings and 93 percent survival of large diameter cuttings. The contrast in these two clones is also shown by the shoot length data. The difference in shoot growth between large and small cuttings for clone NC 5328 averaged only 14 percent but for clone NC 5260 was 250 percent. The four other clones represented a spectrum of intermediate responses. The ranking of clones, based on response to cutting diameter, showed clone 5260 most responsive followed by NE 1, NE 299, NE 58, NE 353, and NC 5328. These results are in accordance with Bogdanov (1968), who showed substantial variation in the survival and growth response to cutting diameter among six Populus clones.

Differences in height between cuttings of various diameters for the three clones used in the Michigan experiment were recorded from July 21 onward (fig. 1). In general, shoots from small cuttings were ⅓ to ⅔ as tall as those from large cuttings during the first 5 weeks after planting. This is the period when unrooted cuttings are most susceptible to environmental stress and weed competition (Aird 1962, Schreiner 1945). The sooner cuttings become established and gain dominance over weed competition, the greater will be the first-year success of a plantation.

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[1] *Northeastern Forest Experiment Station (NE) numbers are used where possible to designate clones mentioned in the text. Otherwise, North Central Forest Experiment Station (NC) numbers are used. NE 1 = NC 5272; NE 299 = NC 5331.*

Table 1.—*Effect of cutting diameter on survival and shoot length of hardwood cuttings of three* Populus *clones after 13 weeks growth in Rhinelander, Wisconsin*

Cutting Diameter (mm)	Clone[1]					
	NC 5260		NE 1		NE 299	
	Survival	Shoot length	Survival	Shoot length	Survival	Shoot length
	Percent	*cm*	*Percent*	*cm*	*Percent*	*cm*
<6	38 c	14 c	43 b	56 c	57 b	39 b
6	63 b	26 b	85 a	68 b	77 ab	50 ab
9-16	93 a	35 a	93 a	95 a	95 a	58 a

[1] For each clone, means followed by the same letter are not significantly different at the 5 percent probability level (Newman-Keuls test).

Table 2.—*Effect of cutting diameter on survival and shoot growth of three* Populus *clones 11 weeks after planting in East Lansing, Michigan*

Cutting diameter (mm)	Clone[1]								
	NE 58			NE 353			NC 5328		
	Survival	Shoot length	Shoot dry weight	Survival	Shoot length	Shoot dry weight	Survival	Shoot length	Shoot dry weight
	Percent	*cm*	*g*	*Percent*	*cm*	*g*	*Percent*	*cm*	*g*
<6	69 a	54 a	16 a	97 a	98 a	25 a	100 a	65 a	28 a
6-10	88 b	61 b	18 a	100 a	102 a	36 ab	100 a	69 ab	26 a
10-13	97 bc	70 c	21 ab	100 a	90 a	33 a	100 a	73 bc	28 a
13-16	100 c	71 c	22 ab	100 a	115 b	50 b	100 a	74 c	34 ab
16-19	97 bc	80 d	28 b	—	—	—	100 a	74 c	39 b

[1] For each clone, means followed by the same letter are not significantly different at the 5 percent probability level (least significant difference).

In the present experiments the difference in growth rate between cuttings of various diameters was less after the first 5 weeks (fig. 1). However, if weeds had not been controlled or if supplemental water were not applied, differences in growth rate between cuttings of various sizes probably would have been greater. Again, contrasts between clones were evident. Clone NE 58, which was moderately responsive to cutting diameter, showed differential growth throughout the first 7 weeks, whereas the unresponsive clone NC 5328 evidenced little effect of cutting size on growth after the first 5 weeks. Clone NE 353 showed a more complex growth response but was generally intermediate between NE 58 and NC 5328.

CONCLUSIONS

Establishment of plantations of *Populus* hybrids showing high survival and good growth requires that many conditions be met, one of which is to use high quality hardwood cutting stock. An important measure of cutting quality revealed by this study is diameter— survival and growth generally increase with increasing cutting diameter. Although clones differed in their response to cutting diameter, cuttings <6 mm average diameter of all *Populus* clones should not be used for field plantings.

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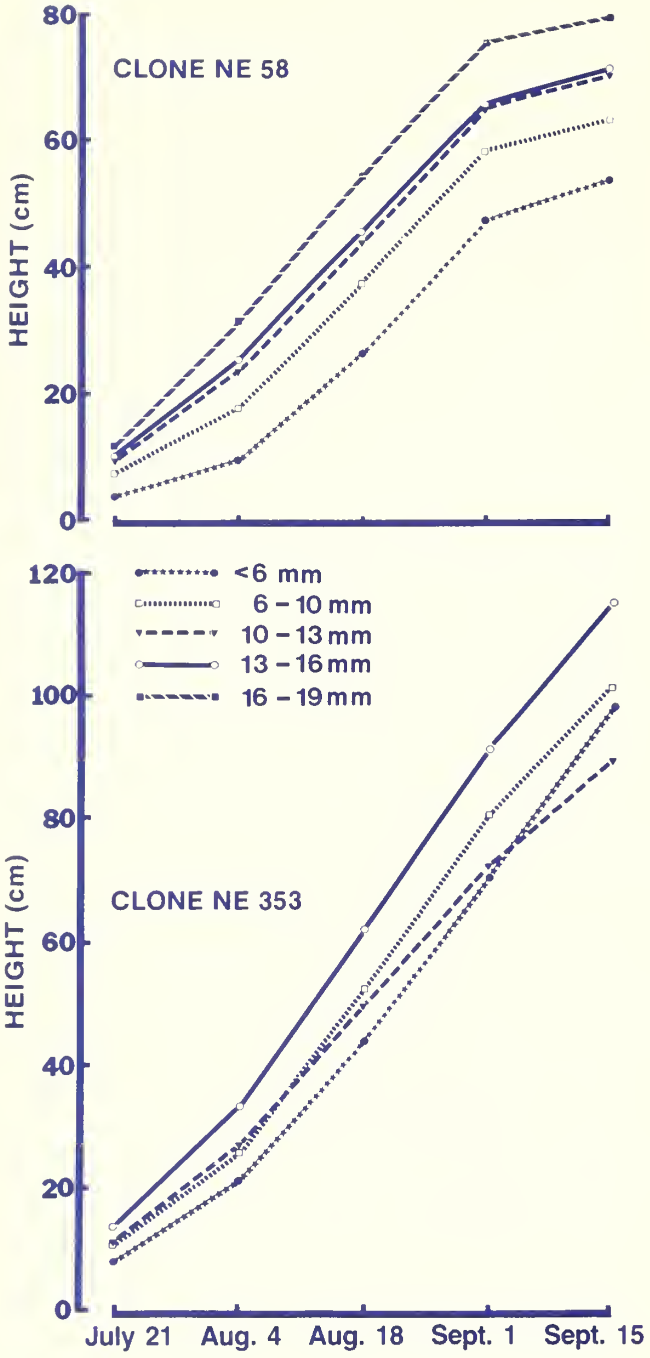

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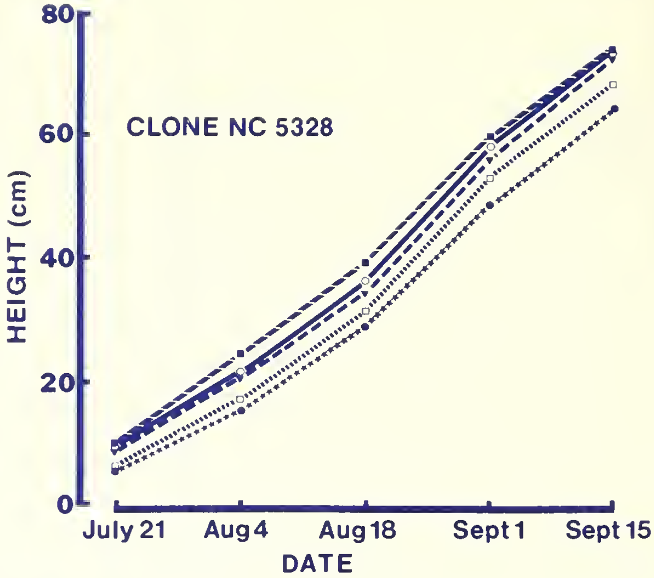

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TIMBER VOLUME IN MINNESOTA, 1977

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Mensurationist

ABSTRACT.—Presents statistics on Minnesota's growing-stock and sawtimber volumes by county for 1977. Includes a map showing growing-stock volume classes by county.

KEY WORDS: Growing stock, sawtimber, species, counties.

Minnesota's 13.7 million acres of commercial forest land supported 11.4 billion cubic feet of growing-stock[1] in 1977. This is an increase of 21 percent since the last inventory in 1962, despite a decrease in the commercial forest land base of 11 percent. However, this increase was not distributed proportionally among all species. Volume in softwoods increased a modest 3 percent while volume in hardwood species jumped 32 percent in the 15 years between inventories. These increased volumes reflect a maturing of Minnesota's forest with average growing-stock volume per acre increasing from 613 cubic feet (7.8 cords per acre) in 1962 to 836 cubic feet (10.6 cords per acre) in 1977. Growing stock trends are shown in the following tabulation:

Growing stock	[2]1962	1977
	(Million cubic feet)	
Softwoods	3,384	3,477
Hardwoods	6,060	7,977
Total	9,444	11,454

Aspen is the most abundant species in Minnesota accounting for 30 percent of the growing-stock volume. Its volume increased by 22 percent between surveys. Paper birch, the second most plentiful species in the State, showed an even more dramatic increase of 50 percent. The third most prominent species, balsam fir, increased 17 percent in the 15 years between inventories. The volumes of the other two species in the top five, spruce and jack pine, declined by 12 and 17 percent, respectively. These five species make up three-fifths of the growing-stock volume in Minnesota. The following tabulation shows growing-stock volumes of these species.

Species	Growing stock (Million cubic feet)
Aspen	3,411
Paper birch	1,274
Balsam fir	894
Spruce	718
Jack pine	594

Included in the growing-stock volume are 25 billion board feet of sawtimber,[3] expanded from 15 billion in 1962. This is an even more rapid accumulation of volume than growing stock, with softwoods expanding by 39 percent and hardwoods by 84 percent.

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[1] *Net volume of all live merchantable trees 5 inches d.b.h. and larger from the stump to a variable 4-inch top diameter outside bark of the central stem. Does not include limbs or cull tree volume.*

[2] *Figures have been adjusted from those published after the 1962 survey to conform to 1977 volumes because of changes in survey procedures and definitions.*

[3] *Net volume of live merchantable sawtimber trees (softwoods 9.0 inches d.b.h. or larger and hardwoods 11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn products is limited by large branches, forks, or other defects, or by a diameter outside bark 7.0 inches for softwoods and 9.0 inches for hardwoods.*

Average sawtimber volume per acre increased from 965 to 1,797 board feet between surveys. Sawtimber trends are shown in the following tabulation:

Sawtimber	**[4]1962**	**1977**
	(Million board feet)[5]	
Softwoods	6,133	8,531
Hardwoods	8,742	16,077
Total	14,875	24,608

As in growing stock, aspen is by far the leading sawtimber species in Minnesota, comprising 25 percent of the volume. Aspen also showed the most rapid growth, increasing by 170 percent in the 15 years between surveys. Red pine is the second-ranked sawtimber species, accounting for 8 percent of the total volume. Red oak, elm, and jack pine, in that order, are the other most abundant sawtimber species in Minnesota. Volumes of all these species have increased since 1962. These five species account for over one-half of the State's sawtimber volume. Shown below are the sawtimber volumes of these species:

Species	**Sawtimber**
	(Million board feet)[5]
Aspen	5,975
Red pine	1,953
Red oak	1,820
Elm	1,607
Jack pine	1,566

The major concentrations of timber are found in a 17-county area in northern Minnesota encompassing the Aspen-Birch and Northern Pine Survey Units (fig. 1). This area contains more than 80 percent of the State's growing stock volume and 77 percent of the State's sawtimber volume. Ninety-seven percent of the State's pine growing-stock volume and 99 percent of its spruce volume is found here. The distribution of growing-stock volumes by survey unit is shown below:

Survey Unit	**Growing-stock volume**	
	Softwoods	**Hardwoods**
	(Percent)	
Aspen-Birch	54.3	33.0
Northern Pine	43.4	44.0
Central Hardwood	2.2	18.5
Prairie	0.1	4.5
Total	100.0	100.0

These statistics are based on results from the cooperative Forest Inventory conducted from July 1974 to July 1978 by the North Central Forest Experiment Station and the Minnesota Department of Natural Resources. This is one of a number of reports that will be prepared to make these resource statistics available.

Sampling error (at one standard deviation) is estimated to be ±1.04 percent for the total growing stock volume in the State of 11.4 billion cubic feet. Sawtimber sampling error is estimated to be ±1.85 percent for the State total of 24.6 billion board feet.

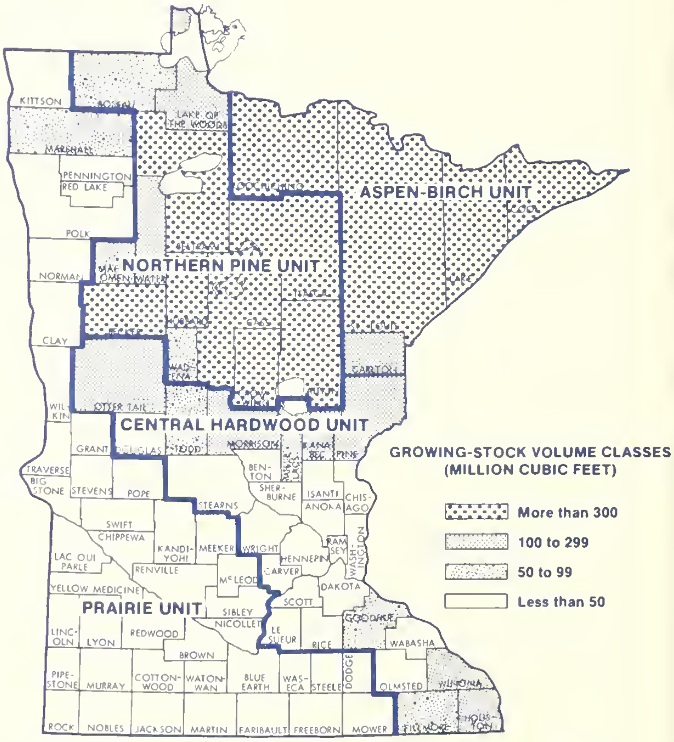

Figure 1.—*Growing stock volume in Minnesota counties, 1977.*

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[4] *Figures have been adjusted from those published after the 1962 survey to conform to 1977 volumes because of changes in survey procedures and definitions.*

[5] *International ¼-inch rule.*

Table 2.--Net volume of sawtimber[1/] on commercial forest land by species[2/] and county, Minnesota 1977

(In thousand board feet)[3/]

ASPEN-BIRCH

		Softwoods			Hardwoods						
County	All species	White and red pine	Jack pine	Other soft-woods	Sugar maple and yellow birch	Basswood	Ash and elm	Red oaks	White oaks	Aspen and paper birch	Other Hard-woods
Carlton	347,958	85,358	6,638	47,633	7,810	11,280	41,259	15,905	4,419	99,160	28,496
Cook	1,083,698	67,244	69,301	429,911	10,501	--	2,385	--	--	486,135	18,221
Koochiching	1,594,444	106,516	38,513	638,758	3,472	15,248	187,599	--	6,333	452,552	145,453
Lake	1,466,852	167,801	86,183	446,024	51,736	8,824	48,538	1,211	--	584,256	72,279
St. Louis	3,831,644	685,486	388,952	876,910	10,481	29,178	209,577	6,169	3,022	1,373,384	248,485
Total	8,324,596	1,112,405	589,587	2,439,236	84,000	64,530	489,358	23,285	13,774	2,995,487	512,934
NORTHERN PINE											
Aitkin	1,039,872	33,952	4,144	123,950	106,188	93,966	168,790	69,744	25,811	321,415	91,912
Becker	620,361	53,149	55,290	50,634	10,714	46,920	67,327	62,776	48,217	207,410	17,924
Beltrami	1,407,730	254,212	148,006	200,846	17,270	55,007	129,970	6,823	19,484	470,334	105,778
Cass	2,027,912	603,785	178,454	213,524	11,467	57,584	96,066	92,021	45,659	669,047	60,305
Clearwater	521,323	82,592	15,719	56,306	10,733	25,648	67,338	32,191	16,444	171,997	42,355
Crow Wing	592,708	79,955	83,806	18,410	6,495	14,202	24,463	110,207	31,990	214,471	8,709
Hubbard	608,538	103,214	167,348	44,747	1,624	3,473	7,673	23,659	19,247	219,748	17,805
Itasca	2,987,983	564,648	139,345	597,974	49,080	91,870	190,418	22,196	17,575	1,099,390	215,487
Lake of the Woods	334,578	5,780	60,432	76,265	--	3,847	17,049	--	3,731	120,867	46,607
Mahnomen	168,247	568	2,196	5,559	2,688	17,612	28,115	9,407	25,666	58,145	18,291
Roseau	183,368	--	53,389	38,440	--	819	13,003	--	3,313	52,134	22,270
Wadena	128,130	18,244	44,484	2,838	--	2,912	11,266	11,699	7,361	22,387	6,939
Total	10,620,750	1,800,099	952,613	1,429,492	216,259	413,860	821,478	440,723	264,499	3,627,345	654,382
CENTRAL HARDWOOD											
Anoka	105,665	1,949	532	1,662	4,268	12,315	26,032	24,602	14,174	4,322	15,809
Benton	73,720	1,553	803	522	3,508	8,679	13,751	22,436	10,835	5,852	5,781
Carver	38,303	515	33	345	2,361	4,614	9,880	7,626	4,286	1,045	7,598
Chisago	136,656	2,195	939	3,211	7,284	16,132	34,802	27,172	15,986	8,141	20,794
Oakota	45,496	997	128	1,179	1,731	3,585	14,594	8,864	4,629	2,682	7,107
Douglas	35,423	750	240	930	1,554	4,491	8,760	7,944	4,798	3,828	2,128
Fillmore	183,563	3,823	1,390	769	5,092	17,826	30,721	68,538	32,281	11,222	11,901
Goodhue	182,049	2,302	600	817	7,418	16,171	32,529	70,644	25,617	9,360	16,591
Hennepin	26,870	321	25	357	1,573	3,484	7,736	3,722	2,629	866	6,157
Houston	392,741	2,951	609	604	15,603	35,314	63,564	171,596	55,055	14,157	33,288
Isanti	97,605	1,979	1,616	4,113	3,833	9,793	23,916	22,659	12,542	7,179	9,975
Kanabec	255,196	7,480	575	5,972	11,596	26,315	54,229	58,390	27,571	45,021	18,047
Le Sueur	36,716	329	36	573	2,795	3,707	11,166	4,987	2,923	1,077	9,123
Mille Lacs	247,242	6,224	299	5,744	13,382	32,758	56,442	49,119	25,140	43,057	15,077
Morrison	366,219	7,673	2,810	5,661	11,756	36,663	72,568	116,113	57,408	27,419	28,148
Olmsted	91,348	2,121	564	492	2,302	9,983	15,888	32,737	16,447	4,925	5,889
Otter Tail	345,069	11,514	1,188	8,076	19,743	48,837	75,680	66,316	32,725	66,325	14,665
Pine	588,231	32,830	5,771	19,555	28,465	60,411	113,321	81,813	44,873	175,996	25,196
Ramsey	--	--	--	--	--	--	--	--	--	--	--
Rice	44,855	371	20	432	3,746	5,825	13,111	5,053	3,811	1,736	10,750
Scott	51,873	531	50	530	3,690	5,885	14,137	9,092	5,157	1,276	11,525
Sherburne	167,266	2,337	1,574	719	5,723	16,215	27,095	68,574	25,738	7,354	11,937
Stearns	178,922	2,987	426	883	6,842	19,442	32,635	63,431	28,054	9,939	14,283
Todd	222,937	4,162	678	4,266	1,701	31,242	54,487	49,230	25,317	27,909	23,945
Wabasha	162,174	2,847	960	1,099	4,630	15,059	27,907	61,474	26,511	9,822	11,865
Washington	34,426	369	25	600	2,284	4,032	10,658	3,461	2,646	1,442	8,909
Winona	360,560	3,030	855	479	13,333	31,594	56,125	160,384	52,114	15,146	27,500
Wright	82,629	1,457	398	1,058	3,701	9,599	17,061	24,540	11,625	7,776	5,414
Total	4,553,754	105,597	23,144	70,648	189,914	489,971	918,795	1,290,517	570,892	514,874	379,402

(Table 2 continued on next page)

(Table 1 continued)

	PRAIRIE											
		Softwoods						Hardwoods				
County	All species	White and red pine	Jack pine	Spruce	Balsam fir	Tamarack and cedar	Other soft-woods	Elm-ash basswood	Oaks	Aspen	Paper birch	Other hard-woods
Big Stone	1,574	--	--	--	--	--	2	566	282	282	22	420
Blue Earth	19,767	--	--	2	--	--	93	9,337	5,596	983	118	3,638
Brown	8,526	--	--	--	--	--	66	3,837	2,498	469	53	1,603
Chippewa	2,438	--	--	--	--	--	5	859	381	487	40	666
Clay	7,296	--	--	12	--	--	8	2,278	1,881	1,435	149	1,533
Cottonwood	2,153	--	--	--	--	--	--	972	292	382	18	489
Dodge	6,136	--	--	--	--	--	69	2,633	2,231	162	36	1,005
Fairbault	5,608	--	--	--	--	--	6	2,889	1,091	446	35	1,141
Freeborn	4,339	--	--	2	--	--	43	1,759	1,543	221	32	739
Grant	2,715	--	--	--	--	--	1	1,019	806	461	57	371
Jackson	1,958	--	--	--	--	--	3	829	524	207	12	383
Kandiyohi	7,947	--	--	3	--	--	57	2,726	2,964	709	72	1,416
Kittson	32,021	186	110	46	68	93	13	3,587	4,452	16,958	185	6,323
Lac qui Parle	3,580	--	--	1	--	--	2	1,727	476	480	32	862
Lincoln	1,867	--	--	--	--	--	9	751	529	230	15	333
Lyon	3,485	--	--	--	--	--	10	1,615	697	359	26	778
McLeod	5,839	--	--	--	--	--	1	2,993	1,539	310	40	956
Marshall	63,118	233	138	201	82	166	41	9,233	9,543	29,098	550	13,833
Martin	3,085	--	--	--	--	--	1	1,318	568	521	28	649
Meeker	9,998	--	--	--	--	--	31	4,752	3,201	208	40	1,766
Mower	4,959	--	--	--	--	--	46	2,159	1,686	204	30	834
Murray	790	--	--	--	--	--	--	359	186	72	5	168
Nicollet	11,490	--	--	1	--	--	20	5,561	3,073	601	49	2,185
Nobles	523	--	--	--	--	--	--	177	86	135	8	117
Norman	15,448	7	4	17	2	4	7	4,318	2,343	5,353	167	3,226
Pennington	20,227	23	14	33	8	12	8	4,457	3,049	8,665	140	3,818
Pipestone	382	--	--	--	--	--	3	141	92	69	4	73
Polk	48,740	24	14	91	8	16	53	15,102	9,275	14,344	550	9,263
Pope	4,762	1	1	10	--	9	22	1,384	1,084	1,120	54	1,077
Red Lake	17,932	18	11	23	6	9	25	3,574	2,897	8,048	94	3,227
Redwood	4,783	--	--	3	--	--	31	1,802	1,230	668	50	999
Renville	6,586	--	--	6	--	4	33	2,929	1,670	584	47	1,313
Rock	319	--	--	--	--	--	1	125	48	49	5	91
Sibley	10,382	--	--	--	--	--	51	4,914	3,029	562	73	1,753
Steele	4,560	--	--	2	--	--	24	2,004	1,438	283	34	775
Stevens	741	--	--	--	--	--	--	270	158	184	17	112
Swift	3,494	--	--	--	--	--	7	1,420	626	639	46	756
Traverse	509	--	--	--	--	--	2	151	80	107	11	158
Waseca	4,007	--	--	--	--	--	10	1,910	1,158	166	23	740
Watonwan	897	--	--	--	--	--	--	557	81	19	--	240
Wilkin	225	--	--	--	--	--	1	49	41	65	7	62
Yellow Medicine	7,006	--	--	--	--	--	20	3,060	1,699	881	74	1,272
Total	362,212	492	292	453	174	313	825	112,103	76,123	97,226	3,048	71,163
All Units	11,453,997	629,353	593,704	717,920	893,608	637,804	4,618	1,371,947	939,835	3,410,720	1,273,982	980,506

[1] Net volume of all live merchantable trees 5 inches d.b.h. and larger from the stump to a variable 4-inch top diameter outside bark of the central stem. Does not include limbs or cull tree volume.

[2] Species groups: Other softwoods-eastern redcedar. Other hardwoods - hickories, yellow birch, maples, butternut, black walnut, black cherry, boxelder, river birch, hackberry, cottonwood, black willow and balsam poplar.

Table 1.--Net volume of growing stock[1] on commercial forest land by species[2] and county, Minnesota 1977

(In thousand cubic feet)

		Softwoods						Hardwoods				
County	All species	White and red pine	Jack pine	Spruce	Balsam fir	Tamarack and cedar	Other soft-woods	Elm-ash basswood	Oaks	Aspen	Paper birch	Other hard-woods
						ASPEN-BIRCH						
Carlton	210,376	17,082	1,767	8,700	17,047	8,117	--	35,370	8,810	57,322	33,721	22,440
Cook	534,017	11,613	21,913	82,685	97,165	31,744	--	7,091	--	171,395	96,544	13,867
Koochiching	928,923	22,753	20,709	170,474	100,736	135,430	--	81,790	1,673	262,888	47,414	85,056
Lake	694,029	33,460	26,106	79,868	85,162	54,112	--	26,747	325	158,441	172,099	57,709
St. Louis	2,154,730	153,850	142,077	214,729	259,277	92,221	138	126,339	3,816	736,692	270,997	154,594
Total	4,522,075	238,758	212,572	556,456	559,387	321,624	138	277,337	14,624	1,386,738	620,775	333,666
						NORTHERN PINE						
Aitkin	487,614	6,128	2,244	13,430	22,870	33,898	184	121,016	38,165	123,423	54,527	71,729
Becker	305,068	11,130	22,148	5,213	9,606	7,191	--	46,437	41,542	107,449	38,416	15,936
Beltrami	683,735	54,307	50,695	26,326	40,957	71,526	--	81,272	16,135	213,220	60,633	68,664
Cass	854,270	115,379	70,765	13,579	50,581	34,875	89	72,866	70,614	274,528	114,616	36,378
Clearwater	266,797	15,612	6,016	5,127	10,647	11,151	--	41,026	18,721	100,995	28,339	29,163
Crow Wing	327,167	17,713	40,629	1,223	4,680	5,501	--	24,342	72,741	109,000	40,456	10,882
Hubbard	344,524	23,132	66,626	5,981	7,290	5,252	--	12,193	29,079	147,637	34,933	12,401
Itasca	1,297,155	112,208	45,407	59,340	166,592	77,511	121	137,473	24,626	426,676	141,622	105,579
Lake of the Woods	192,801	2,920	24,196	18,428	11,176	28,461	--	9,217	965	58,679	12,735	26,024
Mahnomen	91,371	120	1,375	318	271	1,067	--	26,815	16,745	29,118	6,114	9,428
Roseau	99,416	--	16,466	6,007	3,362	13,351	--	9,020	1,178	29,068	4,693	16,271
Wadena	72,976	4,870	24,122	779	102	1,183	--	5,144	8,014	22,466	1,680	4,616
Total	5,022,894	363,519	370,689	155,751	328,134	290,967	394	586,821	338,525	1,642,259	538,764	407,071
						CENTRAL HARDWOOD						
Anoka	28,414	580	241	27	25	693	54	9,393	9,703	2,202	1,092	4,404
Benton	22,075	846	425	25	36	127	18	5,750	8,219	2,758	1,345	2,526
Carver	9,221	97	14	4	5	143	11	3,346	2,838	487	269	2,007
Chisago	39,317	1,032	479	137	101	1,286	78	13,003	11,236	3,960	1,733	6,272
Dakota	13,381	222	63	31	34	570	36	5,006	3,582	1,367	548	1,922
Douglas	12,281	151	84	27	38	284	37	3,776	3,588	2,208	800	1,288
Fillmore	54,832	747	472	1	18	162	192	12,345	26,634	5,949	3,055	5,257
Goodhue	52,365	558	247	11	29	258	139	12,783	24,755	4,440	2,724	6,421
Hennepin	6,455	64	12	6	6	160	8	2,595	1,547	394	170	1,493
Houston	106,619	574	227	11	21	114	159	25,170	55,301	6,244	5,241	13,557
Isanti	32,797	1,454	797	183	100	1,620	93	9,499	9,734	3,942	1,657	3,718
Kanabec	101,060	1,555	302	297	381	2,038	166	24,854	26,728	26,220	8,880	9,639
Le Sueur	9,030	71	18	10	10	259	11	3,628	1,955	520	237	2,311
Mille Lacs	95,532	1,323	219	285	389	1,985	194	26,964	23,362	22,976	8,239	9,596
Morrison	115,167	1,932	1,095	130	141	2,025	347	29,550	46,689	14,803	6,609	11,846
Olmsted	26,266	405	191	1	7	140	81	6,359	12,635	2,572	1,370	2,505
Otter Tail	140,234	2,524	667	487	730	2,601	373	38,361	32,445	35,703	13,047	13,296
Pine	299,170	8,336	2,699	3,209	3,225	7,399	175	60,644	48,972	107,800	33,398	23,313
Ramsey	--	--	--	--	--	--	--	--	--	--	--	--
Rice	10,778	73	10	19	14	136	12	4,387	2,153	820	321	2,833
Scott	12,340	103	20	9	7	222	12	4,666	3,382	589	328	3,002
Sherburne	48,087	985	601	94	174	151	392	11,124	23,494	3,543	2,367	5,162
Stearns	49,181	574	149	30	47	283	66	13,060	22,172	4,286	2,661	5,853
Todd	77,260	846	308	162	259	1,262	154	24,637	21,722	14,058	5,306	8,546
Wabasha	48,661	564	336	8	23	342	164	11,232	23,294	5,049	2,733	4,916
Washington	8,726	81	15	21	19	328	8	3,510	1,553	779	281	2,131
Winona	100,794	597	311	2	22	32	199	22,691	52,859	6,915	5,270	11,896
Wright	26,773	290	149	33	52	280	82	7,353	10,011	3,913	1,714	2,896
Total	1,546,816	26,584	10,151	5,260	5,913	24,900	3,261	395,686	510,563	284,497	111,395	168,606

(Table 1 continued on next page)

(Table 2 continued)

PRAIRIE

County	All species	Softwoods: White and red pine	Softwoods: Jack pine	Softwoods: Other Softwoods	Hardwoods: Sugar maple and yellow birch	Hardwoods: Basswood	Hardwoods: Ash and elm	Hardwoods: Red oaks	Hardwoods: White oaks	Hardwoods: Aspen and paper birch	Hardwoods: Other Hard-woods
Big Stone	5,317	--	--	5	--	585	2,042	48	1,041	259	1,337
Blue Earth	88,482	--	--	143	4,462	17,264	30,215	7,753	16,833	889	10,923
Brown	37,925	--	--	96	1,392	6,895	12,240	4,026	6,870	474	5,932
Chippewa	7,575	--	--	10	--	791	3,087	87	1,221	458	1,921
Clay	23,101	--	--	84	558	1,077	9,012	802	6,452	1,026	4,090
Cottonwood	7,863	--	--	--	--	925	3,699	62	1,043	363	1,771
Dodge	28,198	--	--	100	1,137	5,668	7,622	3,777	6,046	136	3,712
Fairbault	24,300	--	--	9	654	4,015	10,739	701	3,998	436	3,748
Freeborn	19,191	--	--	72	815	3,787	5,000	2,515	4,249	165	2,588
Grant	9,536	--	--	2	239	455	4,371	343	2,940	286	900
Jackson	7,902	--	--	4	404	1,328	2,670	554	1,696	183	1,063
Kandiyohi	33,130	--	--	102	114	4,626	8,936	1,784	11,727	649	5,192
Kittson	44,047	1,198	416	331	--	2,203	8,843	1,380	9,620	10,361	9,695
Lac qui Parle	14,047	--	--	12	--	1,720	6,772	110	1,822	483	3,128
Lincoln	7,511	--	--	13	171	1,150	2,498	539	1,759	203	1,178
Lyon	14,137	--	--	15	247	2,364	5,582	743	2,243	350	2,593
McLeod	26,304	--	--	1	1,471	4,930	10,802	921	5,794	216	2,169
Marshall	111,282	1,500	521	980	285	5,973	27,094	2,522	24,699	19,448	28,260
Martin	11,394	--	--	1	330	1,564	4,730	342	1,891	474	2,062
Meeker	47,438	--	--	44	3,778	10,411	13,788	5,672	9,258	196	4,291
Mower	22,417	--	--	66	1,085	4,524	6,288	2,975	4,460	175	2,844
Murray	3,197	--	--	1	75	651	1,140	159	722	64	385
Nicollet	52,093	--	--	36	3,528	10,426	17,486	4,997	9,010	592	6,018
Nobles	1,553	--	--	1	--	115	660	10	279	118	370
Norman	39,652	45	16	105	--	2,960	15,318	532	7,033	4,386	9,257
Pennington	43,803	148	51	200	185	3,567	14,463	1,225	8,371	6,732	8,861
Pipestone	1,338	--	--	4	6	175	478	95	253	59	268
Polk	144,142	154	54	559	1,532	13,240	56,532	3,931	31,043	11,202	25,895
Pope	14,027	6	2	42	141	1,414	4,474	797	2,990	962	3,199
Red Lake	36,804	116	40	165	185	3,493	10,269	1,904	7,237	6,334	7,061
Redwood	17,862	--	--	62	139	2,637	5,966	1,187	3,849	581	3,441
Renville	27,371	--	--	56	729	4,201	10,107	2,024	4,955	552	4,747
Rock	1,054	--	--	1	--	155	429	19	157	48	245
Sibley	46,617	--	--	73	2,268	8,883	16,268	4,068	9,289	458	5,310
Steele	20,074	--	--	43	1,239	3,962	5,996	2,512	3,936	216	2,170
Stevens	2,389	--	--	1	--	124	1,166	7	600	139	352
Swift	12,142	--	--	10	12	1,542	5,213	303	2,085	542	2,435
Traverse	1,477	--	--	3	--	76	569	5	243	106	475
Waseca	18,469	--	--	15	1,566	4,055	5,519	2,469	2,954	165	1,726
Watonwan	4,240	--	--	--	--	724	2,125	50	354	52	935
Wilkin	537	--	--	1	--	18	160	--	117	52	189
Yellow Medicine	28,157	--	--	30	625	3,801	11,260	1,560	5,741	763	4,377
Total	1,108,095	3,167	1,100	3,498	29,372	148,474	371,628	65,510	226,880	71,353	187,113
State Total	24,607,195	3,021,268	1,566,444	3,942,874	519,545	1,116,835	2,601,259	1,820,035	1,076,045	7,209,059	1,733,831

[1] Net volume of live merchantable sawtimber trees (softwoods 9.0 inches d.b.h. or larger and hardwoods 11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn produjcts is limited by large branches, forks, or other defects, or by a diameter outside bark 7.0 inches for softwoods and 9.0 inches for hardwoods.

[2] Species groups: Other softwoods - eastern redcedar. Other hardwoods--hickories, black, red, and silver maple, balsam poplar, butternut, black walnut, black cherry, boxelder, river birch, hackberry, cottonwood and black willow.

[3] International 1/4-inch rule.

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1981

SUMMER MOISTURE CONTENT OF SOME NORTHERN LOWER MICHIGAN UNDERSTORY PLANTS

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ABSTRACT.—Summer moisture contents and factors for converting fresh plant weights to ovendry weights were determined for selected herbs, ferns, and small shrubs commonly found on upland sites in northern Lower Michigan. Sampling was done weekly from mid-June through early September 1978, following the period of major plant growth. Average summer moisture contents ranged from 120 percent for blueberry (*Vaccinium* spp.) to 370 percent for wild lily-of-the-valley (*Maianthemum canadense*). Generally, moisture content decreased through the summer. Moisture content averages and trends were similar for plant groups sampled in both northern Lower Michigan and northeastern Minnesota. Herbaceous fuel moisture percentages computed using the 1978 National Fire Danger Rating System for the same time period showed a similar general trend but were significantly lower than observed values.

KEY WORDS: forest fuels, fuel modeling, plant biomass, fire danger.

The moisture content of shrubs, ferns, and herbaceous plants can greatly influence wildland fire behavior. In fact, live fuel moisture input is required for predicting fire behavior (Rothermel 1972, Albini 1976, Deeming *et al.* 1977). Moisture content information is also used to compute factors for converting field green weights to dry weights, which are used to determine forest fuels, range forage, wildlife foods, or simply biomass.

Estimating both herbaceous and woody live fuel moisture is part of the National Fire Danger Rating System—NFDRS (Deeming *et al.* 1977, Burgan 1979). However, Loomis *et al.* (1979) found that estimates produced by the NFDRS algorithm for predicting herbaceous live fuel moistures were significantly lower than observed field measurements of live fuel moisture. This suggested a need for further study of live fuel moisture contents under other eastern forest stands.

This paper reports on live fuel moisture contents found in northern Lower Michigan and compares them to live fuel moisture contents measured in Minnesota (Loomis *et al.* 1979). Live fuel moisture estimates based on the NFDRS are also examined.

METHODS

Above-ground parts of living herbs, ferns, and small shrubs were collected weekly in Roscommon County, Michigan. Eight plant species or species groups were studied. Samples were collected from within a forest stand or from small openings. The two principal overstory species were jack pine (*Pinus banksiana* Lamb.) and northern pin oak (*Quercus ellipsoidalis* Hill). The stands were approximately 50 years old. Soils were predominantly sandy. The first samples were collected on June 13 and the last on September 6, 1978.

Ten 5-gram samples of fresh material were collected per plant group. These were sealed in metal cans, transported to the laboratory, and ovendried at 105°C for at least 16 hours. An average moisture content (expressed as percent of ovendry weight) for each plant group was determined. In addition, factors for converting green weights to ovendry weights were computed (conversion factor = ovendry weight ÷ green weight).

The time series of weekly moisture contents were examined and compared on the basis of magnitude, seasonal trend, and location. Graphical analysis, multiple comparisons, t-tests, covariance analysis, and regression analysis were the principal analytical methods used. The NFDRS live fuel moistures were computed using weather data for the Houghton Lake Airport, which is located about 10 miles from the data collection area.

RESULTS AND DISCUSSION

Average seasonal moisture contents ranged from 370 percent for wild lily-of-the-valley (*Maianthemum canadense*) to 120 percent for blueberry (*Vaccinium* spp.) (table 1). Moisture contents decreased during the summer sampling period. Therefore, we stratified the data into "early" (June 13 to July 24) and "late" (July 25 to September 6) season and computed separate averages for each.

Species differences were examined with a multiple comparison plot. Most of the plant group responses were different, but means of certain plant group combinations were not significantly different. Linear regressions of changes in moisture content yielded significant relations for all species groups except grass[1] (table 2). All regressions, including that for grass, represented expected response.

A multiple comparison plot was made for six of the eight plant groups studied in Michigan that were also studied in Minnesota during the summer of 1976 (fig. 1). Eight of 11 pairs tested were not significantly different. Moisture contents for Minnesota wild lily-of-the-valley (late), large-leaved aster (early), and

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[1] *Covariance analysis supported these combinations.*

Table 1.—*Moisture contents, standard errors, and conversion factors for some grasses, forbs, and small shrubs in northern Lower Michigan*

Plant group	All (June 13 to Sept. 6)			Early (June 13 to July 24)			Late (July 25 to Sept. 6)		
	Moisture content[1]	Standard error	Conversion[2] factor	Moisture content[1]	Standard error	Conversion[2] factor	Moisture content[1]	Standard error	Conversion[2] factor
	Percent			*Percent*			*Percent*		
Wild lily-of-the-valley *(Maianthemum canadensis)*[3]	370	15	0.21	403	18	0.20	331	10	0.23
Large-leaved aster *(Aster macrophyllus)*[3]	349	15	.22	369	27	.21	328	5	.23
Bracken fern *(Pteridium aquilinum)*[3]	258	17	.28	287	31	.26	229	7	.30
Grass[4]	200	15	.33	219	25	.31	180	14	.36
Rubus *(Rubus spp.)*[3]	167	9	.37	194	10	.34	141	4	.41
Sedge (upland) *(Carex spp.)*[3]	146	23	.41	163	8	.38	129	4	.44
Sweet fern *(Myrica asplenifolia)*	124	6	.45	140	7	.42	108	2	.48
Blueberry *(Vaccinium spp.)*[3]	120	5	.45	134	16	.43	105	2	.49

[1] Moisture content percent = (100 × moisture content ÷ ovendry weight).
[2] Conversion factor = ovendry weight ÷ green weight.
[3] Used for the comparison with data from Minnesota.
[4] Includes *Adropogon gerardi*, *Schizachyrium scoparium*, *Agropyron caninum*.

Table 2.—*Equations for predicting summer moisture contents of certain living plant groups in northern Lower Michigan: where Y = moisture content percentage, X = number of days since June 12*

Plant group	Equation	r^2	Sy·x
Wild lily-of-the-valley and Large-leaved aster	Y = 430.39–1.76X	0.38	60.
Bracken fern	Y = 320.97–1.47X	.48	46.
Grass	Y = 244.49–1.03X	.32	45.
Rubus spp.	Y = 215.30–1.11X	.94	9.
Carex spp.	Y = 176.37–0.70X	.75	12.
Sweet fern and blueberry	Y = 147.97–0.60X	.76	10.

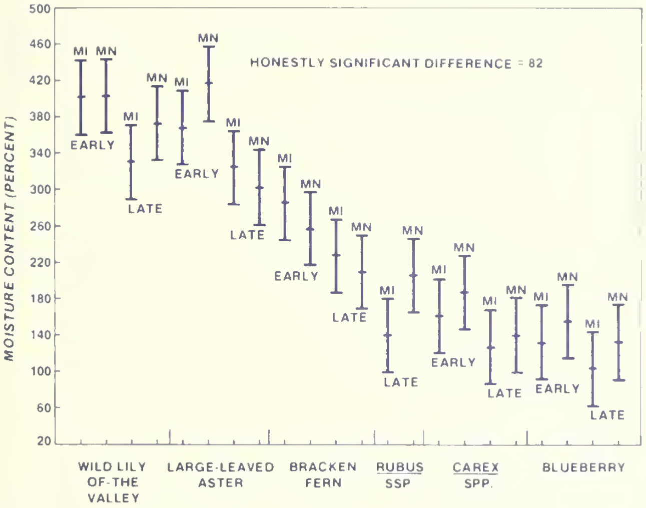

Figure 1.—*Multiple comparison of Minnesota and Michigan summer living plant moisture contents using Tukey's honestly significant differences. (HSD)*

Rubus (late) were significantly higher than those for Michigan.

The NFDRS-computed herbaceous and woody live fuel moistures for climate class 3 were calculated for the sampling period.[2] Weekly mean NFDRS moisture contents were compared to the weekly moisture contents of *Carex* spp. (low moisture content), bracken fern (medium moisture content), and large-leaved aster (high moisture content) (fig. 2). No inventory was available for determining an average herbaceous fuel moisture for Michigan as was done in the 1976 Minnesota study. However, it is obvious that the composite herbaceous fuel moisture content of any particular area can vary greatly depending upon numbers of various plant species. All herbaceous species we studied had moisture contents exceeding the NFDRS estimates, similar to results in Minnesota. Thus, use of the NFDRS herbaceous fuel moistures is not acceptable when absolute fuel moisture estimates are needed.

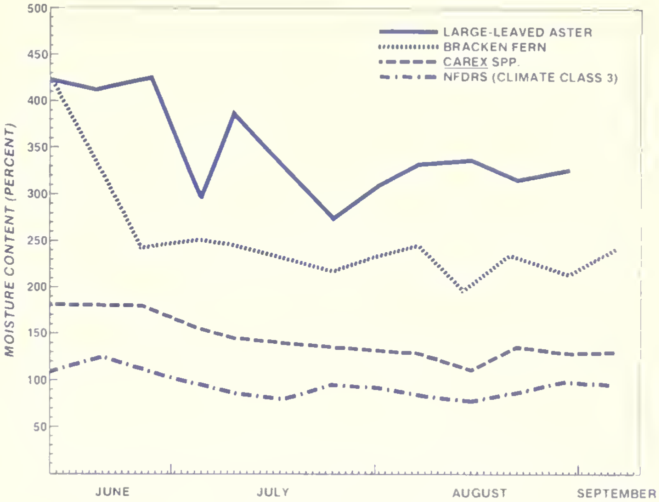

Figure 2.—*A comparison of National Fire Danger Rating System (NFDRS) climate class 3 herbaceous fuel moistures and some actual herbaceous moisture contents in Roscommon County, Michigan, 1978.*

The overall summer weather was similar for Michigan in 1978 and Minnesota in 1976 in that it was unusually dry. Thus, the plants at both locations were subjected to above average moisture stress. Samples at both locations were taken shortly after mid-day when plants would most likely be having difficulty maintaining full tugor pressure.

The moisture contents of blueberry and Rubus, which are common small woody plants, were compared with NFDRS woody fuel moisture (fig. 3). Both had statistically significant decreasing moisture trends through the season. In contrast, the NFDRS woody fuel moisture shows an increasing trend. Therefore, actual measurements again are best when absolute fuel moisture estimates are required.

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[2] *Climate class 3 was used because it is recommended for use throughout most of the eastern forest area.*

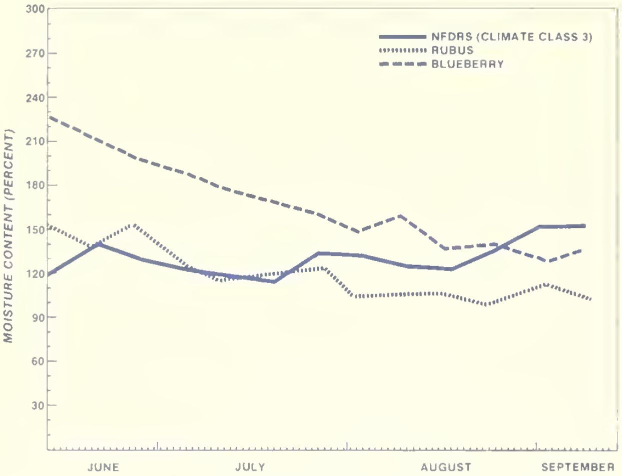

Figure 3.—*A comparison of National Fire Danger Rating System (NFDRS) climate class 3 woody fuel moistures and some actual small woody plant moisture contents in Roscommon County, Michigan, 1978.*

CONCLUSIONS

The NFDRS algorithms may be used to compute herbaceous and woody fuel moistures to estimate relative fire behavior trends for a season. However, they should not be used when absolute values are required because they are subject to error, particularly for herbaceous fuel moistures. The average moisture content values reported here are appropriate when general estimates are needed for planning over broad areas and for large trends in Lake States northern forests. The conversion factors are suitable for dry weight determination when approximate estimates are sufficiently accurate. These results further suggest that moisture response characteristics of similar plant species may be nearly uniform throughout the Lake States northern forest.

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ON-SITE SOCIAL SURVEYS AND THE DETERMINATION OF SOCIAL CARRYING CAPACITY IN WILDLAND RECREATION MANAGEMENT[1]

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ABSTRACT.—It has been suggested that on-site surveys of users fail to measure crowding accurately because long time users who knew the area before the "crowds" came tend to feel the most crowded, and thus do not return. Such "displaced" users would not be included in current on-site survey samples. Results from a limited test at the Sylvania Recreation Area in Michigan do not support this "displacement thesis." However, further research is needed in other settings to test this hypothesis more fully.

KEY WORDS: Wilderness areas, social carrying capacity, social surveys, displacement, crowding.

As use continues to intensify in backcountry recreation areas, wildland managers are under increasing pressure to establish user limitation levels, or "carrying capacities," and somehow to arrive at and justify these levels through objective analysis. "Social carrying capacity" commonly is defined as that aspect of total carrying capacity concerned with the number of other people users can tolerate and still maintain a quality experience.

Numerous studies of social carrying capacity have pointed to the weak relation between perceived crowding and satisfaction (Heberlein 1977, Randal 1977, Shelby and Nielson 1975, Lee 1975). Heberlein (1977) suggested two important processes which may contribute to this weak relation. First, old time users who knew an area before the "crowds" came tend to feel the most crowded, and thus do not return. Since these sensitive past users are no longer in the area, current on-site social surveys cannot measure their dissatisfaction. Second, many of the current users are there for the first time and have no previous experience with the area. Therefore, they tend to accept whatever level of density they experience as normal. For the purpose of discussion, we will call these two processes the "displacement effect" and the "uninitiated newcomer effect." Heberlein suggests that, as a result of these two processes, indicators from on-site social surveys will show continued high levels of satisfaction and unconcern about overcrowding as actual use and density continue to increase. Heberlein indicates that these dynamics invalidate on-site social surveys of perceived crowding and satisfaction. But do the "displacement effect" and the "uninitiated newcomer effect" really exist, or are they pronounced enough to invalidate on-site survey measures?

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[1] *This research was funded by the North Central Forest Experiment Station, USDA Forest Service.*

There is some empirical evidence supporting the "uninitiated newcomer effect" (Vaske *et al.* 1980, Nielson *et al.* 1977). However, there is no direct evidence available regarding the displacement thesis. Heberlein and co-workers have provided indirect evidence that the displacement phenomenon may exist. In a study of the Apostle Islands they found early users of the area perceived more environmental damage and viewed increases in the number of users negatively (Vaske *et al.* 1980). There was no measure of actual displacement from the area, but researchers did find certain islands were avoided by long term users who perceived more crowding. Similar "avoidance" behavior was noted in a study of Bois Brule River users (Heberlein and Vaske 1977). While this evidence is suggestive, avoidance behavior within an area is different than complete displacement and does not constitute a direct test of the displacement thesis. This paper reports one attempt to directly measure the displacement thesis in a study of backcountry users at the Sylvania Recreation Area in the Ottawa National Forest in Michigan.

STUDY METHODS

The study is composed of two surveys. The first survey was an on-site survey of users conducted in the summer of 1978. The second was a phone survey of past users of the area. Each of these surveys was used to test the above hypotheses in different ways.

In the on-site survey, a sample of 321 backcountry campers were interviewed at the Sylvania Recreation Area during July and August of 1978. Interviews were conducted during the morning and afternoon. One of these two time frames was selected randomly for each day of the 2 month period except Wednesday. A 100 percent sample was taken during each randomly selected time frame. Interviewers were placed at the two major access points (Clark Lake and Crooked Lake) to interview campers as they returned from their backcountry trips. A proportional sample also was selected from the registration cards of people who camped on Whitefish Lake, an area which has a separate remote access point that is not used frequently. These users were interviewed by phone within 10 days after their trip.

On-site surveys of current users would not be sufficient to test Heberlein's theories. Thus, a major part of this study consists of a phone survey of past users of the area. From the registration cards from the 1973 season, a random sample of users was selected. Extensive efforts were made to locate anyone who had moved. Out of a total sample of 520 persons, 301 (57 percent) were interviewed. Of the remaining 219 persons, 168 (32.2 percent) had no phone or could not be located, and 49 (9.4 percent) were located but could not be reached. There were two refusals (0.4 percent).

THE STUDY AREA

The Sylvania area is managed as a multiple use backcountry recreation area by the U.S. Forest Service. It currently is proposed for wilderness designation in the RARE II proposals by the Forest Service. This 20,000 acre backcountry is a unique area with very clear oligotrophic northern lakes. Use is limited in the backcountry to 87 designated sites. These sites are developed with latrines to insure minimum impact on the water quality. With these technological improvements, social carrying capacity is a more restrictive factor than ecological carrying capacity in the area.

We should note that the Sylvania Recreation Area may be a special case for testing the displacement thesis. Although we can distinguish early users from newcomers there, the time span involved is shorter than in many backcountry areas, since the Sylvania area was established in 1968. The displacement thesis thus needs further testing in areas with a longer history of use.

We asked in what years (1967-1978) individuals had visited the area, which permitted us to categorize users into various temporal user types. "Old timer dropouts" were defined as persons who came to the area in 1973 and at least one previous year, but who had not returned in the last 5 years. "One timers" were defined as those who came in 1973 only and had not come either before or since that year. "Recent regulars" were defined as those who came in 1973, 1974, and at least 1 year since then. "Long time regulars" were defined as persons taking at least one trip before 1973, during 1973 and 1974, and one trip between 1975 and 1978.

We asked "old timer dropouts" and "one timers" who had not returned to the area their reasons for not coming back. The responses were put into categories including "overcrowding." This allowed us to assess the importance of crowding as a reason for not returning in relation to other factors. A direct question also was asked of all respondents about overcrowding during the 1973 trip. This question was: "During your 1973 trip(s) would you say the backcountry was 'very overcrowded,' 'somewhat overcrowded,' 'not crowded,' or 'don't know'?"

Since we were asking people to remember events from 5 years ago, recall accuracy might have been a problem. Thus, we attempted to measure recall accuracy on some aspects to see how much this might affect results. We knew that all respondents had come in 1973, but when we called these individuals we said only that we were interviewing "past" users. We then asked what years they had visited Sylvania and checked to see if they accurately recalled their 1973 visit. Sixty-five percent of the respondents remembered the exact year of their visit, while 89 percent remembered within 1 year of the correct year. Thus, while there may be some distortion due to recall problems, recall accuracy was fairly good, at least to the extent we were able to measure it.

RESULTS

If Heberlein's notions about the "displacement effect" and the "uninitiated newcomer effect" are correct, we should expect the following:

1. Old timer dropouts should have felt more overcrowded than other users.
2. Newcomers should feel less crowded than old timers.
3. Persons who have not revisited the area since 1973 should tend to list overcrowding as the most important reason for not returning.

Table 1 presents data to test the first two expectations from the phone survey of 1973 users. The two newcomer types, the "one timer" and the "recent regular," showed a slight tendency to be bothered less by crowding than did the two types of old timers. However, the precentage differences are small and are not significant statistically. In comparing the two types of old timers, we found the regulars (those who came before and after 1973) felt more crowded in 1973 than did the old time dropouts (table 2). Contrary to what we expected from the displacement thesis, old timers who came back after 1973 actually felt more crowded in 1973 than old timers who did not return. In conclusion, there are no sharp differences between "old time dropouts" and "uninitiated newcomers" in their perception of crowding, and perception of crowding is not associated with old time users dropping out.

These findings from the phone survey of 1973 users are valuable because they reflect the attitudes of those who did not return after 1973. However, one drawback of the 1973 data is that the use levels during that year were quite low, therefore, the proportion of persons feeling crowded also was low. In the survey of 1973 users, only 11.5 percent of the sample felt crowded. The displacement phenomena may occur only at higher densities where more users feel crowded. That is, there may be a threshold of crowding beyond which the displacement process becomes more pronounced.

Table 1.—*Perception of crowding by temporal user type (from the phone survey of 1973 users)*

Temporal user type[1]	Perception of crowding Over-crowded	Not over-crowded	Don't know	Total
One timer	(7)	(81)	(0)	(88)
	8%	92%	0%	100%
Old timer	(3)	(24)	(0)	(27)
dropout	11%	88.9%	0%	100%
Long time	(8)	(43)	(0)	(51)
regular	15%	84%	0%	100%
Recent	(5)	(40)	(1)	(46)
regular	10.8%	87%	2.2%	100%
Other	(6)	(60)	(1)	(67)
	8.9%	86.9%	1.4%	100%

[1] Definition of Categories: "One Timer"—1973 only; "Old Timer Dropout"—1973 and at least one previous year; "Long Time Regular"—at least one trip before 1973, during 1973, 1974, and one trip between 1975 and present; "Recent Regular"—at least one trip each in 1973 and 1974, and one trip between 1975 and present.

Table 2.—*Reasons for not returning by perception of crowding*

Reasons for not returning[1]	Perception of crowding Crowded	Not crowded	Total
No time	(2)	(26)	(28)
	16.7%	21.7%	21%
Crowding	(1)	(1)	(2)
	8.3%	0.8%	1.5%
Litter	(0)	(1)	(1)
	0%	0.8%	0.8%
Moved farther	(1)	(4)	(5)
away	8.3%	3.3%	3.8%
New children in	(0)	(14)	(14)
family	0%	11.7%	10.6%
Gone elsewhere for	(4)	(45)	(49)
recreation	33.3%	37.5%	37.1%
Other	(4)	(29)	(33)
	33.3%	24%	25%
Total	(12)	(120)	(132)
	100%	100%	100%

[1] Includes both One Timers and Old Timer Dropouts

We can test this partially from the on-site survey of 1978 users. In the on-site survey of 1978 users, densities were higher and more people felt crowded (22.1 percent). The 1978 survey data does not allow us to detect directly those who did not return after 1978. However, we do have a surrogate measure. Respondents were asked whether they planned to return to the Sylvania area in the next 5 years. While this does not predict behavior precisely, a vast majority of respondents had definite future plans. Only two (0.6 percent) respondents answered the question "don't know."

Table 3 presents the results for the relation between crowding and intent to return. The displacement thesis would predict those who felt crowded would be less likely to say they would return. Here again the data do not support the displacement thesis. There is no relation between feeling crowded and the intent to return. Very few persons plan not to come back. Of those who felt crowded, the vast majority still plan to return, suggesting that crowding will not create further displacement. This further refutes the displacement thesis and possibly expands it to somewhat higher density levels.

Table 3.—*Relation between perceived crowding and intention to return to Sylvania (from the on-site survey of 1978 users)*

Intention to return or not to return to Sylvania	Perception of crowding		
	Crowded	Not crowded	Total
Definitely will return	(54) 77.1%	(190) 76.9%	(244) 77.0%
Might return	(14) 20.0%	(53) 21.5%	(67) 21.1%
Probably won't return	(1) 1.4%	(2) 0.8%	(3) 0.9%
Definitely won't return	(1) 1.4%	(0) 0%	(1) 0.3%
Don't know	(0) 0%	(2) 0.8%	(2) 0.6%
Total	(70) 100%	(247) 100%	(317) 100%

IMPLICATION

This study found that, at the Sylvania Recreation Area, older users who have not returned to the area since 1973 do not have siginficantly greater perceptions of crowding than other users, and that newcomers in 1973 did not feel significantly less crowded than older users. Persons who did drop out, did not do so because of crowding. These findings were supported from results of the 1978 survey which involved higher densities and a greater degree of perceived crowding.

We must, of course, be cautious in generalizing these findings. It is possible the dynamics Heberlein identifies may be present in other areas or at still higher levels of use. The displacement thesis should be tested in other areas, especially those with higher densities and longer histories of use. What may emerge from these cumulative findings from different areas, are hypotheses about conditions under which the displacement phenomenon will be more or less pronounced.

Rather than abandoning social survey measures of social carrying capacity, perhaps the results need only be used more sensitively. For instance, where surveys show great variability in perception of crowding, establishing a single uniform carrying capacity may not be advisable, especially where the "uninitiated newcomer effect" may raise average capacity. Rather, managers should think in terms of establishing "variable use level capacities" through spatial or temporal zoning. In situations where the displacement phenomena may be more pronounced, the extent of "old timer dropout" concern about crowding should be assessed and incorporated to help determine low density zones.

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NORTH CENTRAL FOREST EXPERIMENT STATION 1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.

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1981

"SUPER" SPRUCE SEEDLINGS CONTINUE SUPERIOR GROWTH FOR 18 YEARS

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ABSTRACT.—White spruce seedlings—20, 19, 18, and 17 inches tall—were selected among 2-2 transplants; controls from the same beds averaged 7.7 inches tall. After 18 years in the field, the selected seedlings continued to have a 30 percent height growth advantage over the controls. This note discusses how to incorporate super spruce seedlings into a tree breeding program.

KEY WORDS: *Picea glauca*, juvenile selection, tree improvement and breeding, seed production areas, vegetative reproduction.

White spruce (*Picea glauca* (Moench) Voss) seedlings selected on the basis of superior nursery growth maintained their growth advantage after 18 years of field testing. Nursery selection of super seedlings may be one way to make long-term breeding programs more efficient.

METHODS

In 1956, 696 white spruce seedlings were selected in 2-2 transplant beds of the Consolidated Paper Company's nursery east of Rhinelander in northeastern Wisconsin. The selected seedlings were grouped into four height classes: 17, 18, 19 and 20 inches (table 1). Controls were picked at random from seedlings next to the selected ones and averaged 7.7 inches tall. The seedlings were paired and planted in rows on the company's Experimental Forest east of Rhinelander. No statistical design other than the pairing was used. The site was not ideal for white spruce because it lacked uniformity in soil moisture and air drainage. Much of it was wet and frosty early in the growing season.

Tree heights were measured in 1961 and 1962 and frost injury scored in 1964. After 7 growing seasons in the field, the selected seedlings had maintained their superiority over the controls. (King *et al.* 1965).

Flushing of the buds was scored in May 1973 using six classes of bud development as described by Nienstaedt and King (1969). Total tree heights were measured later that fall.

RESULTS

By 1973, 84 percent of the seedlings had survived and 74 percent of the pairs were intact. There were no important differences in survival between the selected seedlings and the controls (table 1).

The selected seedlings continued to have a 30 percent height growth advantage over the controls on the average. This, according to the t-test on the pairs, is highly significant statistically, unlike the effect of seedling height class. The 7-year heights were highly correlated with 18-year heights with r values exceeding 0.8. Not only are the selected trees taller than the controls, but the frequency distribution of the two groups is normal (fig. 1). In the selected

Table 1.—*Survival and height growth of surviving seedling pairs at 18 years after field planting*

Class	Pairs planted	Pairs surviving	Seedlings surviving	Seedling survival	Height	S.D.	t[1]	Superiority
		Number		*Percent*	*Feet*			*Percent*
S			53	90	12.85	3.35		
20	59	45					4.741	
C			50	85	9.65	3.39		33.2
S			68	67	12.17	3.63		
19	102	56					5.126	36.7
C			77	75	8.90	3.03		
S			176	88	12.33	4.02		
18	201	161					9.794	33.9
C			182	91	9.21	3.17		
S			288	86	12.27	3.59		
17	334	244					9.172	26.5
C			280	84	9.70	3.19		
S			585	84	12.33	3.71		
Combined	696	506					14.95	30.55
C			589	85	9.45	3.21		

[1] t-test for heights.

population, 296 trees are 12 feet or smaller while 289 are taller than this mean height; in the control population, 489 trees are 12 feet or smaller and only 100 are taller.

Minor differences in the time of flushing were not significant and are not shown.

DISCUSSION

Reducing the age at which reliable phenotypic selections can be made will substantially reduce the cost and increase the effectiveness of forest tree improvement programs. Several options for incorporating juvenile selections into such programs are available depending on program objectives and funding.

If early production of improved planting stock is the objective, vegetative propagation of the selected seedlings may be the option to try. Such programs are now underway for Norway spruce in Germany (Kleinschmidt 1974, Kleinschmidt *et al.* 1973), Denmark (Roulund 1976, 1979) and elsewhere. In addition, mass production techniques for juvenile white spruce material are now being developed in Canada and the United States (Rauter 1974, Nienstaedt 1979, Armson *et al.* 1980). Using perfected rooting techniques and hedges to maintain rooting ability, about 200 selections should produce 300,000 to 500,000 plantable trees annually after 5-7 years (Nienstaedt 1979).

Incorporating the juvenile selections into multigeneration breeding programs will require testing as in our study. Control seedlings can be omitted from such tests if suitable land is scarce. The test site should be uniform and capable of producing good white spruce.

If early seed production is an objective and funding limited, developing the test planting into a seed production area (SPA) could be the best approach. The test in our study covers a little less that 1 acre with an original spacing of about 6 feet by 5 feet. Because SPA spacing should be about 20 feet by 20 feet, the test planting would need to be thinned to 104 trees in the 16 foot height class or taller: 97 select trees and seven control trees (fig. 1). A broad genetic base would be required from the beginning of the program; the selection and breeding strategy would depend on the populations available, the breeding zone and the agencies involved.

To assure full development of the crowns, thinning should begin as soon as flowering does—on most sites it could probably begin at about 12 years from seed and end at 20 years. By this approach, further genetic improvement could be achieved with repeated two-stage mass selection in the nursery and plantation representing advancing generations of the population.

If maximum yield improvement through a long-term intensive breeding program is the main goal and funding not a limiting factor, the approach

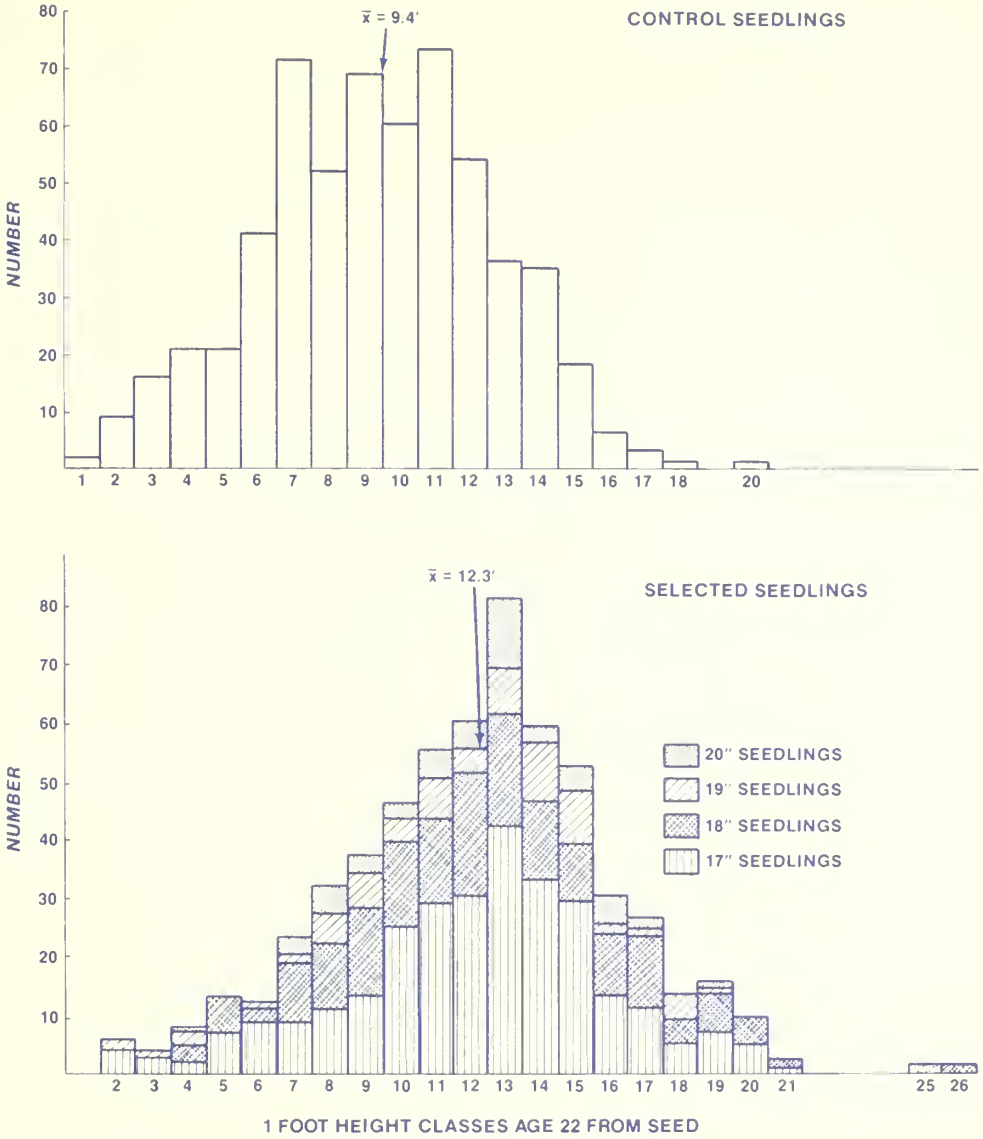

Figure 1.—*Frequency distributon in 1-foot height classes of white spruce trees grown from select and control nursery stock—18 years after field planting.*

should be to incorporate a few of the best trees as parent trees in the initial breeding population. These trees should be selected in the field test as soon as flowering begins. For example, in our study, the selections— those larger than the mean height of the nursery selections plus two standard deviations —would include 14 trees in the 20 foot height class or taller (table 1); 13 trees would represent the nursery selections and one tree the controls.[1]

The results suggest that with a selection differential of 125 percent (selected seedlings 125 percent taller than average) or more, white spruce seedlings can be selected at 4 years in the nursery and about three-fourths of them should continue to be superior growers. There is no evidence that more rigorous selection—equivalent to selecting only 20 inch seedlings in the population studied—would be worthwhile.

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[1] *The breeding population would have included many more selections.*

Although the ultimate proof of genetic superiority will require progeny testing of the selected trees, the high correlation between height at 7 and 18 years is evidence that these super seedlings may be genetically superior.

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1981

EFFECT OF CALCIUM CYANAMIDE ON THE GROWTH OF PLANTED HARDWOODS

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ABSTRACT.—Calcium cyanamide, a nitrogenous fertilizer, was evaluated in new plantings of black walnut, white ash, and white oak seedlings and 2- and 3-year-old white oak and white ash trees, respectively. Only the growth of black walnut seedlings and white ash trees was improved by $CaCN_2$. Some weeds were controlled by $CaCN_2$, but the amount of weed control was not significantly influenced by the rate of $CaCN_2$. Only the survival of white oak seedlings was affected by $CaCN_2$.

KEY WORDS: weed control, fertilization, seedling survival, old field, mulch.

Black walnut (*Juglans nigra* L.), white ash (*Fraxinus americana* L.), and white oak (*Quercus alba* L.), like most hardwood species, have specific site requirements and demand intensive care to produce satisfactory growth. Their growth on abandoned agricultural land is often poor, possibly because of low fertility and weed competition for nutrients and moisture.

Fertilization of planted hardwood seedlings often intensifies weed competition, offsetting fertilizer benefits (von Althen 1976). If plantations of these three species are to be successful, weeds must be controlled at least the first 2 years. Both mechanical and chemical weed control methods have proven to be successful, but some can be expensive. Some chemicals used for weed control may also be toxic to hardwoods.

Calcium cyanamide ($CaCN_2$), an alkaline nitrogenous fertilizer containing about 22 percent nitrogen and 20 percent lime, may also act as a herbicide (Auchmoody and Wendel 1973). In the soil, $CaCN_2$ hydrolyzes principally to calcium hydroxide and urea with the formation of unstable intermediate compounds that are toxic to some seeds and plants.

In the spring of 1976, we began a study on abandoned fields in southern Illinois to evaluate the effects of $CaCN_2$ on weeds and on growth of black walnut, white ash, and white oak when applied immediately after planting and in established plantations.

METHODS

Two abandoned fields, one adjacent to Hutchins Creek and the other to Kinkaid Lake in southern Illinois, were selected as planting sites for black walnut, white ash, and white oak seedlings. A dense cover of broadleaf weeds was well established in both fields. Soils in the Hutchins Creek planting are Cape and Piopolis silty clay loams. These bottomland soils have slow permeability and high available moisture content. Soil in the Kinkaid planting is moderately well drained Ava silt loam. In addition, we located plantations of white ash and white oak that had received $CaCN_2$ at rates ranging from 0 to 1,120 kg/ha.

The fields were tilled and 150 seedlings of each species were planted at a 3.7 x 3.7 meter spacing. The following treatments were immediately applied in a completely randomized design: (1) control, (2) hoeing three times per season and (3) $CaCN_2$ at rates of 448 kg/ha, 672 kg/ha, 896 kg/ha, and 1,120 kg/ha. $CaCN_2$ and hoeing were applied over a 1.2 m diameter area and repeated before weed growth began (about March 15) in the second and third years. Hoeing was repeated again about mid-June each year of treatment.

For the trees, 150 3-year-old white ash and 150 2-year-old white oak were selected. Both plantings had been cultivated twice a year for the previous 2 years. Tall fescue (*Festuca arundinacea*) had invaded the white ash planting and broadleaf weeds had invaded the white oak planting. Spacing was similar to that of the seedlings. Soil in the white ash planting is Wakeland silt loam. This site is nearly level and has poor to moderate drainage. The white oak planting is on a moderately well drained, gently sloping site with Alford silt loam soil. The trees averaged 1.5 and 1.4 m tall and 2.1 and 1.3 cm in diameter at 15 cm above ground for white ash and white oak, respectively.

Instead of hoeing, we placed a 1.2 m square of black plastic around each tree and anchored it with soil. Otherwise, the treatments and time of application were the same as those used for the seedlings.

Height and diameter (15 cm above ground) for seedlings and trees were measured at the beginning of the study and at the end of each growing season for 4 years. Weed cover was estimated about June 1 and August 1 of each year. Treatment effects were examined by an analysis of variance and Scheffe technique (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

Survival

Survival differences were small. Only white oak seedlings were adversely affected by $CaCN_2$, generally the higher the rate of application the lower the survival (fig. 1). Many of the surviving seedlings suffered repeated dieback. Survival of the white oak trees was not affected, suggesting white oak is more tolerant when older.

Weed Control

Both hoeing and black plastic mulch provided much better weed control than $CaCN_2$ at any rate (fig. 2). The most noticeably suppressed weeds on all

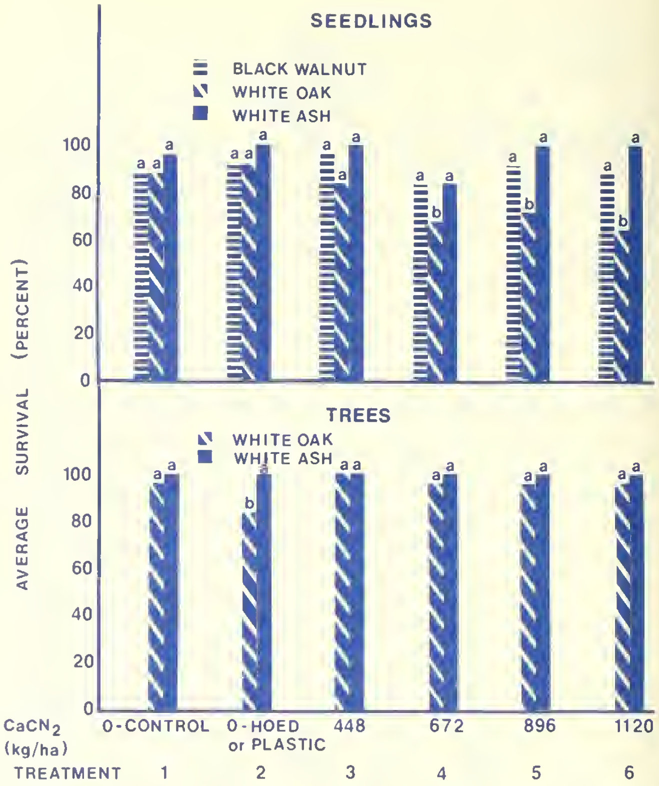

Figure 1.—*Average survival of seedlings and trees 4 years after initiation of $CaCN_2$ treatment. Species statistically analyzed separately; a is different from b for the same species at the 0.05 level.*

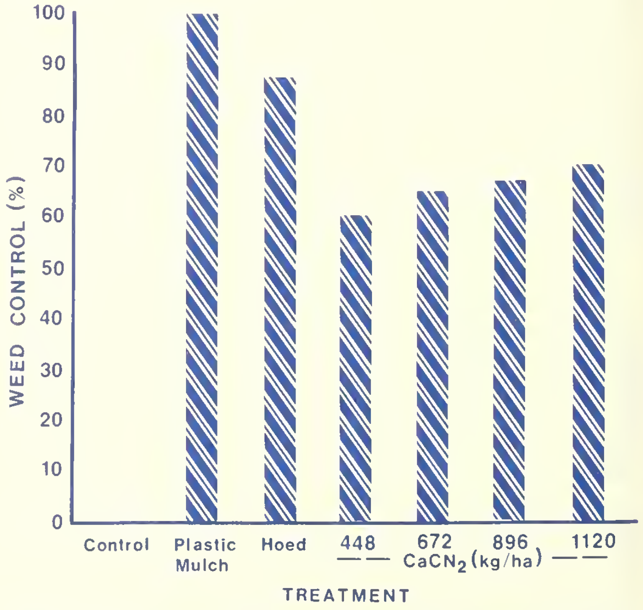

Figure 2.—*Average weed control provided by treatment in three hardwood species in June 1978.*

sites were ragweed (*Ambrosia artemesulfolia* L.), yellow nutgrass (*Cyperus esculentus* L.), goldenrod (*Solidago ulmifolia* Muhl.), bitter dock (*Rumex obtusifolius* L.), and plantain (*Plantago* sp.). The amount of annual weeds present increased toward the end of the season in all plantings. The amount of fescue in the white ash tree planting was reduced by $CaCN_2$ at all rates during the second and third growing season.

Weeds that develop from underground parts were suppressed by $CaCN_2$ during the early part of the growing season, but by late July grew vigorously, perhaps in response to reduced competition and additional nutrients. These species included bermuda grass (*Cynodon dactylon* (L.) Pers.), dewberry (*Rubus* sp.), ground cherry (*Physalis heterophylla* Ness), trumpet creeper (*Campsis radicans* (L.) Pers.), and wild potato vine (*Ipomoea pandurate* L.).

Growth

Hoeing and plastic mulching generally produced the greatest height growth, except for black walnut in the Kinkaid planting and white oak trees. We suspect that plastic caused a heat buildup in the soil that retarded white oak growth, because there were no visible symptons of stress or poor nutrition. $CaCN_2$ did not increase diameter growth except for white oak seedlings at the 448 kg/ha rate (tables 1 and 2).

Walnut grew faster at Hutchins Creek than at Kinkaid, probably because of better soil fertility and moisture conditions. However, $CaCN_2$ at the two highest rates did increase the height growth of walnut at Kinkaid significantly over the control. The combination of weed control and nutrients supplied by $CaCN_2$ seemed to be more beneficial in the Kinkaid planting than at Hutchins Creek, where only the hoed treatment was significantly different from other treatments.

The poor overall growth of white oak seedlings was probably due to the stunting effect of $CaCN_2$ on many of the surviving seedlings (table 1). Further, the height growth of white oak trees was not significantly affected by $CaCN_2$.

Height growth of white ash seedlings treated with $CaCN_2$ was on the average no better than the control, but the higher rates of $CaCN_2$ significantly increased height growth of white ash trees over the control (table 2). $CaCN_2$ treated trees had greener foliage than other trees, suggesting better nutrition.

No attempt was made to separate the contributions of fertilizer and weed control to height growth. But

Table 1.—*Average height and diameter of 4-year-old black walnut (2 locations), white ash, and white oak seedling treated with $CaCN_2$ for 3 years after planting*[1]

	WALNUT HUTCHINS CREEK		WHITE OAK HUTCHINS CREEK	
Treatment	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)
Control	0.96a	1.46a	0.68a	0.58a
Hoed	1.35b	2.73b	1.00a	1.39b
448 kg/ha	1.20a	2.04a	0.57a	1.18b
672 kg/ha	1.19a	2.11a	0.41a	0.54a
896 kg/ha	1.26a	2.11a	0.53a	0.74a
1,120 kg/ha	1.19a	2.10a	0.50a	0.66a
	WALNUT KINKAID		WHITE ASH HUTCHINS CREEK	
Control	0.87a	1.14a	1.45a	2.03a
Hoed	1.16ab	1.74a	1.82a	2.83a
448 kg/ha	1.04ab	1.34a	1.55a	2.24a
672 kg/ha	1.09ab	1.54a	1.42a	2.13a
896 kg/ha	1.41b	1.91a	1.55a	2.39a
1,120 kg/ha	1.36b	1.99a	1.49a	2.24a

[1] Values for each species in the same column followed by the same letter are not significantly different (0.05 level) as determined by the Scheffe technique.

Table 2.—*Average height and diameter of 6-year-old white oak and 7-year-old white ash trees treated with $CaCN_2$ at ages 2 thru 4 and 3 thru 5*[1]

	WHITE OAK	
Treatment	Height (m)	Diameter (cm)
Control	2.49a	3.89a
Plastic	2.39a	4.11a
448 kg/ha	2.49a	3.81a
672 kg/ha	2.62a	4.14a
896 kg/ha	2.62a	4.35a
1,120 kg/ha	2.66a	4.47a
	WHITE ASH	
Control	3.16a	5.94a
Plastic	4.06b	7.26a
448 kg/ha	3.42a	6.24a
672 kg/ha	3.59a	6.77a
896 kg/ha	3.81ab	7.32a
1,120 kg/ha	3.93ab	7.29a

[1] Values for each species in the same column followed by the same letter are not significantly different (0.05 level) as determined by the Scheffe technique.

because the higher rates of $CaCN_2$ were usually associated with better growth and there was not much difference in weed control, we concluded that height growth above that reported for the 448 kg/ha rate may be attributed to $CaCN_2$ as a fertilizer.

Summary

Black walnut seedlings and white ash trees grew faster in response to broadcast $CaCN_2$ treatments than white ash and white oak seedlings or white oak trees. The faster height growth was usually associated with the higher rates of $CaCN_2$ application (886 and 1,120 kg/ha). Both growth and survival of white oak seedlings were reduced when treated with $CaCN_2$. Results also suggest that white ash seedlings may be sensitive to $CaCN_2$.

Both the amount of weed control and weed growth varied according to site conditions. Differences in weed control between the lowest and highest rates of $CaCN_2$ were insignificant. Residual weed control was equal to about half the weed control of the previous year.

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NORTH CENTRAL
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1981

TREE BIOMASS ESTIMATES FOR MINNESOTA'S ASPEN-BIRCH FOREST SURVEY UNIT

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ABSTRACT.—Live tree biomass estimates are presented for five counties of northeastern Minnesota. Tree biomass is given in green tons for forest types and species groups.

KEY WORDS: Volume, tops and limbs, cull, growing-stock, boles.

An increasing demand for wood fiber, advances in wood technology, and other changes in the Nation's forest resources have spurred interest in complete tree utilization. Such developments require a measure of total tree volume that includes more than just merchantable volume. Estimating tree biomass is the first step in estimating the total wood volume on commercial forest land.

Tree biomass, including the bark, is made up of five components:

1. **Growing-stock boles**.—the above-ground volume in growing-stock trees from a 1-foot stump to a variable 4-inch top diameter outside the bark (t.d.o.b.).
2. **Growing-stock tops and limbs**.—the above-ground volume in growing-stock trees from a 1-foot stump, excluding the growing-stock bole.
3. **Cull tree boles**.—the above-ground volume in cull trees from a 1-foot stump to a 4-inch t.d.o.b.
4. **Cull tree tops and limbs**.—the above-ground volume of cull trees from a 1-foot stump, excluding the cull bole.
5. **1- to 5-inch d.b.h. trees**.—the total above-ground volume of all trees 1 to 5 inches in diameter at breast height.

In Minnesota, estimates of tree biomass on commercial forest land outside the National Forests were obtained during the fourth Minnesota Forest Inventory (dated 1977). The recently completed Superior National Forest Inventory (dated 1979) has provided tree biomass estimates for that forest. Information from the two surveys has been combined to estimate the tree biomass on commercial forest land in the Aspen-Birch Forest Survey Unit (Carlton, Cook, Koochiching, Lake, and St. Louis Counties).

METHOD

Tree biomass was estimated with the following method: First, net cubic foot volumes were converted to green tons by using weight conversion factors for each species (Markwardt 1930). The weight of the bole bark was then computed using bark correction factors for individual species, the gross volume of the bole, and an average bark weight of 37 pounds per cubic foot. Tops and limbs for growing-stock and cull trees were estimated as 45 percent of the gross bole volume (Young *et al.* 1976). Finally, the biomass for trees less than 5 inches d.b.h. was computed from a regression equation fit to Young's tree weight table (Young *et al.* 1976). This regression equation uses d.b.h. to estimate total above-ground biomass as 80 percent of the above- and below-ground biomass.

FINDINGS

Tree biomass in the Aspen-Birch Forest Survey Unit was estimated at 250.8 million green tons in 1978, or about 43.5 green tons per acre of commercial forest land. Sixty-five percent of the Unit's biomass is made up of growing-stock trees (table 1). Biomass in 1- to 5-inch d.b.h. trees accounts for more than one-quarter of the Unit's total tree biomass. The distribution of tree biomass among the five components differs for softwoods and hardwoods (fig. 1).

Hardwood tree species make up most of Minnesota's tree biomass. Of the 149.3 million green tons of hardwood tree biomass, 108.9 million green tons are in aspen and paper birch. Softwood tree biomass is concentrated in balsam fir and black spruce. More than 50 percent of the black spruce tree biomass is in 1- to 5-inch d.b.h. trees.

The 250.8 million green tons of tree biomass in the Aspen-Birch Unit equal 11.8 billion cubic feet. Tree biomass in growing-stock boles totals 5.3 billion cubic feet. Data from the fourth Minnesota Forest Inventory and the Superior National Forest Inventory show that net growing-stock volume in the Unit is 4.4 billion cubic feet. The difference between biomass cubic foot volume in growing-stock boles and the net growing-stock volume in cubic feet is the bark component of biomass. Bark accounts for almost 20 percent of the growing-stock bole biomass.

Forty-eight percent of the biomass is in stands less than 51 years old (table 2). The importance of small diameter trees in supplying biomass is shown in the distribution of biomass among diameter classes (table 3). Twenty-six percent of the total biomass is made up of trees less than 5 inches d.b.h., 18 percent is made up of trees 5.0-6.9 inches d.b.h., and 19 percent is made up of trees 7.0-8.9 inches d.b.h. (table 3).

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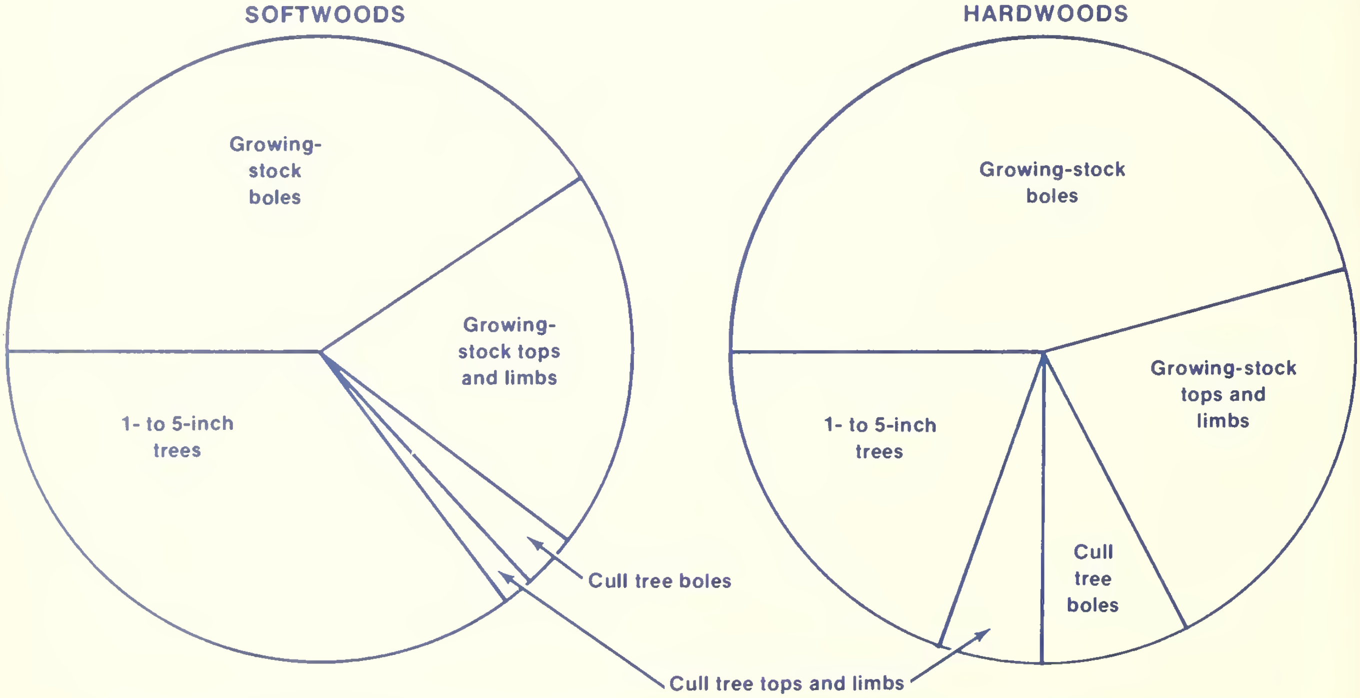

Figure 1.—*Distribution of biomass among components, softwoods and hardwoods, Aspen-Birch Unit, Minnesota, 1978.*

Table 3.--All live biomass by species and diameter class, Aspen-Birch Unit, Minnesota, 1978

(In thousand green tons)

Species	All classes	Diameter class (inches) 0.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9
SOFTWOODS:								
White pine	3,199	13	93	103	211	224	489	371
Red pine	7,276	44	534	500	1,031	1,584	1,243	854
Jack pine	7,624	34	314	1,013	1,842	2,283	1,212	506
White spruce	4,865	254	685	554	650	721	674	457
Black spruce	25,383	2,634	10,339	6,363	3,929	1,430	440	149
Balsam fir	36,008	3,845	11,025	8,706	6,646	3,776	1,430	456
Tamarack	5,555	389	1,790	1,426	1,111	476	263	62
Northern white-cedar	11,483	751	3,117	1,310	1,762	1,750	1,153	738
Other softwoods	47	10	17	6	3	8	--	3
Total	101,440	7,974	27,914	19,981	17,185	12,252	6,904	3,596
HARDWOODS:								
Select white oaks	348	13	36	46	48	47	54	18
Select red oaks	623	11	50	70	78	122	122	83
Other red oaks	--	--	--	--	--	--	--	--
Hickory	--	--	--	--	--	--	--	--
Yellow birch	920	7	28	25	45	48	184	133
Hard maple	6,087	563	1,406	1,133	854	561	382	331
Soft maple	4,715	723	1,790	832	673	323	159	101
Ash	11,270	983	2,272	2,329	2,054	1,665	966	519
Balsam poplar	11,546	426	1,484	1,436	2,425	2,192	1,597	1,019
Paper birch	39,436	1,739	6,828	8,830	9,977	6,478	3,145	1,250
Bigtooth aspen	1,533	16	106	158	260	307	337	135
Quaking aspen	67,959	2,946	6,712	10,105	14,478	14,129	9,531	5,747
Basswood	1,557	24	162	207	285	325	161	108
Elm	2,675	54	195	210	277	308	343	308
Select hardwoods	31	13	14	4	--	--	--	--
Other hardwoods	117	11	53	12	14	10	8	--
Noncommercial species	534	332	126	51	15	6	4	--
Total	149,351	7,861	21,262	25,448	31,483	26,521	16,993	9,752
All species	250,791	15,835	49,176	45,429	48,668	38,773	23,897	13,348

(Table 3 continued on next page)

Table 2.--All live biomass by forest type and stand-age class, Aspen-Birch Unit, Minnesota, 1978

(In thousand green tons)

Forest type	All classes	Stand-age class (years)												
		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121-140	141+
Jack pine	7,014	628	267	107	1,633	1,328	1,717	735	106	307	59	127	--	--
Red pine	8,042	66	13	93	3,265	485	629	1,212	1,244	882	88	65	--	--
White pine	2,155	--	22	--	--	--	--	356	466	82	799	430	--	--
Balsam fir	27,796	911	1,271	1,833	4,012	9,483	5,976	2,437	553	584	234	502	--	--
White spruce	2,134	103	414	32	211	457	283	50	458	89	--	37	--	--
Black spruce	28,193	631	2,424	3,585	3,917	2,902	3,730	2,872	3,344	2,438	1,556	314	480	--
Northern white-cedar	13,461	240	218	476	585	1,032	959	1,438	1,549	1,835	1,018	1,700	2,411	--
Tamarack	4,162	164	498	765	237	441	423	362	277	285	40	481	156	33
Oak	372	--	--	--	58	190	124	--	--	--	--	--	--	--
Elm-ash-cottonwood	10,343	312	475	233	348	1,101	1,699	1,675	919	1,388	1,090	532	571	--
Maple-basswood	12,304	180	473	158	619	1,907	2,033	789	2,329	836	1,539	858	583	--
Aspen	95,065	4,659	5,422	5,936	12,330	22,845	24,453	10,106	4,611	2,187	2,106	383	--	27
Paper birch	29,490	678	874	1,164	2,271	7,480	9,471	3,867	2,519	767	288	111	--	--
Balsam poplar	9,850	331	292	308	1,812	3,150	1,663	994	837	357	106	--	--	--
Nonstocked	410	410	--	--	--	--	--	--	--	--	--	--	--	--
All types	250,791	9,313	12,663	14,690	31,298	52,801	53,160	26,893	19,212	12,037	8,923	5,540	4,201	60

Table 1.--All live biomass by species and component, Aspen-Birch Unit, Minnesota, 1978

		Biomass component						Biomass component				
		Growing-stock		Cull				Growing-stock		Cull		
Species	All components	Boles	Tops and limbs	Boles	Tops and limbs	1- to 5-inch trees	All components	Boles	Tops and limbs	Boles	Tops and limbs	1- to 5-inch trees
	- - - - - - - - - - -Thousand green tons- - - - - - - - - -						- - - - - - - - - - - - Thousand cubic feet- - - - - - - - - - - -					
SOFTWOODS:												
White pine	3,199	1,966	926	129	72	106	175,754	108,683	51,297	7,143	3,904	4,727
Red pine	7,276	4,512	2,076	72	38	578	353,234	220,180	101,916	3,557	1,819	25,762
Jack pine	7,624	4,659	2,167	290	159	349	321,131	195,845	90,688	12,341	6,747	15,510
White spruce	4,865	2,612	1,228	53	34	938	265,150	148,644	69,698	3,046	1,929	41,833
Black spruce	25,383	8,200	3,820	247	143	12,973	1,342,012	505,407	235,202	15,194	8,824	577,385
Balsam fir	36,008	13,628	6,363	734	412	14,871	1,629,183	623,207	290,359	33,721	19,046	662,850
Tamarack	5,555	1,968	994	262	152	2,179	244,504	86,021	43,395	11,450	6,683	96,955
Northern white-cedar	11,483	3,966	2,011	920	718	3,868	695,319	273,765	138,607	62,647	48,150	172,150
Other softwoods	47	11	5	2	2	27	2,246	574	281	88	49	1,254
Total	101,440	41,522	19,590	2,709	1,730	35,889	5,028,533	2,162,326	1,021,443	149,187	97,151	1,598,426
HARDWOODS:												
Select white oaks	348	189	86	14	10	49	12,773	6,706	3,020	512	368	2,167
Select red oaks	623	333	153	44	32	61	22,654	11,659	5,372	1,611	1,272	2,740
Other red oaks	--	--	--	--	--	--	--	--	--	--	--	--
Hickory	--	--	--	--	--	--	--	--	--	--	--	--
Yellow birch	920	314	149	221	200	36	35,494	11,646	5,531	8,559	8,165	1,593
Hard maple	6,087	1,900	910	754	554	1,969	245,741	71,984	34,430	29,435	22,226	87,666
Soft maple	4,715	823	416	558	405	2,513	208,424	35,632	17,910	24,745	18,079	112,058
Ash	11,270	4,929	2,399	392	295	3,255	488,619	210,671	102,554	17,207	13,210	144,977
Balsam poplar	11,546	5,802	2,733	648	452	1,911	575,561	294,779	139,004	33,241	23,402	85,135
Paper birch	39,436	18,335	8,541	2,460	1,533	8,567	1,664,275	759,303	354,243	103,581	65,220	381,928
Bigtooth aspen	1,533	763	366	174	108	122	72,899	36,525	17,396	8,379	5,202	5,397
Quaking aspen	67,959	33,005	15,954	5,288	4,054	9,658	3,222,458	1,576,987	761,830	256,358	197,174	430,109
Basswood	1,557	847	393	69	62	186	74,227	40,645	18,851	3,390	3,081	8,260
Elm	2,675	1,390	644	222	170	249	106,905	54,489	25,206	8,983	7,128	11,099
Select hardwoods	31	2	1	1	1	26	1,379	73	40	37	27	1,202
Other hardwoods	117	13	6	17	16	65	5,251	549	270	758	746	2,928
Noncommercial species	534	--	--	45	32	457	23,855	--	--	1,993	1,455	20,407
Total	149,351	68,645	32,751	10,907	7,924	29,124	6,760,515	3,111,648	1,485,657	498,789	366,755	1,297,666
All species	250,791	110,167	52,341	13,616	9,654	65,013	11,789,048	5,273,974	2,507,100	647,976	463,906	2,896,092

(Table 3 continued)

	Diameter class (inches)						
Species	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-28.9	29.0-38.9	39.0+
SOFTWOODS:							
White pine	333	287	250	268	370	150	37
Red pine	580	433	297	114	62	--	--
Jack pine	245	137	24	10	4	--	--
White spruce	406	188	151	92	33	--	--
Black spruce	63	25	9	2	--	--	--
Balsam fir	102	13	9	--	--	--	--
Tamarack	26	12	--	--	--	--	--
Northern white-cedar	416	232	147	43	59	5	--
Other softwoods	--	--	--	--	--	--	--
Total	2,171	1,327	887	529	528	155	37
HARDWOODS:							
Select white oaks	36	12	5	--	28	5	--
Select red oaks	55	16	16	--	--	--	--
Other red oaks	--	--	--	--	--	--	--
Hickory	--	--	--	--	--	--	--
Yellow birch	82	114	81	71	91	11	--
Hard maple	379	211	102	60	105	--	--
Soft maple	57	38	7	12	--	--	--
Ash	294	106	50	9	23	--	--
Balsam poplar	515	308	74	51	19	--	--
Paper birch	619	303	124	66	77	--	--
Bigtooth aspen	138	50	15	11	--	--	--
Quaking aspen	2,362	1,130	524	173	122	--	--
Basswood	113	79	47	31	15	--	--
Elm	265	258	114	119	155	48	21
Select hardwoods	--	--	--	--	--	--	--
Other hardwoods	2	5	2	--	--	--	--
Noncommercial species	--	--	--	--	--	--	--
Total	4,917	2,630	1,161	603	635	64	21
All species	7,088	3,957	2,048	1,132	1,163	219	58

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MINNESOTA'S ASPEN RESOURCE

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ABSTRACT.—The fourth Minnesota Forest Inventory shows that aspen continues to dominate the State's forests. Thirty-nine percent of Minnesota's commercial forest area is in the aspen forest type. Aspen species accounted for the largest portion of growing-stock inventory, net annual growth, and removals.

KEY WORDS: Forest survey, forest area, timber volume, removals, growth.

The fourth Minnesota Forest Inventory shows that aspen continues to dominate the State's forests. In 1977, the aspen forest type covered 5.3 million acres of commercial forest land—39 percent of the total commercial forest area in Minnesota. Although the total aspen area in the State declined slightly between inventories, the area of aspen in north-central Minnesota increased (table 1).

Farmers own nearly one-quarter of the State's aspen (table 2). County and municipal agencies and miscellaneous private owners hold another large block of the aspen resource.

Most of Minnesota's aspen area is in poletimber stands; only 15 percent of the aspen stands are sawtimber (table 3). Twenty-eight percent of the commercial forest area in other forest types is in sawtimber stands.

Aspen stands are younger, on average, than stands of all other forest types. Seventy-two percent of the aspen forest type acreage is less than 51 years old; only 47 percent of the stands in forest types other than aspen are less than 51 years old (fig. 1).

Table 1.—*Aspen commercial forest area by Forest Survey Unit for 1962 and 1977, Minnesota*
(In thousand acres)

Unit	Aspen area 1962	Aspen area 1977	Percent change
Aspen-Birch	2,070.8	1,947.4	–6
Northern Pine	2,360.8	2,541.7	+7
Central Hardwood	640.0	560.2	–12
Prairie	328.2	253.0	–23
All units	5,399.8	5,302.3	–2

Table 2.—*Commercial forest area by ownership class and forest type, Minnesota, 1977*
(In thousand acres)

Ownership class	All types	Aspen type	Other types
National Forest	1,715.1	598.5	1,116.6
Bureau of Land Management	43.9	13.9	30.0
Indian	466.8	187.2	279.6
Miscellaneous Federal	110.5	33.1	77.4
State	2,650.5	846.6	1,803.9
County and municipal	2,341.6	1,057.9	1,283.7
Forest Industry	772.0	315.8	456.2
Farmer	3,403.7	1,278.8	2,124.9
Miscellaneous private	2,191.0	970.5	1,220.5
All owners	13,695.1	5,302.3	8,392.8

Table 3.—*Commercial forest area by stand-size class and forest type, Minnesota, 1977*
(In thousand acres)

Stand-size class	All types	Aspen type	Other types
Sawtimber	3,134.8	791.4	2,343.4
Poletimber	6,956.1	3,032.3	3,923.8
Sapling and seedling	3,434.8	1,478.6	1,956.2
Nonstocked areas	169.4	—	169.4
All classes	13,695.1	5,302.3	8,392.8

Aspen volume in Minnesota totaled 4.0 billion cubic feet in 1977. Most of this volume is in growing-stock trees (table 4).

As aspen stands matured, growing-stock volume increased from 2.8 billion cubic feet in 1962 to 3.4 billion cubic feet in 1977. Aspen growing-stock volume per acre increases steadily to age 70, then levels off (fig. 2).

The northern two Forest Survey Units account for 89 percent of the aspen growing-stock volume (fig. 3). Except for Pine County, no county outside the Aspen-Birch and Northern Pine Survey Units has more than 36 million cubic feet of aspen.

Some aspen occurs in all forest types in Minnesota showing that management of other forest types can also yield aspen volumes (table 5).

Table 4.—*Net volume of aspen by species class and tree class, Minnesota, 1977*
(In thousand cubic feet)

Species class	All live	Growing stock	Cull trees	
			Short-log	Rough and rotten
Total softwoods	3,682,926	3,477,007	27,060	178,859
Hardwoods:				
Quaking aspen	3,782,905	3,236,405	60,256	486,244
Bigtooth aspen	201,225	174,315	3,398	23,512
Aspen subtotal	3,984,130	3,410,720	63,654	509,756
Other hardwoods	5,178,774	4,566,270	93,743	518,761
Total	9,162,904	7,976,990	157,397	1,028,517
All species	12,845,830	11,453,997	184,457	1,207,376

Although cubic feet of growing-stock is a traditional measure of tree volume, the tree biomass on commercial forest land outside the national forests was estimated during the fourth Minnesota Forest Inventory. Tree biomass gives a more complete measure of volume, because it is the above-ground volume of all live trees from a 1-foot stump, including the bark. Biomass in aspen species totaled 163 million green tons in 1977 (table 6).

Net annual growth of quaking and bigtooth aspen growing-stock totaled 94 million cubic feet in 1976—2.8 percent of total aspen volume. In the aspen forest

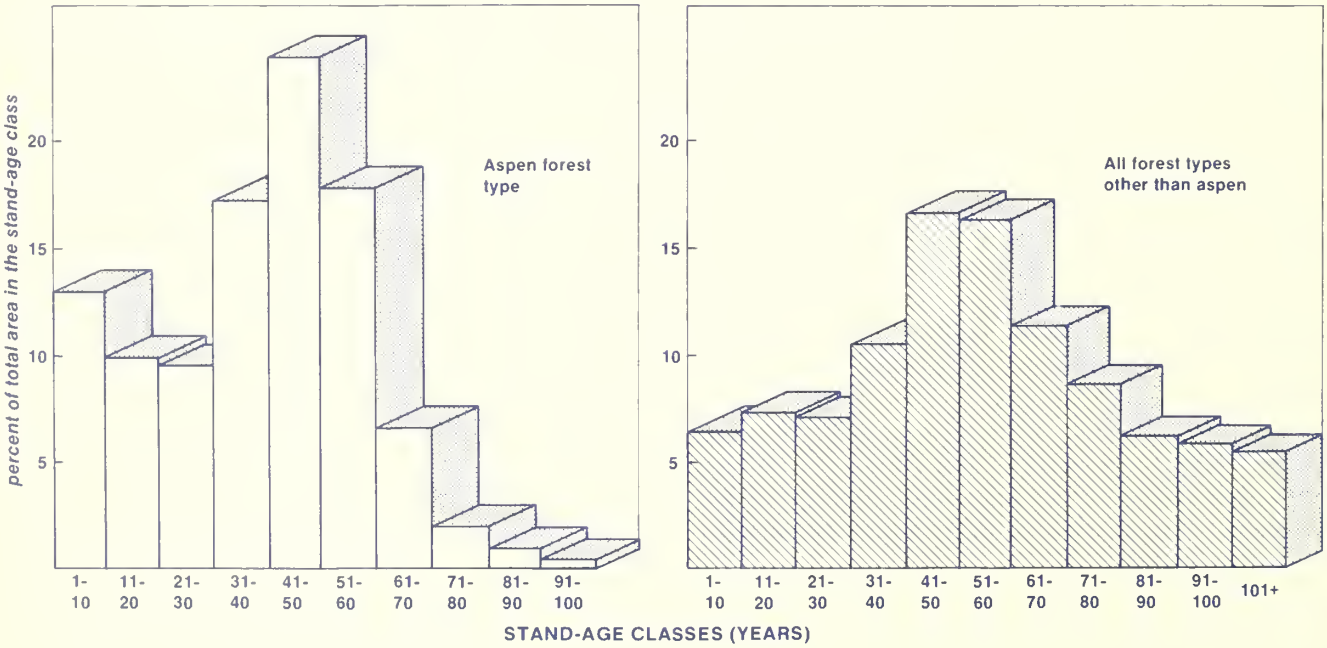

Figure 1.—*Percent distribution of area among stand-age classes, aspen forest type, and all other forest types, Minnesota, 1977.*

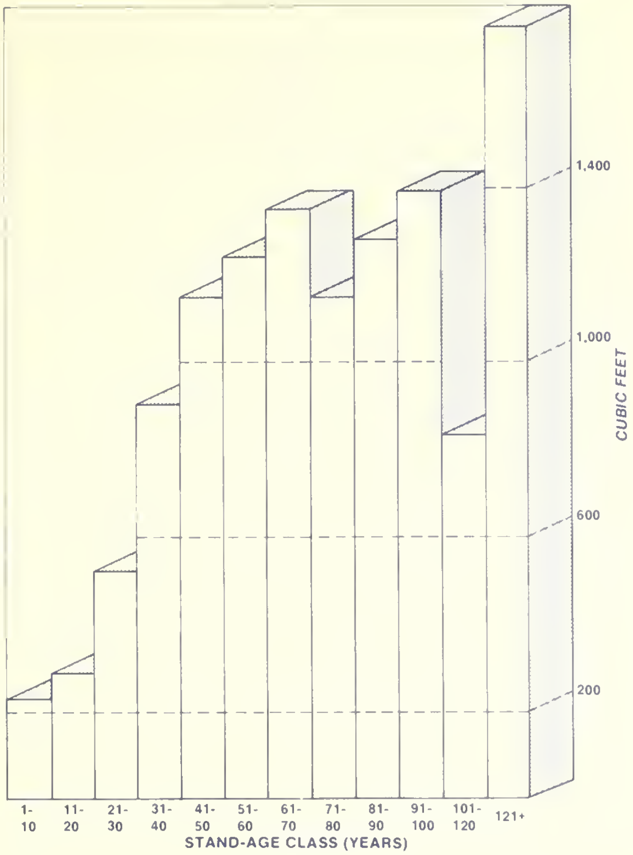

Figure 2.—*Growing-stock volume per acre by stand-age class, aspen forest type, Minnesota, 1977.*

type, growth totaled 153 million cubic feet, an average of 29 cubic feet per acre.

Although aspen growing-stock accounted for 27 percent of the total net annual growth in 1976, it made up 38 percent of growing-stock removals. In 1976, removals from aspen growing stock totaled 73 million cubic feet, up 60 percent from the 46 million cubic feet removed in 1962. More than half the aspen removals (43 million cubic feet) went to pulpwood (table 7). Other removals and logging residue accounted for another 20 percent of the total aspen removals. Other removals are growing-stock trees felled but not used for products, or trees left standing but "removed" from the commercial forest land base by land-use change. Such removals include those resulting from timber stand improvement, land clearing, and other management activities.

Aspen mortality in Minnesota in 1976 was 71 million cubic feet. More than 63 percent of the aspen mortality was caused by disease:

Cause	Aspen mortality *(Thousand cubic feet)*
Insects	612
Disease	45,218
Fire	6,817
Animals	2,259
Weather	10,982
Suppression	—
Unknown and other	5,472
Total	71,360

Table 5.—*Growing-stock volume by forest type and species class, Minnesota, 1977*
(In thousand acres)

Forest type	All species	Softwoods	Hardwoods: Total	Hardwoods: Other hardwoods	Hardwoods: Quaking aspen	Hardwoods: Bigtooth aspen
Jack pine	560,341	501,398	58,943	17,256	38,439	3,248
Red pine	379,361	335,285	44,076	26,861	14,328	2,887
White pine	104,078	86,336	17,742	7,562	10,143	37
Balsam fir	679,143	472,151	206,992	128,647	77,556	789
White spruce	49,960	33,121	16,839	9,323	7,516	—
Black spruce	493,495	449,169	44,326	11,689	32,326	311
Northern white-cedar	378,567	329,828	48,739	40,914	7,309	516
Tamarack	203,820	193,989	9,831	7,227	2,604	—
Oak-hickory	784,286	18,768	765,518	701,371	53,146	11,001
Elm-ash-cottonwood	584,282	77,871	506,411	482,904	22,274	1,233
Maple-basswood	1,212,875	82,457	1,130,418	1,035,227	85,594	9,597
Aspen	4,681,925	655,248	4,026,677	1,193,037	2,697,885	135,755
Paper birch	919,682	173,502	746,180	613,448	124,144	8,588
Balsam poplar	407,592	60,344	347,248	287,428	59,467	353
Nonstocked	14,590	7,540	7,050	3,376	3,674	—
All types	11,453,997	3,477,007	7,976,990	4,566,270	3,236,405	174,315

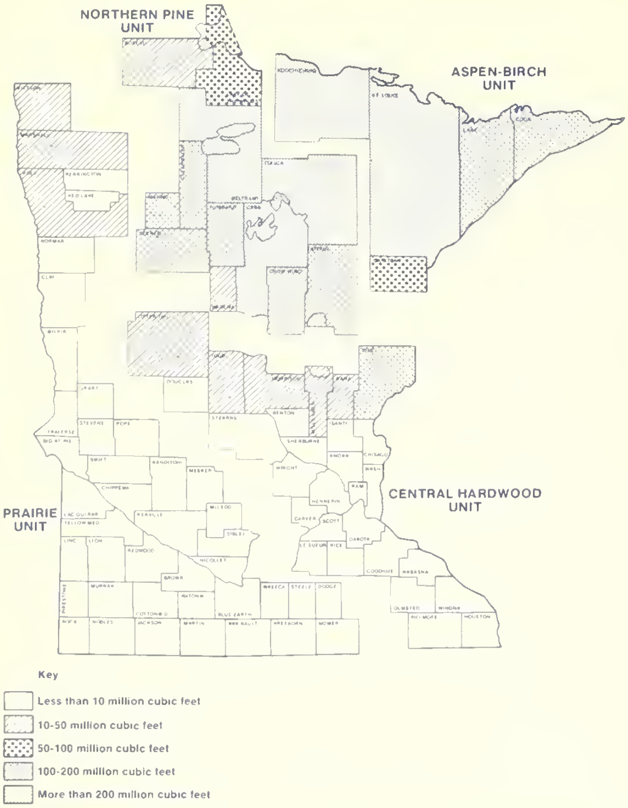

Figure 3.—*Aspen growing-stock volume by county, Minnesota, 1977.*

Table 6.—*Aspen biomass by biomass component and Forest Survey Unit, Minnesota, 1977*
(In thousand green tons)

Biomass component	All units	Aspen-Birch	Northern Pine	Central Hardwood	Prairie
Growing-stock boles	74,159.9	25,271.0	38,880.0	7,445.3	2,563.6
Growing-stock tops and limbs	37,197.0	12,336.2	19,674.3	3,827.6	1,358.9
Cull tree boles	15,867.1	4,255.9	9,095.8	1,733.1	782.3
Cull tree tops and limbs	11,982.7	3,344.9	6,679.6	1,310.3	647.9
1-5-inch trees	23,467.2	8,548.8	10,688.1	2,562.7	1,667.6
All components	162,673.9	53,756.8	85,017.8	16,879.0	7,020.3

Table 7.—*Timber removals from growing-stock by item and species class, Minnesota, 1976*
(In thousand cubic feet)

Item	All species	Total softwoods	Hardwoods		
			Total	Other	Aspen
Pulpwood	89,880	43,165	46,715	4,090	42,625
Saw logs	27,498	10,932	16,566	7,560	9,006
Fuelwood	9,065	511	8,554	6,850	1,704
Posts	1,799	1,544	255	235	20
Veneer logs	460	—	460	395	65
Poles	610	610	—	—	—
Other products	5,723	188	5,535	928	4,607
Logging residue	5,060	1,157	3,903	1,619	2,284
Other removals	53,505	10,693	42,812	30,144	12,668
All items	193,600	68,800	124,800	51,821	72,979

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REVISED SITE INDEX CURVES FOR BALSAM FIR AND WHITE SPRUCE IN THE LAKE STATES

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ABSTRACT.—The original site index curves for balsam fir and white spruce are revised from a breast height age to a total age basis. Site index values from these revised curves are thus comparable to site index values for other species that are based upon total tree age. This note also includes formulations for estimating site index by using computers or programmable, hand-held calculators.

KEY WORDS: total age revisions; site index formulation.

Harmonized site index curves have been published for balsam fir (*Abies balsamea* (L.) Mill.) and white spruce (*Picea glauca* (Moench) Voss) in the Lake States (Gevorkiantz 1956, 1957). These curves define site index as the height of dominant and codominant trees at breast-height-index age of 50 years. In contrast, the index age for most standard site index curves is total tree age at 50 years. Basing site index on breast height age avoids including much of the erratic initial height growth of trees that may suffer from early suppression, frost damage, or animal and insect injury. However, site index values estimated from curves based on breast height age cannot be directly compared to those estimated from site curves based on total tree age.

Our site index curves (figs. 1 and 2) for balsam fir and white spruce are adopted from the original Gevorkiantz harmonized site index curves. We have merely redrafted the original curves by converting them from breast height age to total tree age. Therefore, the revised site index curves have the shortcomings of the original harmonized curves.

These revised curves can be used in the field for directly estimating site index. But this process is slow and tedious, particularly when site indices are estimated from many trees such as in forest surveys or in timber management plans. Moreover, such site index estimates may be subject to error when interpolations are made between the site curves on the site index graphs. Therefore, we include height growth and site index equations that can be used with programmable, hand-held calculators or with programs written for digital computers.

METHODS

Unfortunately, the amount and kind of data and the statistical procedures used for the original curves are not well described by Gevorkiantz (1956, 1957). Data were probably total height and age values measured from dominant and codominant trees on forest survey and yield plots. These height and age data probably were then used for calculating average height-age guiding curves from which a family of proportional harmonized site index curves were constructed.

Using each of Gevorkiantz's site index curves, we read total tree height values for each 10-year breast height age. Then we added a number of years to breast height age to obtain total tree age, the number depending on site class:[1]

Site Index Class	30	40	50	60	70	80
Years added	15	13	11	10	9	8

The total age and total height values for each site class were then used to plot height-age curves. Proportional methods were used to adjust these plotted curves so that at a total age of 50 years the tree heights conformed exactly with the 50-year height specified for each site index class (figs. 1 and 2).

The values used for plotting the revised site index curves were next used for computing height growth equations that describe the revised curves. We also computed site index prediction equations. The equation models we used are:

$$H = b_1 S^{b_2} \left(1 - e^{b_3 A}\right)^{b_4 S^{b_5}} \quad (1)$$

$$S = b_1 H^{b_2} \left(1 - e^{b_3 A}\right)^{b_4 H^{b_5}} \quad (2)$$

where H = Total height of dominant and codominant trees in feet

S = Site index (total height of dominant and codominant trees at 50 years total age)

A = Total age in years

e = Base of the natural logarithms

$b_1 \, .. \, b_5$ = Parameters to be estimated, using weighted nonlinear least squares regression.

Parameters for balsam fir and white spruce are:

Species	b_1	b_2	b_3	b_4	b_5	R^2	SE	Bias
								(Percent)
Balsam fir H =	2.0901	0.9296	–0.0280	2.8280	–0.1403	0.99	0.54	0.01
Balsam fir S =	0.2198	1.1644	–0.0110	–2.0364	–0.1775	0.99	1.10	–1.17
White spruce H =	10.8738	0.5529	–0.0343	34.6880	–0.6139	0.99	2.33	–0.27
White spruce S =	0.0833	1.3965	–0.0196	–8.0895	–0.3659	0.98	3.22	2.11

DISCUSSION

Because these revised site index curves are based only on the original curves calculated by Gevorkiantz, they have the same errors and disadvantages of the original harmonized site index curves. New site curves based on stem analysis methods are recommended for balsam fir and white spruce in the Lake States.

When height growth and site index equations are used with a programmable calculator, the parameters and a simple program for solving the equation are entered and then stored. The estimates of site index are obtained by manually entering the species code and values for total height and total age.

The standard precautions in using site index curves also apply in using these equations for site index: site trees should be at least 20 years old and should be free growing, uninjured, dominant and codominant trees. Such trees commonly occur in well stocked, even-aged stands that have not been disturbed by past cutting. We recommend that increment cores for tree age be taken at breast height. Breast height age and total height values should then be compared to the site index curves for an estimate of the general site class. Next d.b.h. age should be converted to total age by using the number of years listed for each site class (figs. 1 and 2). These total age and total height values are then used for graphically estimating site index from the curves or for estimating site index using the formulae.

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[1] *These assumed years are currently used by the forest survey crews of the USDA Forest Service. Because the assuracy of these assumptions is unknown, much error in estimating both total age and site index can occur if trees initially grow faster or slower in height than assumed.*

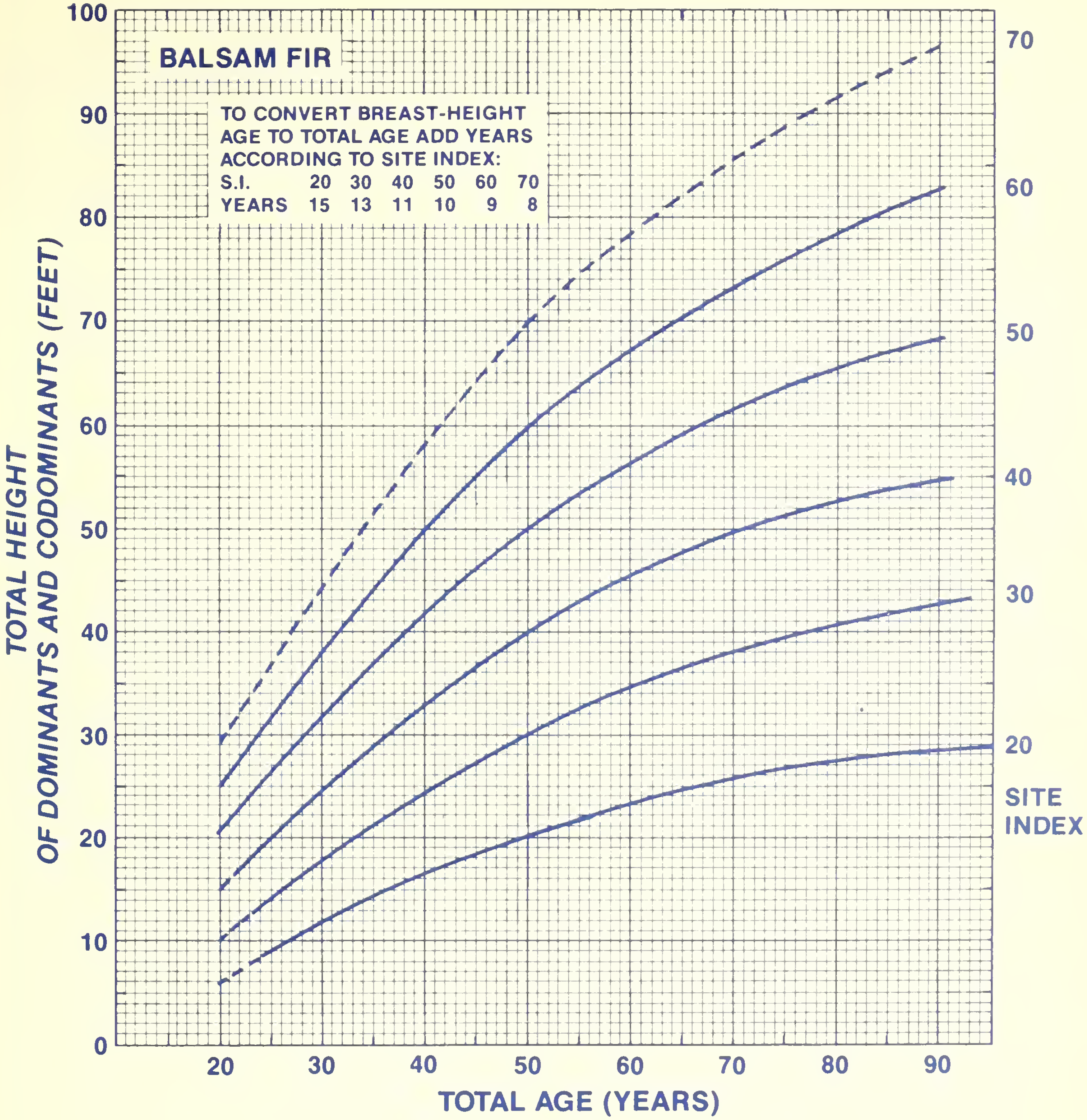

Figure 1.—*Site index curves for balsam fir in the Lake States. These are revised from the original curves published by Gevorkiantz (1956). Add the appropriate number of years from table 1 to breast height age to obtain total age.*

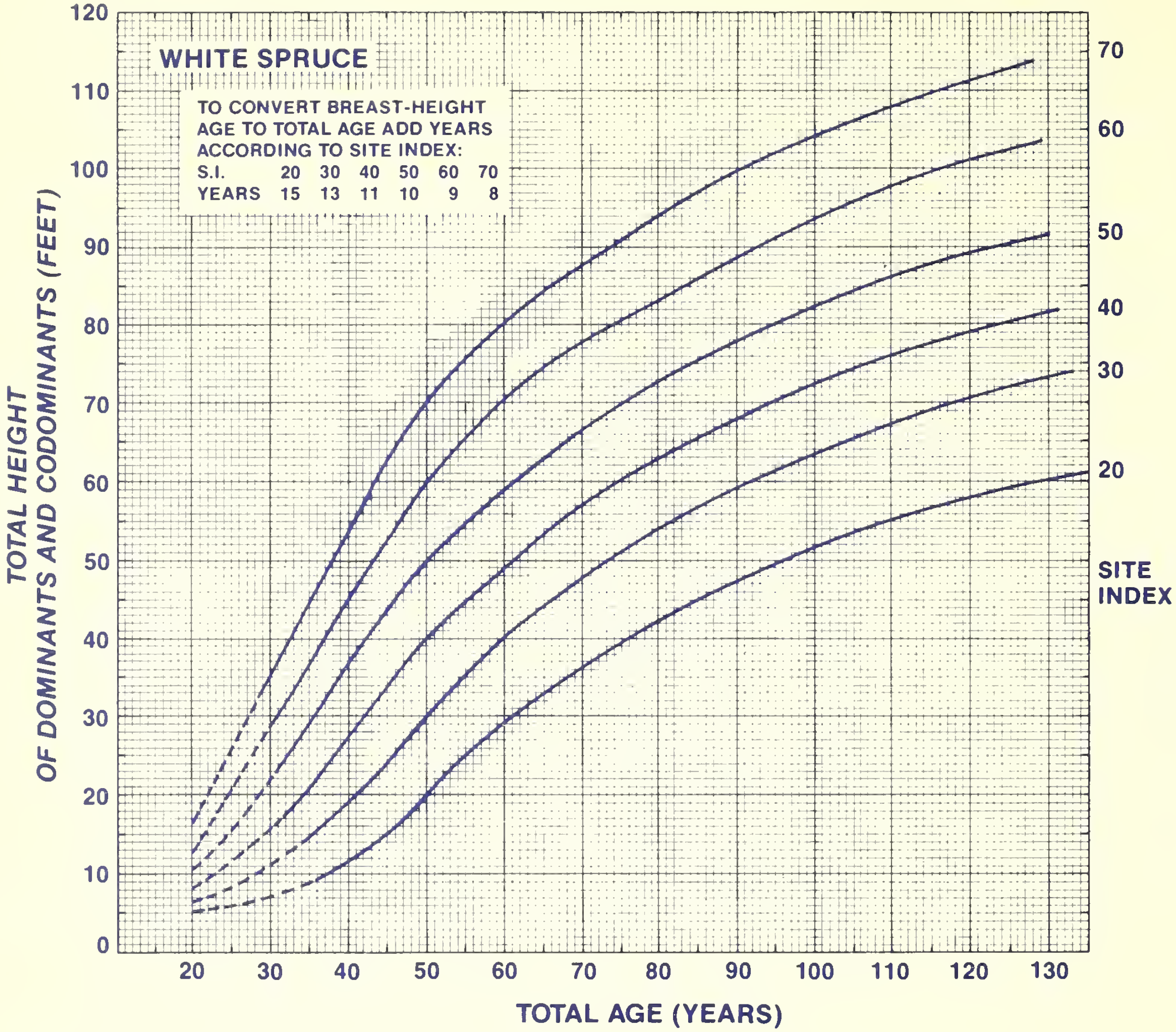

Figure 2.—*Site index curves for white spruce in the Lake States. These are revised from the original curves published by Gevorkiantz (1957). Add the appropriate number of years from table 1 to breast height to obtain total age.*

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NORTH CENTRAL FOREST EXPERIMENT STATION
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1981

A HOMEMADE INSTRUMENT FOR COLLECTING SOIL WATER FROM POROUS CERAMIC CUPS

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ABSTRACT.—An efficient Ceramic-Cup Water Collection Instrument (CCWCI, "quickie") is described. Soil water collection from ceramic-cup samplers may require compositing by equal volume from distantly spaced samplers, or simultaneous water collection from closely spaced samplers without compositing. All collection must be done with minimal opportunity for sample contamination. The CCWCI combines these and other soil water collection needs into a streamlined system that may be adapted to a variety of experimental designs and field conditions.

KEY WORDS: porous cups, soil solution, soil leachate, ceramic-cup lysimeters, nutrients.

Porous ceramic-cup samplers are widely used in soil nutrient studies to extract soil water from various soil depths. Under vacuum, these samplers draw water from the soil and temporarily store it. Then, the stored water must be collected and transported to a laboratory for chemical analysis. Unfortunately, there are no collection instruments commercially available for this time-consuming and repetitive procedure. To fill that gap, we have developed a Ceramic-Cup Water Collection Instrument (CCWCI, pronounced "quickie"). The CCWCI is well suited to studies with many ceramic-cup samplers that require sample collection at frequent intervals or require sample compositing in the manner suggested by Hansen and Harris (1975).

The basic features of CCWCI are:

1. It permits compositing by equal volumes from widely spaced samplers.
2. It permits simultaneous sample collection from several samplers located adjacent to each other.
3. It retains a vacuum while being moved from one subsampling point to the next, thereby minimizing the vacuum pumping operation.
4. It permits the reapplication of a vacuum to the samplers in one continuous operation with sample collection.
5. It minimizes sample contamination from outside sources.
6. It permits splitting of composited samples into two or more sample storage containers.
7. It has space for carrying sample storage pacs and sampler repair materials.
8. It is fabricated from lightweight commonly available materials using conventional shop tools.
9. It may be modified to meet the needs of different sampling schemes.
10. It is intended for use with two-line porous ceramic-cup samplers similar to those described by Linden (1977), and Knighton and Streblow (1981).

MATERIALS

The CCWCI system described here (fig. 1) is designed to collect subsamples at two soil depths at each of two widely spaced subsampling points. The materials required are:

Material	Quantity	Cost
Available through Curtin Matheson:[1]		
Tubing, latex 5 mm (³⁄₁₆ in.) I.D. Cat. No. 244-491	203 cm (80 in.)	$ 1.75
Tubing, latex, 6 mm I.D. × 16 mm O.D. (¼ in. × ⅝ in.) Cat. No. 203-471	30.5 cm (12 in.)	.90
Tubing, polyethylene 3 mm (⅛ in.) I.D. Cat. No. 204-875	203 cm (80 in.)	1.75
Available through Plasticware catalog:[2]		
Desiccator, vacuum 171 mm (6 in.) Cat. No. 6514-10	1 each	27.00
Available through Chemical Lab:		
Clamps, pinchcock	10 each	6.00
Flask, Erlenmeyer 500 ml heavy wall	4 each	7.04
Stoppers, rubber #00 1-hole	2 each	.20
Stoppers, rubber #7 3-hole	4 each	1.68
Y-connector, polypropylene 6 mm (¼ in.)	2 each	.36
Available through most local hardware stores:		
Aluminum sheet 24 gauge	16.5 cm × 28 cm (6-½ in. × 11 in.)	1.25
Angle aluminum 19 mm × 2 mm (¾ in. × ¹⁄₁₆ in.)	5.34 m (17 ft 6 in.)	8.40
Bolts, flat or round head, 5 mm × 19 mm (³⁄₁₆ in. × ¾ in.)	4 each	.25
Aluminum Rivet Back-up Plates 3 mm (⅛ in.)	30 each	1.00
Door pull handle 15 cm (6 in.)	1 each	1.50
Hasp, draw pull 16 mm × 41 mm (⅝ in. × 1-⅝ in.)	1 each	1.10
Hinge 2.5 cm × 2.5 cm (1 in. × 1 in.)	7 each	3.25
Hinge 3.8 cm × 3.8 cm (1-½ in. × 1-½ in.)	2 each	1.10
Lid support	1 each	2.00
Masonite, tempered 5 mm (⅛ in.)	122 cm × 52 cm (48 in. × 20-¼ in.)	1.50
Nuts, 5 mm (³⁄₁₆ in.) thread	4 each	.15
Plexiglass, clear, 3 mm (⅛ in.)	23 cm × 51 cm (9 in. × 20-⅛ in.)	4.00
Plexiglass, clear, 6 mm (¼ in.)	25 cm × 25 cm (9-¾ in. × 9-¾ in.)	2.75
Pop-rivets, aluminum 3 mm × 6 mm (⅛ in. × ¼ in.), 3 mm × 9 mm (⅛ in. × ³⁄₁₆ in.), 3 mm × 12 mm (⅛ in. × ½ in.)	125 total	5.00
Rubber band 3 mm × 15 cm (¼ in. × 6 in.)	1 each	.15
S-hooks, 25 mm (1 in.)	2 each	.34
Strap aluminum, 13 mm × 3 mm (½ in. × ⅛ in.)	35.5 cm (14 in.)	.66
Tape		
Velcro, 19 mm × 3 mm (¾ in. × ⅛ in.)	61 cm (24 in.)	4.00
	TOTAL	$ 95.08

An experienced craftsman can fabricate one CCWCI in 30 working hours.

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[1] *Curtin Matheson Scientific, Inc., P.O. Box 1546, Houston, Texas 77001.*

[2] *Plasticware catalog, Cole-Parmer Instrument Co., 7425 North Oak Park Ave., Chicago, Illinois 60648.*

there are four ceramic-cup samplers per plot with one deep and one shallow sampler at each of two widely spaced subsampling points. It is assumed the samples collected from the two shallow samplers are to be composited, as are the samples from the two deep samplers.

1. At one pair of samplers, attach the shallow sampler collection line to the right front CCWCI sample collection line and similarly attach the deep sampler to the left front CCWCI sample collection line.
2. Release the clamps on the two front vacuum-overflow lines attached to the samplers.
3. Attach a vacuum pump to the vacuum line on the overflow reservoir.[3]
4. Release the clamp on the vacuum line and draw a vacuum. Water will be drawn from the samplers into the flasks. The flask will retain approximately 400 ml and the excess will be drawn into the overflow reservoir.
5. Be prepared to place a clamp on each air inlet line of the ceramic samplers immediately when it is visibly, or audibly evident air is being drawn into the attached flask which indicates the sampler is empty.
6. After both samplers are empty, continue to draw a vacuum until the entire system is recharged to the desired vacuum.
7. Place clamps on the ceramic sampler lines, on the vacuum-overflow lines, and on the vacuum pump line.
8. Disconnect the samplers, attach the sampler line ends together, and remove the two clamps. The vacuum will be lost in the flasks but not in the overflow reservoir.
9. Disconnect the pump, move to the next pair of samplers, and repeat steps 1 to 8 using the back flasks and matching the shallow and deep samplers on the same sides of the CCWCI used at the previous subsampling point.
10. Composite the two deep samples and the two shallow samples. Do this by drawing the two drain lines out through the CCWCI side access door and draining an equal sample volume from each flask into a sample container. If the composited sample must be split into different containers to meet analytical requirements, do this by draining visually estimated equal volumes into each container.[4]
11. Drain excess sample water out of the flasks. It is not normally necessary to flush the CCWCI between samples because the dilution effect is overwhelming. However, flushing with distilled water may be necessary if extreme differences in element concentrations are expected.
12. Remove the bottom of the overflow reservoir and discard overflow water only when necessary because this destroys the vacuum in the CCWCI.
13. Move to the next plot and repeat the procedure.

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[3] *Either a large-volume pump equivalent to the Boekel 2043 (Curtin Matheson Scientific, Inc., Cat. No. 196-758) equipped with a vacuum gauge or a smaller pump equivalent to the Pressure-Vacuum Hand Pump (Cat. No. 2001) from Soilmoisture Equipment Corp., P.O. Box 30025, Santa Barbara, California 93105.*

[4] *Plastic 6-oz. Whirl-pac bags (Curtin Matheson Scientific, Inc., Cat. No. 205-070) are convenient for sample collection and storage.*

Modify the desiccator to serve as a vacuum and water overflow reservoir. Drill two holes, 1.2 cm in diameter, in opposite sides of the lid. Center them 2 cm from the knob. Place the desiccator base in the hole provided in the bottom panel of the CCWCI. Attach tubing compatible with the vacuum pump to the existing vacuum port on the side of the desiccator lid. Position the lid on the desiccator base and extend the tubing about 5 cm to 6 cm out of the hole in the plexiglass front. Secure the desiccator to the CCWCI by stretching a large rubber band from the side panel hooks across the desiccator lid. Insert the "Y's" into No. 00 1-hole rubber stoppers and set the stoppers in the drilled holes in the desiccator lid.

Invert four Erlenmeyer flasks in the flask support, and attach tubing to each housing using a 3-hole No. 7 rubber stopper as follows:

1. Sample collection line—use polyethylene tubing from 18 cm beyond the inside stopper surface through the stopper to just inside the closest CCWCI side panel sample collection line hole which is 1 cm in diameter. Use 10 cm of latex tubing to extend this line through the hole.
2. Vacuum-overflow line—use polyethylene tubing from 16 cm beyond the inside stopper surface to 2 cm beyond the outside stopper surface. Use latex tubing to extend this line to a "Y" on the overflow reservoir (desiccator) lid.
3. Drain line—use polyethylene tubing from flush with the inside of the stopper to 2 cm outside. Use 20 cm of latex tubing beyond this and dangle it from the stopper.

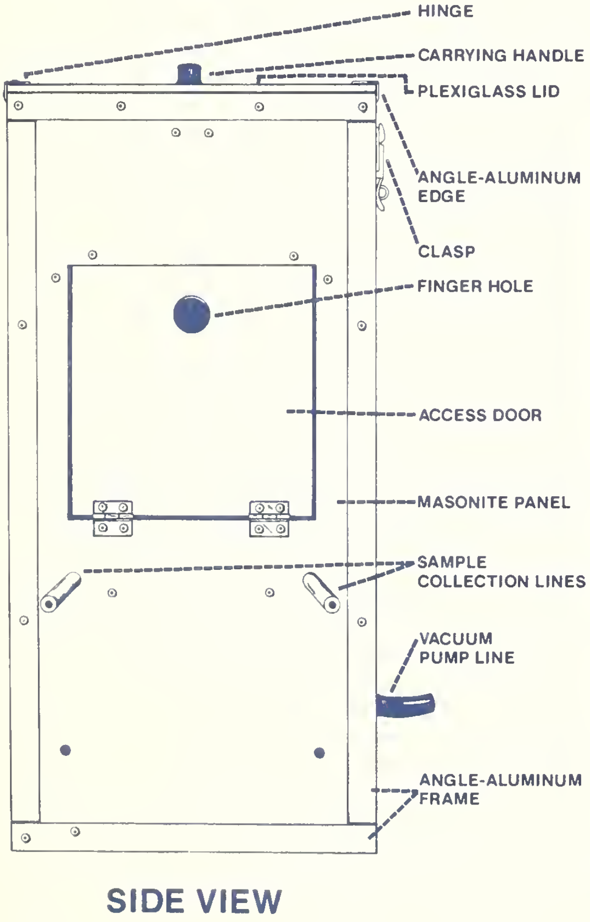

Figure 3.—*Side view of the completed CCWCI.*

Once the lines are installed securely, tape the stoppers to the flask. Attach pinchcock clamps to each drain line and to each overflow line. The completed CCWCI is illustrated in figure 4 with two models of ceramic-cup samplers and a small hand-held vacuum pump.

OPERATION

Many variations exist for collecting individual or composite samples. The following steps describe the procedure for field operation of the CCWCI when

Figure 4.—*Completed CCWCI with ceramic soil water samplers and small hand-held vacuum pump.*

FABRICATION

Construct a box (fig. 1) to contain the CCWCI sample collection equipment. Use angle-aluminum for the frame; use masonite for the bottom, flask-support, sides, and back panels; and use plexiglass for the front and top panels. Use pop rivets with backup plates as fasteners. Details and dimensions are illustrated in figures 2 and 3.

Assemble the outside angle-aluminum frame first. The inside flask-support frame should not be cut or installed until the side panels have been placed in the frame. Cut the bottom, front, side and back panels to inside frame dimensions. Use two layers of masonite for the bottom panel and cut a hole 10.3 cm in diameter in the upper layer to hold the bottom of the overflow reservoir when it is in place. Cut access doors 17 cm^2 in each masonite side panel as indicated (fig. 3). The doors should be located so that they close against the angle-aluminum frame of the flask-support. Glue strips of Velcro to the leading edge of each door and to the aluminum doorstop to hold the doors closed. Cut an access door in the back panel just above the lower angle-aluminum frame 19 cm wide and at least 24 cm long. An aluminum bar must be installed inside the upper edge of the door opening to serve as a doorstop. Use Velcro strips to hold the door closed. Fingerholes, 2 cm in diameter, should be drilled near the leading edge of each door for easy opening. Drill two holes 6 mm in diameter in each side panel as indicated for sample collection lines. Storage pockets may be attached inside each side panel beneath the access doors using sheet-aluminum folded to desired dimensions. We use the pockets to hold whirl-pac sample storage bags that are prelabeled and may have sample preservative added in advance. Drill one hole in the front panel for a vacuum line. After the panels are secured in the aluminum frame, the flask-support frame and panel may be cut to inside dimension of the box and assembled. Cut a hole 7.8 cm in diameter in the center of each quadrant of the flask-support panel to hold inverted Erlenmeyer flasks. Cut the CCWCI plexiglass lid and fasten a strip of angle-aluminum along the leading edge (fig. 3) and attach the clasp loop to the aluminum. Also, attach a carrying handle and a support bracket to the lid.

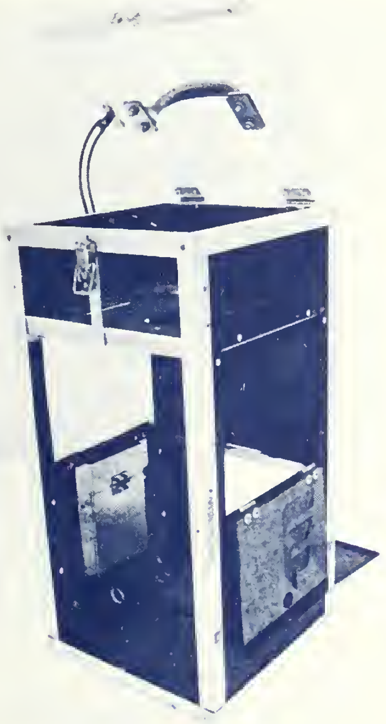

Figure 1.—*Front view of the empty CCWCI box.*

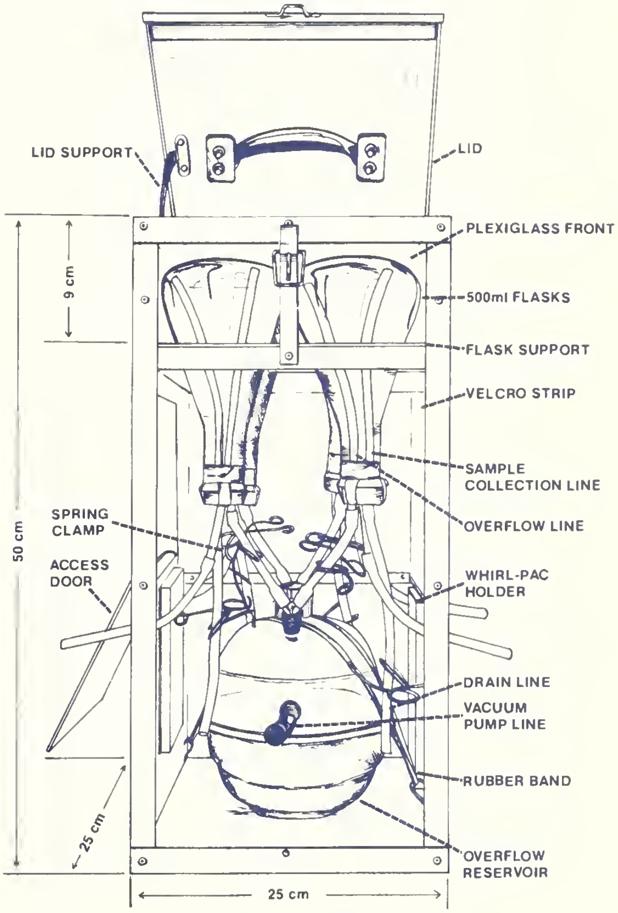

Figure 2.—*Front view of the completed CCWCI.*

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NORTH CENTRAL FOREST EXPERIMENT STATION
Research Note NC-271
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INSOLATION AT CARTERVILLE, ILLINOIS

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ABSTRACT.— Insolation measured with a precision spectral pyranometer, was recorded near Carterville, Illinois, for 1 year. The pyranometer was tilted at an angle of 25° in summer, 50° in winter, and 37.5° in spring and fall. The insolation measured in winter was found to be significantly larger than the insolation estimated on a horizontal surface.

KEY WORDS: Pyranometer, tilting, horizontal surface, beam radiation, reflected radiation.

A better understanding of insolation, the total solar radiation, throughout the year is needed to evaluate the efficiencies of the solar collectors and solar kilns used in hardwood drying research. So insolation has been measured daily with a pyranometer at the North Central Forest Experiment Station's Wood Processing Pilot Plant near Carterville, Illinois (37.5° N), since the fall of 1978. This precision spectral pyranometer was considered more sensitive, precise, durable, and rapid in response than other types of instruments that measure total solar radiation. It was mounted on top of a solar collector (fig. 1) that was tilted at an angle of 25° in summer, 50° in winter, and 37.5° in spring and fall to increase the reception of solar radiation. Daily insolation was recorded automatically on strip charts by a dual pen recorder with an electronic integrator. The upper pen traces the instantaneous values of insolation (peaks), while the lower pen produces an oscillatory trace, or integration, on a marginal scale to provide a count of the area under the peaks traced simultaneously by the upper pen.

RESULTS

Mean daily insolation, with standard deviation, was calculated for each month in 1979; maximum and minimum daily insolation was also noted. Insolation peaked during June and reached the lowest level during November (fig. 2). Amplitude, the range between maximum and minimum daily insolation, was greatest in February and the mean daily insolation was low; amplitude was least in July and the mean daily insolation was high. This is contrary to observations in West Virginia over a longer period of time (Patric and Caruso 1979).

The insolation measured in winter was significantly larger than the insolation estimated on a horizontal surface (table 1) (U.S. Department of Commerce 1968). Tilting the pyranometer to a 50° inclination probably caused the measured insolation to increase in winter. The pyranometer received not only more beam radiation (direct from the sun) but also more reflected radiation due to the snow-covered ground, especially during January and February (table 1).

To determine the solar collector size necessary to supply a certain portion of the heating requirement, one should consider the average daily temperatures of different months and seasons as well as the insolation (table 1). The ambient temperature does affect the efficiency of solar collectors.

Figure 1.—*The precision spectral pyranometer mounted on top of a solar collector at the Wood Processing Pilot Plant near Carterville, Illinois (37.5° N).*

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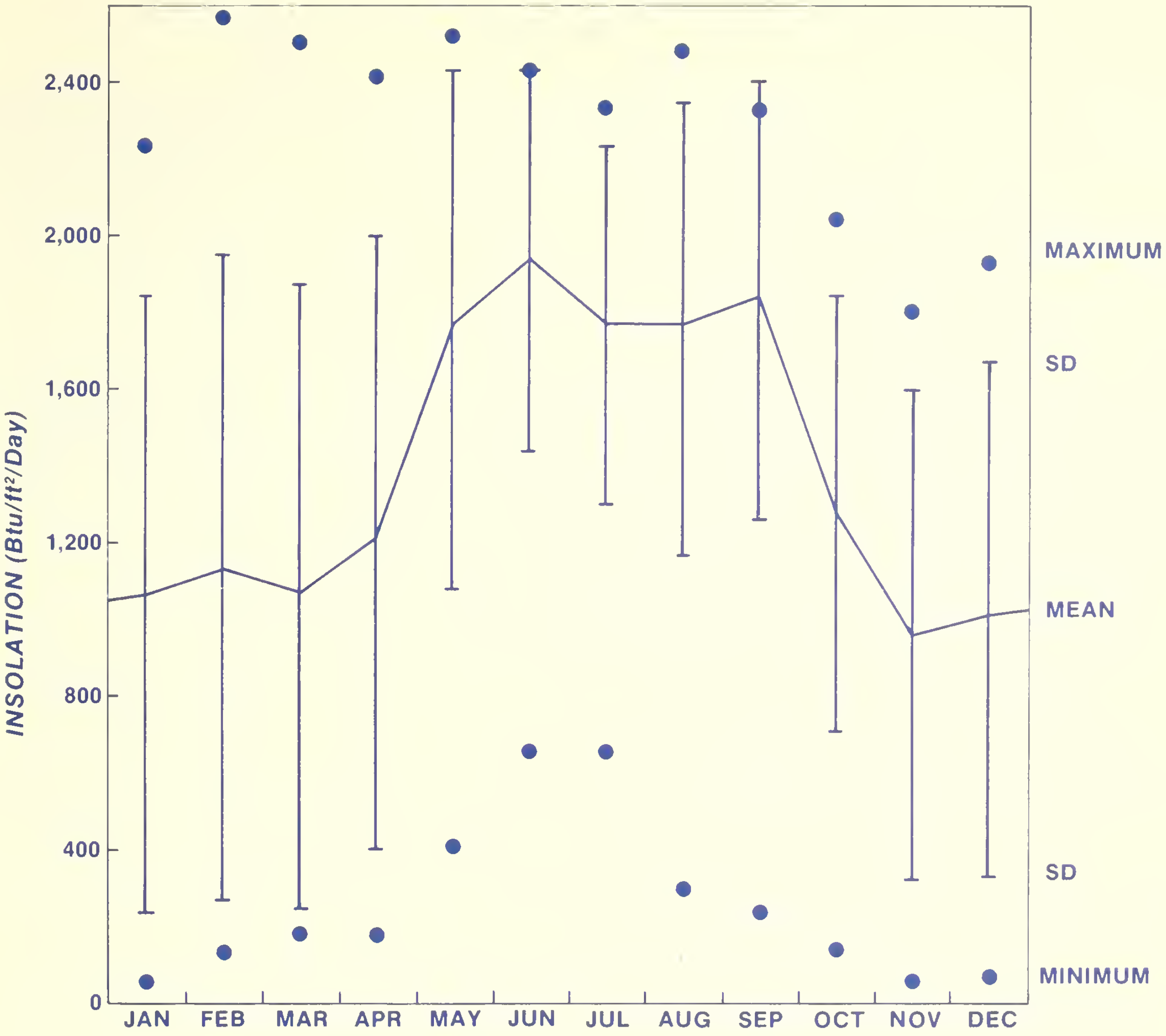

Figure 2.—*The range of measured daily insolation at the Wood Processing Pilot Plant near Carterville, Illinois. Mean daily values are plotted as a curve; standard deviations are plotted as vertical bars. Maximum and minimum values are the most and the least daily insolation observed for each month in 1979.*

Table 1.—*Measured versus estimated average daily insolation, monthly precipitation, and average daily temperatures at Carterville, Illinois*

Month	Insolation		Monthly precipitation (snowfall)[2]		Average daily temperature	
	Measured	Estimated[1]			Maximum	Minimum
	Btu/ft²/day		Inches		°F	
January	1,042	701	3.92	(20.6)	28.5	9.8
February	1,108	904	6.30	(15.7)	36.1	12.6
March	1,060	1,255	5.26	(1.0)	53.1	35.4
April	1,201	1,587	8.26	0	63.4	44.7
May	1,756	1,937	3.32	0	73.4	51.4
June	1,933	2,030	4.68	0	84.3	62.4
July	1,767	2,030	6.54	0	85.4	66.7
August	1,759	1,827	5.47	0	84.0	64.1
September	1,831	1,568	1.58	0	80.0	51.0
October	1,276	1,199	1.72	0	70.5	41.1
November	961	812	6.31	0	54.3	30.7
December	1,003	572	2.54	0	45.9	25.0

[1] (U.S. Department of Commerce 1968).

[2] (U.S. Department of Commerce 1979).

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1981

ESTIMATING TOTAL-TREE HEIGHT FOR UPLAND OAKS AND HICKORIES IN SOUTHERN ILLINOIS

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Research Forester,
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Biometrician

ABSTRACT.—An equation to predict total-tree height from merchantable length was developed for hardwoods: $\hat{Y} = 30.0 + 0.85 X$, with $R^2 = 0.87$.

KEY WORDS: Regression, merchantable height, Lake States, hardwoods.

Total-tree height is often used for determining weight or volume of standing trees. It is difficult to measure in hardwoods due to the lack of visibility and a well defined terminal. In this paper we examine relations between total-tree height and more easily measured variables. We find that total height can be estimated from merchantable height.

Data for this study came from measurements on 155 felled trees in the Shawnee National Forest in southern Illinois. Trees were selected from three 25-acre blocks on upland oak-hickory sites. The aspect was predominantly southern and the trees were dispersed from top to bottom of the slope. Trees were selected to give a representative range of size classes for each species. Species included are red oak, white oak, black oak, and hickories. Measured variables were:

D.B.H.—tree diameter at 4.5 feet above ground, on the uphill side of the tree;

Merchantable length—distance above 1-foot stump to a point on the main stem where diameter outside bark is 5 inches;

Total height—height above ground to the tip of the tree. Averages and ranges for these variables are:

Variable	Average	Range
D.b.h. (inches)	13.5	5.0-23.6
Merchantable length (feet)	50.8	8.5-78.5
Total height (feet)	73.2	37.5-96.6

A more complete display of the data (table 1), shows trends between the variables and the little variation in total height within a given merchantable height class.

After examining various plots of the data and screening several equation forms, we decided that a simple linear regression relating total-tree height to merchantable height was the best relation ($Y = 30.0 + 0.85x$, with $R^2 = 0.87$). Gevorkiantz and Olson (1955) present total height as a function of merchantable height and d.b.h. for Lake States species. But we found that including d.b.h. did not appreciably improve our equation for southern Illinois trees (increased R^2 by .003).

Total-tree height can be estimated from merchantable length measurements for selected hardwoods in southern Illinois by using the equation, graph or table (fig. 1, table 1). When merchantable length is estimated as number of 8-foot bolts, use this tabluation:

Merchantable length *(No. 8-ft. bolts)*	**Total height** *(Feet)*
1	37
2	44
3	50
4	57
5	64
6	71
7	78
8	84
9	91

These results essentially agree with those of Gevorkiantz and Olson (1955) but give a simplified procedure and equation for obtaining total-tree height. Our data points and resulting equation approximate the diagonal of the Gevorkiantz and Olson table of total height by d.b.h. and merchantable height.

Because our results are essentially the same as those of Gevorkiantz and Olson, their tables should apply in southern Illinois and our equation and tables should apply in the Lake States. But bottomland hardwoods, particularly eastern cottonwood, might require a different equation or table.

REFERENCE

Gevorkiantz, S. R., and L. P. Olson. 1955. Composite volume tables for timber and their application in the Lake States. U.S. Department of Agriculture Forest Service, Technical Bulletin 1104, 51 p.

Table 1.—*Number of observations (n) and average total height ($\bar{y}$) by diameter at breast height (d.b.h.) and number of bolts*

	Number of 8-foot bolts																	
D.b.h.	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**	
	n	$\bar{y}$	*n*	$\bar{y}$	*n*	$\bar{y}$	*n*	$\bar{y}$	*n*	$\bar{y}$	*n*	$\bar{y}$	*n*	$\bar{y}$	*n*	$\bar{y}$	*n*	$\bar{y}$
4																		
5	2	43	2	43														
6			2	40														
7			3	42	4	56	1	57										
8					7	55	4	59	2	60								
9							4	60	11	68	1	71						
10							2	56	3	68	3	74						
11									6	68	6	74	1	80				
12									1	70	4	73	2	81				
13									1	67	2	70	5	85				
14									2	69	4	81	9	82				
15									1	68	1	76	1	96	2	89		
16											1	78	2	80	2	89		
17											1	97	4	80	1	84	1	92
18													9	81	3	85		
19									1	56			2	72	5	87	1	88
20											1	73	5	79	4	86		
21											1	76	1	79	4	86	2	93
22															2	90		
23															1	81	1	97
24															1	88		
25																		
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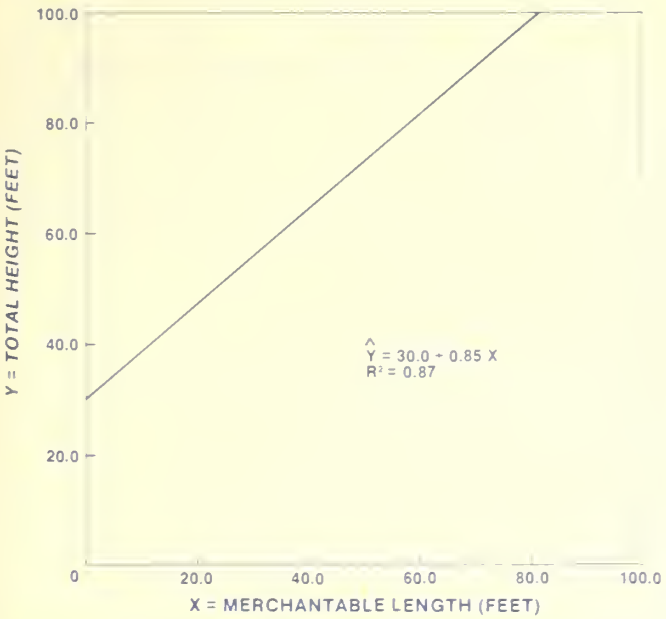

Figure 1.—*Relation between total-tree height and merchantable length for upland oaks and hickories in southern Illinois.*

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NORTH CENTRAL FOREST EXPERIMENT STATION
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ACIDITY OF LAKES AND IMPOUNDMENTS IN NORTH-CENTRAL MINNESOTA

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ABSTRACT.—Measurements of lake and impoundment pH for several years, intensive sampling within years, and pH-calcium plots verify normal pH levels and do not show evidence of changes due to acid precipitation. These data in comparison with general lake data narrow the northern Lake States area in which rain or snow may cause lake acidification.

KEY WORDS: Acid rain, acid precipitation, limnology, lake pH.

Acidity has increased in poorly buffered lakes of southern Scandinavia and eastern North America during the last 30 to 40 years (Wright and Gjessing 1976). Acid precipitation is thought to be the cause. It has spread in North America in recent decades (Likens *et al.* 1979), and lakes and streams in some watersheds with low buffering capacity are becoming more acid as a result (Jeffries *et al.* 1979, Henriksen 1979). We studied pH changes in lakes and impoundments in north-central Minnesota to see if lakes in this area showed signs of acidification due to acid precipitation.

METHODS

In the spring of 1974, we measured surface water pH and specific conductance (corrected to 25°C) in 17 lakes near the Marcell Experimental Forest in north-central Minnesota (fig. 1). We used this information in combination with water table maps to classify the lakes as perched, transitional, or strongly groundwater-fed (Hawkinson and Verry 1975). We remeasured these lakes in the fall of 1979 and measured four additional lakes in the same area. In the spring of 1980 we again measured pH and conductance in all 21 lakes and analyzed the water for calcium using atomic absorption (Perkin-Elmer 1973) and apparent color using a [1]Hellige Aqua Testor™ with colored glass discs calibrated to platinum-cobalt standards such that one color unit equals 1 mg Pt/l. True color was determined the same way after passing the water through a 0.45 μm filter. Lake samples were taken by gently lowering a glass beaker into the surface water of the littoral. Acidity (pH) and conductance were measured immediately with field-calibrated instruments and these values were checked the same or following day with laboratory meters. Lakes were in a mixed condition when all samples were taken. Changes in pH (calculations done with hydrogen ion activities) between the three measurement dates were tested for statistical significance at the 5 percent level of confidence using a paired t-test.

Seven shallow waterfowl impoundments in the Chippewa National Forest were measured for pH for 4 years (from April 1975 to May 1979) at least every 2 to 4 weeks throughout the year. One deep water marsh (Goose "Lake") in the Chippewa National Forest was similarly measured for 3 years (from March 1976 to May 1979).

In the spring of 1980, pH and calcium data for some of the 21 lakes were plotted and compared with Henriksen's lake acidification curve.

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[1] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

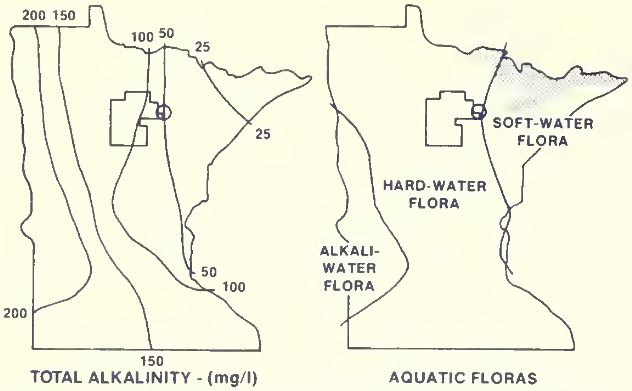

Figure 1.—*Location of sample lakes, Marcell Experimental Forest (circle), and impoundments, Chippewa National Forest (rectangle) in relation to Moyle's (1954) general lake data. Shaded area is exposed formation of Precambrian igneous and metamorphic rocks. These formations extend across the northern half of Minnesota to the Red River Valley but are generally covered with glacial drift.*

RESULTS AND DISCUSSION

Perched lakes in 1980 were 0.3 pH unit higher than in either 1974 or 1979 (table 1). Groundwater lakes were 0.2 pH unit lower in 1979 and 0.6 pH unit lower in 1980 than in 1974. Transitional lakes and data from other years for perched and groundwater lakes showed no statistically significant changes.

The most significant conclusion associated with these lake pH data is that no lake had a pH value below 6.0. Fish are not adversely affected at pH 6.0 and above. Thus, none of these lakes can be considered abnormally acidic. Even though some lake categories showed a statistical change in pH, it is presumptive to conclude that these changes represent a trend because lakes and impoundments normally vary approximately 1 pH unit annually.

The pH of the impoundments we studied ranged from 0.9 to 1.9 units annually (table 2). Such ranges in annual lake pH are also common. Lohammar (1938) measured lake pH at 70 sites in Sweden 3 or 4 times a year in 1933, 1934, and 1937 and found an average range of 0.9 pH units with ranges for individual lakes from 0.2 to 2.6 units. Juday *et al.* (1935) found a range in pH up to 1.4 pH units for 222 lakes measured for a period of 2 to 6 years (from 1925 to 1932) in northeastern Wisconsin and ranges up to 2.5 units in 23 additional lakes. Thus, interpretation of long-term lake pH changes from small sample numbers per year is difficult in light of normal within-year variation. Intensive sampling throughout the year on selected lakes would establish a pH record over several years and would be more easily interpreted.

The pH of snow at the Marcell Experimental Forest ranges from 3.5 to 4.9. Jeffries *et al.* (1979) suggested that stream or lake water may approach these values during and after snowmelt and thus watersheds that are not able to buffer acid snowmelt would be identified.

Impoundment water pH does not show a depression to near snow pH values, but ranges from 5.7 to 7.7 during and after snowmelt (fig. 2). The impoundments we studied covered a range of water quality conditions. Ketchum impoundment is strongly fed by groundwater springs and has abundant water and an average specific conductance of 350 µmhos. Bear Brook has a large organic soil surface watershed but significant amounts of groundwater inflow and an average specific conductance of 190. Cuba impoundment has a small watershed and is totally fed by surface water. It has an average specific conductance of 65. Water supply is not dependable and the impoundment nearly dried up during 1976 and 1977—two severe drought years. The pH of snow may not affect impoundment or lake pH if the snowpack is small. Snow water contents at maximumpack average 13 cm; only 1977 had a small snowpack: 1975, 20 cm; 1976, 13 cm; 1977, 4 cm; 1978, 11 cm; and 1979, 18 cm.

Acidity (pH) of the impoundments is least variable during February and March and generally low at this time. These under-ice values may result from respiration-generated carbon dioxide. Ice-out on these impoundments generally occurs during the third week of April—about 1 to 1½ weeks after snow has

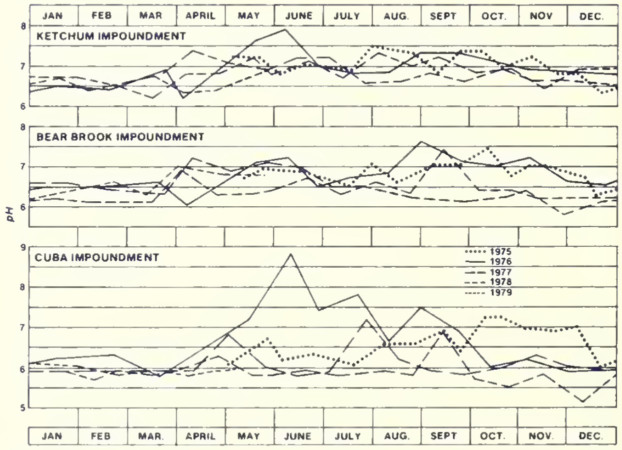

Figure 2.—*pH (25°C) of three impoundments on the Chippewa National Forest.*

Table 1.—*Chemical characteristics of lakes near the Marcell Experimental Forest*[1]

	Spring 1974		Fall 1979		Spring 1980				
Lake	**Specific conductance**	**pH**	**Specific conductance**	**pH**	**Specific conductance**	**pH**	**Apparent color units**	**True color units**	**Ca**
PERCHED LAKES									
	µmhos		µmhos		µmhos				mg/1
Blandin	16	6.2	15	6.0	14	6.6	30	25	1.0
Willeys	16	6.6	16	6.5	15	7.0	15	7	1.5
White Porky	18	6.6	16	6.3	18	6.9	20	15	1.4
Moss	19	6.8	13	6.5	11	6.7	25	15	1.1
Moon	19	6.4	17	6.6	17	7.3	25	15	1.2
Spring	20	6.4	18	6.5	16	6.4	75	50	1.3
Lum	21	6.3	21	6.3	20	6.6	40	30	1.8
Sawyer	22	6.1	17	6.1	16	6.9	25	20	1.6
Bog	23	6.6	19	6.2	18	6.6	65	45	1.4
Nose	—	—	22	6.2	20	6.6	25	15	1.6
Three Island	—	—	26	6.6	24	6.9	30	20	2.3
Shorty's	—	—	23	6.1	21	6.1	130	110	2.6
Tubby	—	—	19	6.1	18	6.6	45	35	1.2
Average	19	6.2a	19	6.2b	18	6.5a,b	42	31	1.5
TRANSITIONAL LAKES									
Burrow's	31	6.4	23	6.8	22	6.5	10	5	2.6
Lost Moose	55	7.4	41	7.0	52	7.0	25	15	6.4
Burnt Shanty	32	6.9	70	7.0	76	6.7	15	5	10.2
Buckman	95	7.3	102	7.3	96	7.0	30	15	10.8
Average	53	6.8	59	7.0	61	6.7	20	10	7.5
GROUNDWATER LAKES									
Sand	144	7.5	120	7.4	113	6.8	15	7	15.9
Hunter	150	7.5	112	7.3	120	7.0	45	25	15.4
Cutaway	160	7.6	161	7.2	160	6.7	25	15	17.1
Lake 19	192	7.2	181	7.0	202	6.9	30	10	10.0
Average	162	7.4cd	143	7.2d	149	6.8c	29	14	17.1
ALL LAKES									
Average	61	6.7	50	6.4e	51	6.6e	35	24	5.6

[1] pH averages followed by the same letter are significantly different (95 percent level of confidence) on the basis of a paired-test.

Table 2.—*Annual pH range of eight waterfowl impoundments on the Chippewa National Forest*[1]

Impoundment	**May 1975 to May 1976**	**May 1976 to May 1977**	**May 1977 to May 1978**	**May 1978 to May 1979**	**Average range**
Ball Club	6.0-7.2	6.1-7.3	5.6-7.5	6.1-6.9	1.3
Bear Brook	6.0-7.4	6.3-7.6	6.1-7.1	6.3-7.4	1.2
Beaver Lodge	6.0-7.5	6.0-7.2	5.7-7.2	6.0-7.0	1.3
Cuba	5.8-7.2	drawn down	5.7-7.2	5.1-6.9	1.6
East Lake	6.4-7.7	6.3-7.6	6.2-7.9	6.4-7.6	1.4
Goose Lake	—	5.2-6.3	4.8-6.3	5.4-6.7	1.3
Ketchum	6.2-7.4	6.8-7.9	6.2-7.2	6.3-7.3	1.1
Sucker Bay	drawn down	drawn down	5.7-6.6	5.3-6.5	1.1
Average annual range	1.3	1.2	1.2	1.2	1.3

[1] pH data were excluded in naturally dry or purposefully drawn-down impoundments.

melted from the uplands. pH varies more in April than under the ice, but generally tends to rise. Thus, these water bodies do not experience a low pH, snowmelt shock as experienced in other areas.

We plotted pH over calcium concentration for 15 lakes and compared these with an empirical curve developed by Henriksen (1979) to show lakes that may be losing bicarbonate ions due to acid precipitation but have not changed greatly in pH. Henriksen's empirical curve was developed with calcium concentrations up to 6 mg/l. Thus six of the lakes we studied are not shown because their calcium concentrations are greater than 10 mg/l (table 1). All but 1 of the 15 lakes plotted well below the empirical line separating lakes that are losing bicarbonate from those that are not (fig. 3). The single point above the line (indicating acidification) represents Shorty's Lake, which receives naturally low pH, highly colored water from surrounding organic soils (table 2). In Henriksen's (1979) words, "When applied to data from such waters (highly colored), the indicator (line) implies an apparent acidification where none has occurred."

A broader interpretation of these data can be made by reference to figure 1 showing Moyle's (1954) areas of alkalinity and hard water-soft water flora in Minnesota. It is unlikely that lakes to the west of the hard water-soft water line or west of the 50 mg/l $CaCO_3$ line will be changed by acid precipitation because of sufficient buffering capacity in watershed soils and groundwater aquifers. Interpretations of the acidification impact on lakes to the east of these lines need further analysis. It is known that lakes in northeastern Wisconsin have had pH values as low as 4.4 since 1925 when they were first measured (Juday *et al.* 1935). Some of these lakes have color values as low as 16. Thus, interpretations in soft water lakes with low pH values are difficult and should be done with intimate knowledge of the lake, its watershed, and hydrology. General surveys such as Moyle's help us sharpen our perspective.

The data in this paper establish a pH record for some lakes and impoundments in north-central Minnesota. Precipitation in this area is acid—listed snow pH values range from 3.5 to 4.9 and rain pH values range from 3.6 to 6.5. However, lakes and impoundments in this area exhibit normal pH values and do not show evidence of becoming more acidic.

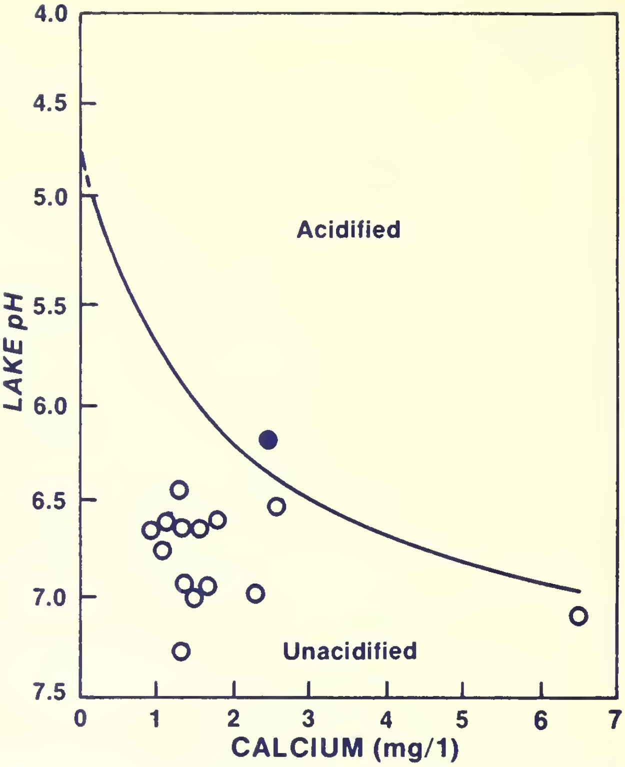

Figure 3.—*pH-calcium plots of 15 lakes in the area of the Marcell Experimental Forest. The solid dot is a highly colored lake. The separation line between acidified and unacidified lakes is from Henriksen (1979).*

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NORTH CENTRAL FOREST EXPERIMENT STATION
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1981

MARKING GROUND TARGETS WITH RADIO TRANSMITTERS DROPPED FROM AIRCRAFT

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ABSTRACT.— Reports development and use of a radio transmitter device that can be dropped from aircraft into target areas in remote habitats. Such a device could be a valuable tool for studying and managing forests and wildlife, for controlling forest fires, and for handling emergencies.

KEY WORDS: Wildlife, forest fire control, telemetry, forest research and management, disease and insect detection.

A radio transmitter that can be dropped from an aircraft for locating pockets of diseased trees in remote areas has been needed for some time. Pockets of diseased trees are often easily seen from the air, but are sometimes difficult to find on the ground because of the characteristics of certain diseases, the density of trees and shrubs, the number of trees affected, and the lack of ground reference points. Locations have been marked by dropping toilet paper, plastic flagging, crepe paper, and aluminum foil, but none of these markers have been entirely satisfactory.

A radio transmitter, however, would enable forest managers to locate areas of diseased trees efficiently and quickly. It would expedite the harvesting of these trees before they are entirely dead and before the wood becomes unusable. Using such a method, forest managers could more easily mark areas and check them on the ground for research or survey purposes. Electronic markers have been successfully used in Canada to locate small forest fires (Ponto and Lynch 1973).

We carried out a study to develop and test radio transmitter packages that could be safely dropped from an aircraft into designated areas, and to find out how quickly those transmitters could be found on the ground. For successful use, the transmitter had to meet four criteria: (1) it would not injure anyone it hit, (2) it would be protected upon impact, (3) it would accurately fall into the target area, and (4) it would emit a signal that could be detected with receivers from a distance of at least 2 miles on the ground and at least 10 miles from the air.

MATERIALS AND METHODS

Tower Drops

Initial tests were made at the University of Minnesota radio-tracking facilities at the Cedar Creek Natural History Area, Bethel, Minnesota. Radio transmitters were placed in several devices, and each device was dropped 12 times from a 100-foot tower. The following devices were tested:

a. Army transmitter with steel point (15 inches long, 70.0 ounces).
b. Plastic toy rocket (5 inches long, 0.35 ounce).
c. Foam rubber Nerf[1] ball (7-inch diameter, 2.5 ounces with a 36-inch plastic flagging tail).
d. Foam rubber Nerf ball (4-inch diameter, 0.5 ounce, with a 36-inch plastic flagging tail).
e. Sponge (6.5 inches long, 2 inches wide, 1.8 ounces).
f. Sponge-type football (5 inches long, 0.3 ounce).

Transmitters encapsulated in acrylic and weighing from 1.8 to 5.3 ounces were placed in the device. Each transmitter had a 12-inch antenna. Transmitter frequencies of 52.810 to 53.270 MHz and 150.700 to 151.275 MHz were used. An AVM[1] Model LA 12 receiver with a hand-held yagi antenna was used most of the time. Some tests were done with a receiver with a loop antenna (fig. 1).

Figure 1.—*Tuning radio receiver to transmitter frequency.*

Aircraft Drops

The 7-inch foam rubber Nerf ball was used in all air drops because it met our four criteria during initial testing and because its bright orange color made it highly visible. A slit was made in the ball and the transmitter was inserted into the center of the ball so that it was completely protected (fig. 2). Plastic flagging was attached to the ball at the slit that was then sewn closed with a heavy thread. Drops were made from single-engine aircraft at altitudes ranging from 100 to 1,200 feet. The aircraft either flew a straight approach or circled the target area at speeds ranging from 70 to 120 mph. Wind speeds ranged from 5 to 10 mph during drops. Twenty drops were made on 6 different dates into various habitats (table 1). Ground searches were conducted either the day of the drop, or 1 day or 5 days after. Distances from the nearest road to the transmitter ranged from 75 to 880 yards.

Figure 2.—*Nerf ball radio transmitter package.*

RESULTS

All transmitter packages were recovered undamaged after being dropped by aircraft into different habitats (table 1). All were found on the ground except one that was lodged in a tree. Search times ranged from 5 to 40 minutes after a signal was received. Distances from roads, brush density, and snow depth influenced the amount of search time needed. In seven drops, the transmitter package was either partially or entirely below the snow surface, leaving only the bright flagging exposed. This added visibility was important in decreasing the time that it took to locate and retrieve the marker.

Search crews were able to find target areas in all but two of the drops: in one, the small target area was missed; in the other, the transmitter landed in a creek and floated downstream, out of the target area. To hit target areas, the drops had to be properly timed in relation to airspeed. Accuracy from higher altitudes was achieved when drops were made from an aircraft circling the target area. Larger target areas were marked using the straight-line approach. On one drop, the tail of the transmitter device became entangled with the antenna, apparently causing greater drift.

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[1] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Table 1.—*Results of aircraft-dropped radio transmitters*

Drop no.	Date	Habitat and ground conditions	Aircraft altitude at drop	Aircraft Speed	Flight approach	Distance from ground target	Search time
			Feet	*m.p.h.*		*Yards*	*Min.*
1	6/13/73	Deciduous woods-shrubs	200	85-90	Straight	70	30
2	6/13/73	Open grassy field	200	85-90	Straight	0	20
3	6/13/73	Open grassy field	200	85-90	Straight	0	15
4	6/13/73	Deciduous woods-shrubs	200	85-90	Straight	50	40
5	8/30/73	White cedar swamp	500	100	Circling	50	5
6	8/30/73	White cedar swamp	500	100	Circling	75	40
7	8/30/73	White cedar swamp	500	100	Circling	65	22
8	8/30/73	White cedar swamp	500	100	Circling	55	7
9	4/9/74[1]	Deciduous woods	500	85-90	Circling	100	5
10	4/9/74[1]	Deciduous woods-snow	500	85-90	Circling	0	30
11	4/9/74[1]	Deciduous woods-snow	500	85-90	Circling	200	10
12	2/13/74	Bog-snow	600	70	Circling	300	9
13	2/13/74	Spruce aspen-snow	1200	80	Circling	100	25
14	2/13/74	Spruce-snow	700	80	Straight	440[2]	15
15	2/14/74	Jackpine-balsam-snow	200	80	Circling	100	20
16	2/14/74	Openfield snow	400	80	Circling	200	20
17	2/14/74	Light brush snow	100	100	Straight	10	15
18	7/5/79[3]	Deciduous woods-shrubs	1000	120	Circling	—[4]	15
19	7/5/79[3]	Deciduous woods-shrubs	1000	120	Straight	0	20
20	7/5/79[3]	Deciduous woods-water	1000	90	Circling	—[5]	10

[1] Search started 1 day after drop.

[2] Tail became tangled with antenna increasing drift.

[3] Search started 5 days after drop.

[4] Target area missed.

[5] Transmitter landed in creek, target area not found.

DISCUSSION AND CONCLUSIONS

Because of its safety and effectiveness, the foam rubber ball transmitter package is more suitable than previous marking devices. Although fixed-winged aircraft were used in this study, we believe that using this device with helicopters would permit even more accurate marking of ground locations.

This technique can have many uses: to quickly locate pockets of diseased and dying trees such as those infected by dwarf mistletoe, oak wilt, Dutch elm disease or insect outbreaks in remote, roadless areas; to mark fires that produce little smoke and are visible only from the air; to mark wolf-killed deer, wolf dens, large bird nests (e.g., goshawk, osprey, bald eagle), and other objects that are difficult to find from the ground; to speed recovery of lost or injured persons or to locate downed aircraft in remote areas.

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NORTH CENTRAL FOREST EXPERIMENT STATION
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1982

FOREST AREA IN NORTH DAKOTA, 1980[1]

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Mensurationist

ABSTRACT.—In 1980 North Dakota's forest resources covered 518,100 acres of land, a slight decline from the 572,400 acres reported in 1954. The area of commercial forest land also dropped from 398,400 acres to 343,200 acres. The aspen forest type makes up 41 percent of the commercial forest area.

KEY WORDS: Commercial forest land, productive-reserved, unproductive, wooded strips, shelterbelts, nonforest with trees, forest type, land use.

One out of every 86 acres in North Dakota is forested—a total of 518,100 acres. Most forested acres occur along the Canadian border, along the valleys of the Red, Missouri, Little Missouri, and Sheyenne Rivers, and around Devils Lake (table 1). An area of 343,200 acres, or 66 percent of the total forest area, is suitable for producing industrial timber and is therefore classified as commercial forest land. The aspen forest type makes up 41 percent (139,500 acres) of the commercial forest area. The second largest forest type, elm-ash, accounts for 33 percent or 113,700 acres. The ponderosa pine forest type has the least area—1 percent or 2,100 acres:

Forest type	Area
	(acres)
Aspen	139,500
Elm-ash	113,700
Oak	44,200
Cottonwood	18,700
Plains hardwoods	15,800
Ponderosa pine	2,100
Nonstocked	9,200
Total	343,200

The Eastern Unit of North Dakota is more heavily forested than the Western Unit (fig. 1). The most heavily forested County, Rolette, has 60,000 acres of commercial forest—10 percent of the land area (table 1).

Forest land declined in North Dakota by 53,900 acres or 9 percent between 1954 and 1980. Commercial forest land decreased 14 percent during the same period.

Land Use	1954	1980	Change since 1954
	Thousand acres		*Percent*
Forest			
Commercial	398.4	343.2	−14
Noncommercial			
Unproductive	170.4	148.0	−13
Reserved	3.2	26.9	+88
Total forest	572.0	518.1	−9
Nonforest	44,264.5	43,821.2	−1
Total land	44,836.5	44,339.3	−1

Published 1954 areas have been adjusted to align the estimates more closely with definitions of land classification and procedures used in the 1980 survey.

Noncommercial forest land totals 174,900 acres. Since 1954, the reserved area has increased 741 percent or 26,900 acres (4,500 acres productive and 22,400 acres unproductive) primarily due to increases in the areas of State and national parks. The remaining 148,000 acres of unproductive forest land, too poor to grow timber products for industrial use, are concentrated in the Badlands area.

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[1] *The sampling error of area for this survey was +3.9 percent for the acres of commercial forest land.*

Table 1.--Area of land, forest land, and nonforest land with trees by county, North Dakota, 1980

EASTERN UNIT

County	All[1] land	Forest land[2]							Wooded[7] strips and Shelterbelts	Total nonforest with trees[8]
		All forest	Productive[3] reserved	Unproductive[4]	Unproductive-reserved[5]	Commercial[6]	All forest	Commercial forest		
	Thousand acres						Percent		Thousand acres	
Barnes	946.6	6.5	--	1.9	--	4.6	0.7	0.5	5.3	9.5
Benson	897.7	31.4	--	3.4	--	28.0	3.5	3.1	11.0	16.1
Bottineau	1,073.4	44.3	--	2.3	--	42.0	4.1	3.9	9.4	15.5
Cass	1,119.3	11.4	--	2.9	--	8.5	1.0	0.8	15.0	23.6
Cavalier	967.5	40.2	--	6.3	--	33.9	4.2	3.5	7.3	15.1
Dickey	731.6	1.2	--	0.4	--	0.8	0.2	0.1	6.3	9.7
Eddy	406.4	3.7	--	0.9	--	2.8	0.9	0.7	5.0	9.2
Foster	413.0	0.2	--	0.1	--	0.1	--	--	2.9	4.4
Grand Forks	920.3	11.0	0.4	2.2	--	8.4	1.2	0.9	5.3	9.9
Griggs	434.3	3.4	--	0.8	--	2.6	0.8	0.6	5.7	9.2
Kidder	868.9	--	--	--	--	--	--	--	2.7	4.6
LaMoure	727.0	1.3	--	0.4	--	0.9	0.2	0.1	9.2	13.7
Logan	640.3	0.2	--	0.1	--	0.1	--	--	2.6	4.3
McHenry	1,202.8	14.3	--	2.9	--	11.4	1.2	1.0	10.7	18.3
McIntosh	634.7	0.4	--	0.2	--	0.2	--	--	5.1	8.0
Nelson	636.9	5.2	--	1.3	--	3.9	0.8	0.6	2.7	5.1
Pembina	719.4	31.0	0.4	4.9	0.4	25.3	4.3	3.5	7.4	11.1
Pierce	664.3	2.1	--	0.6	--	1.5	0.3	0.2	6.9	11.6
Ramsey	799.0	2.8	--	0.4	--	2.4	0.3	0.3	5.3	8.5
Ransom	551.1	15.9	--	4.0	--	11.9	2.9	2.2	3.6	7.3
Richland	927.4	9.0	--	1.6	--	7.4	1.0	0.8	7.7	13.3
Rolette	584.0	64.1	0.7	3.4	--	60.0	11.0	10.3	12.9	23.4
Sargent	545.9	1.3	--	0.5	--	0.8	0.2	0.2	5.0	8.0
Steele	454.5	3.6	--	1.1	--	2.5	0.8	0.6	3.5	5.9
Stutsman	1,449.2	2.8	--	0.9	--	1.9	0.2	0.1	7.6	12.9
Towner	667.5	0.1	--	--	--	0.1	--	--	0.6	1.2
Traill	551.0	8.4	--	2.4	--	6.0	1.5	1.1	11.7	18.7
Walsh	823.0	17.6	--	2.8	--	14.8	2.1	1.89	0.8	3.8
Wells	831.3	1.4	--	0.5	--	0.9	0.2	0.1	3.6	7.0
Total	22,208.3	334.8	1.5	49.2	0.4	283.7	1.5	1.3	177.1	308.9

WESTERN UNIT

Adams	633.1	0.1	--	0.1	--	--	--	--	1.4	3.7
Billings	729.0	17.2	--	9.5	4.2	3.5	2.4	0.5	6.7	66.8
Bowman	748.7	0.5	--	0.3	--	0.2	--	--	2.1	5.5
Burke	716.0	0.7	--	0.2	--	0.5	0.1	--	3.1	8.2
Burleigh	1,040.2	7.8	--	2.7	--	5.1	0.8	0.5	6.1	15.2
Divide	831.8	0.3	--	0.1	--	0.2	--	--	3.2	8.5
Dunn	1,275.0	37.9	0.4	26.0	--	11.5	3.0	0.9	30.4	73.5
Emmons	962.0	5.1	--	2.2	--	2.9	0.5	0.3	5.7	16.4
Golden Valley	649.0	2.4	--	1.1	--	1.3	0.4	0.2	8.6	26.0
Grant	1,066.1	2.9	--	1.9	--	1.0	0.3	0.1	8.7	22.0
Hettinger	726.0	0.4	--	0.2	--	0.2	--	--	2.6	6.7
McKenzie	1,750.4	55.1	2.6	32.1	15.7	4.7	3.2	0.3	20.9	193.7
McLean	1,321.6	7.4	--	2.6	--	4.8	0.6	0.4	10.2	22.9
Mercer	666.6	3.0	--	1.4	--	1.6	0.5	0.2	3.9	10.7
Morton	1,228.9	6.1	--	3.1	0.1	2.9	0.5	0.2	7.0	18.2
Mountrail	1,164.2	8.7	--	2.9	--	5.8	0.8	0.5	9.5	24.9
Oliver	461.3	3.7	--	2.3	--	1.4	0.8	0.3	5.9	14.4
Renville	567.2	0.9	--	0.4	--	0.5	0.2	0.1	1.5	3.9
Sheridan	632.7	0.4	--	0.2	--	0.2	--	--	1.4	3.7
Sioux	705.8	2.2	--	0.6	--	1.6	0.3	0.2	2.0	6.5
Slope	783.8	7.5	--	3.0	2.0	2.5	0.9	0.3	8.3	55.3
Stark	842.3	4.2	--	1.4	--	2.8	0.5	0.3	6.0	14.7
Ward	1,308.2	5.4	--	2.0	--	3.4	0.4	0.3	4.0	10.9
Williams	1,321.1	3.4	--	2.5	--	0.9	0.3	0.1	12.3	45.4
Total	22,131.0	183.3	3.0	98.8	22.0	59.5	0.8	0.3	171.5	677.7
State Total	44,339.3	518.1	4.5	148.0	22.4	343.2	1.2	0.8	348.6	986.6

[1] 1970 Bureau of the Census estimates.

[2] Land at least 16.7 percent stocked by forest trees of any size, or formerly having such tree cover, excludes land currently developed for nonforest use such as urban or heavily settled residential or resort area, city parks, orchards, improved roads or improved pasture land. The minimum forest area classified was 1 acre. Classified as forest were roadside, streamside, and shelterbelt strips of timber with a crown width of at least 120 feet and unimproved roads and trails, streams, and clearings in forested areas if less than 120 feet wide.

[3] Land sufficiently productive to qualify as commercial forest land but withdrawn from timber utilization through statute or administrative designation, or exclusive use for Christmas tree production as indicated by annual shearing.

[4] Forest land incapable of producing 20 cubic feet per acre of industrial wood under natural conditions, because of adverse site conditions i.e., sterile soils, dry climate, poor drainage, high elevation, steepness, and rockiness.

[5] Forest land incapable of producing 20 cubic feet per acre of wood under natural conditions and withdrawn for utilization through statute administrative designation.

[6] Forest land producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation.

[7] An acre or more of continuous forest land that would otherwise meet the standards for commercial forest land except that it is less than 120 feet wide.

[8] Areas of land with trees but have less than 16.7 percent stocking and/or are less than 120 feet wide area i.e., cropland with scattered trees, improved pasture with scattered trees, wooded strips, windbreaks, and idle farmland with scattered trees.

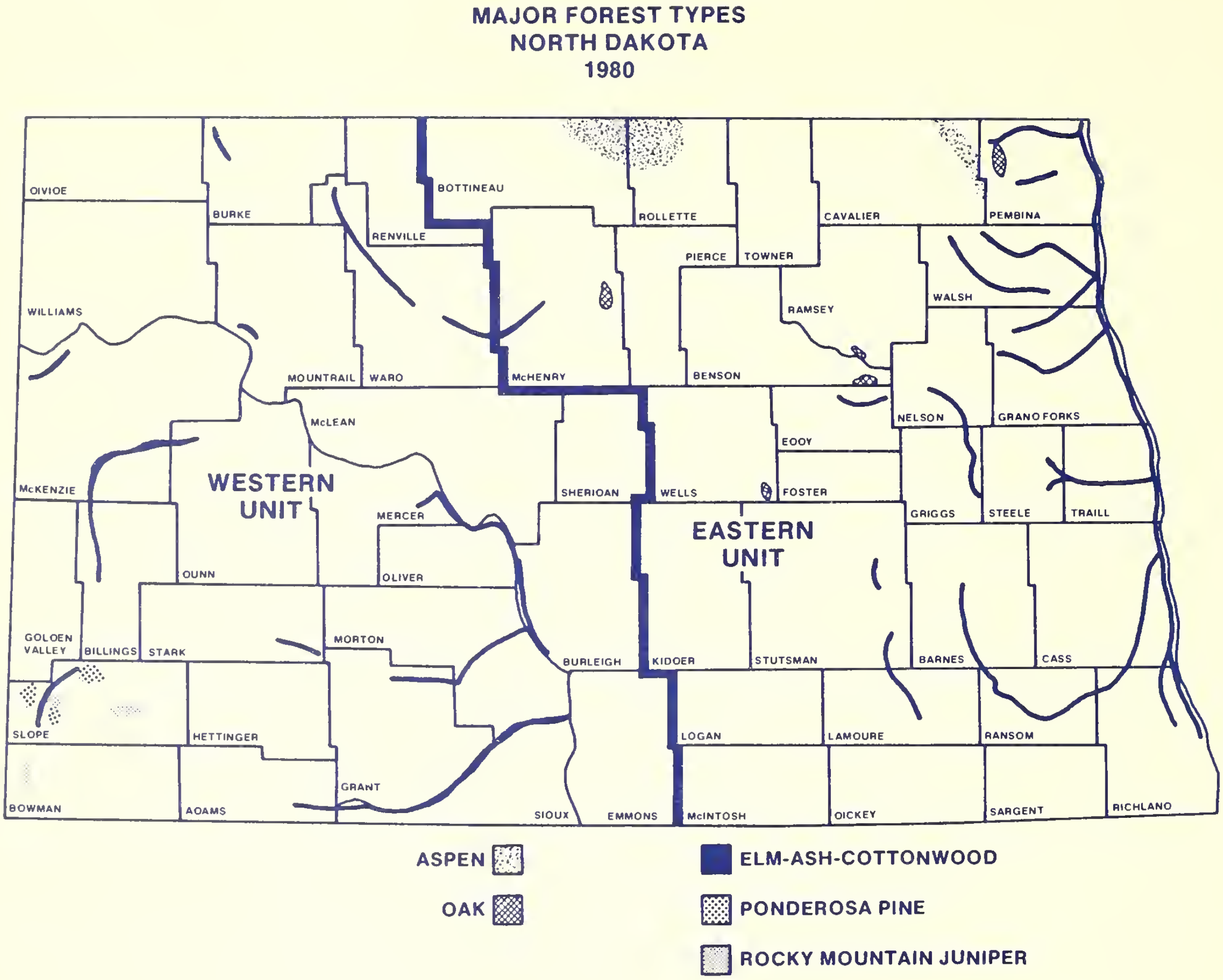

Figure 1.—*Major forest types, North Dakota, 1980.*

An important North Dakota resource not included in the forest land area are the 354,300 acres of natural and planted wooded strips and shelterbelts. This area does not include windbreaks around farm buildings and other structures.

The information in this note comes from the second North Dakota forest inventory made during 1978-1980 by the North Central Forest Experiment Station. Other publications giving further details will be available in the future.

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MICHIGAN SAW LOG PRODUCTION AND SAWMILL INDUSTRY, 1978

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ABSTRACT.—Michigan's saw log production climbed to 563 million board feet in 1978 from 514 million board feet in 1977. Eight percent was shipped to out-of-State mills. Michigan's 341 active sawmills received 525 million board feet of logs; only 1 percent came from other States.

KEY WORDS: Exports, lumber, aspen, oak, maple, pine.

Michigan loggers harvested 563 million board feet of saw logs in 1978, up 10 percent from 1977 (table 1). Eighty-eight percent was hardwood. Nearly three-fifths of the harvest was from three species—aspen, hard maple, and red oak. White pine was the major softwood cut. Major harvest gains were in aspen, maple, and oak; declines were concentrated in pine, spruce, and elm.

Demand was high for pallets, furniture stock, and railroad ties. Markets were good for construction lumber as national housing starts pushed above the 2 million mark in 1978 for the first time since 1973.

Table 1.-- Michigan saw log production by species, 1977 and 1978

(In thousand board feet)[1]

Species	1977	1978	Change
SOFTWOODS			
Cedar	4,228	5,498	1,270
Balsam fir	3,439	3,396	-43
Hemlock	8,724	8,907	183
Jack pine	15,697	9,821	-5,876
Red pine	21,973	13,231	-8,742
White pine	30,841	22,276	-8,565
Spruce	6,595	1,770	-4,825
Tamarack	0	221	221
Total	91,497	65,120	-26,377
HARDWOODS			
Ash	15,465	18,664	3,199
Aspen	98,361	127,078	28,717
Balsam poplar	244	1,450	1,206
Basswood	15,480	19,364	3,884
Beech	19,035	17,987	-1,048
Paper birch	9,870	6,646	-3,224
Yellow birch	4,018	8,087	4,069
Cottonwood	3,139	5,848	2,709
Elm	19,202	12,481	-6,721
Hickory	681	1,435	754
Hard maple	90,352	104,075	13,723
Soft maple	35,903	47,465	11,562
Red oak	82,766	93,495	10,729
White oak	22,590	29,105	6,515
Walnut	271	855	584
Other species	5,082	4,168	-914
Total	422,459	498,203	75,744
All species	513,956	563,323	49,367

[1] International ¼-inch rule.

Out-of-State sawmills procured 43 million board feet of Michigan logs (table 2, see page 4). Wisconsin was the primary customer, followed by Indiana and Kentucky. The western Upper Peninsula (UP) sup-

Table 3.--Saw log production

(In th

Unit and county	All species	Cedar	Balsam fir	Hemlock	Jack pine	Red pine	White pine	Spruce	Tama-rack	Ash
E. UPPER PENINSULA										
Alger	20,402	122	0	813	0	120	1,029	56	0	82
Chippewa	5,950	286	134	30	17	352	465	154	4	162
Delta	3,852	712	12	12	0	156	328	3	0	53
Luce	15,938	81	27	196	823	721	1,878	88	4	14
Mackinac	6,241	242	177	21	7	88	172	240	4	143
Menominee	14,744	1,374	139	1,311	1	287	1,312	168	140	207
Schoolcraft	13,485	132	0	28	260	1,426	1,426	32	0	35
Total	80,612	2,949	489	2,411	1,108	3,150	6,610	741	152	696
W. UPPER PENINSULA										
Baraga	10,807	36	3	1,169	1	88	620	52	0	75
Dickinson	5,504	329	6	2	521	1,026	1,244	70	0	36
Gogebic	21,860	19	17	1,709	462	716	1,739	104	17	354
Houghton	26,202	23	16	287	900	1,095	2,443	67	0	35
Iron	15,265	2	16	383	282	775	983	161	2	110
Keweenaw	6,251	0	0	264	0	104	525	107	0	81
Marquette	23,317	78	1	1,543	420	1,166	2,502	346	0	69
Ontonagon	12,797	10	4	520	206	353	800	55	5	166
Total	122,003	497	63	5,877	2,792	5,323	10,856	962	24	926
N. LOWER PENINSULA										
Alcona	10,102	0	0	0	24	603	579	0	0	147
Alpena	3,826	250	500	0	64	18	8	0	0	47
Antrim	6,968	0	0	127	0	100	14	0	0	928
Arenac	4,535	0	0	0	34	25	31	0	0	144
Bay	660	0	0	0	0	58	67	0	0	23
Benzie	2,244	0	0	10	0	15	17	0	0	189
Charlevoix	3,313	0	0	116	0	50	5	0	0	186
Cheboygan	17,890	208	563	19	167	107	89	13	40	464
Clare	10,871	10	10	0	353	78	20	0	0	144
Crawford	10,835	0	0	0	625	796	695	0	0	474
Emmet	6,484	0	0	41	4	66	15	0	0	410
Gladwin	8,497	15	15	0	23	63	30	0	0	106
Grand Traverse	1,074	0	0	0	0	14	127	0	0	100
Iosco	5,415	0	0	0	75	287	342	0	0	131
Isabella	4,122	0	0	0	0	25	10	0	0	334
Kalkaska	4,532	0	0	16	339	112	59	0	0	515
Lake	8,142	0	0	0	611	107	6	0	0	48
Leelanau	3,699	0	0	205	0	8	98	54	0	153
Manistee	1,273	0	0	0	0	27	18	0	0	156
Mason	4,487	0	0	0	0	62	8	0	0	8
Mecosta	6,945	0	0	4	0	49	7	0	0	265
Midland	10,731	0	0	0	250	33	17	0	0	499
Missaukee	2,860	2	2	4	0	27	36	0	0	144
Montmorency	13,135	460	750	0	260	222	102	0	0	32
Newaygo	14,961	0	0	0	0	150	605	0	0	446
Oceana	10,337	0	0	0	0	50	100	0	0	175
Ogemaw	8,505	0	0	0	77	182	168	0	5	64
Osceola	11,596	0	0	69	0	226	149	0	0	516
Oscoda	5,122	0	0	0	128	195	125	0	0	54
Otsego	7,229	3	0	0	95	95	18	0	0	523
Presque Isle	7,344	1,100	1,000	0	65	231	185	0	0	2
Roscommon	7,582	2	2	5	2,727	495	150	0	0	9
Wexford	1,836	2	2	3	0	63	482	0	0	23
Total	227,152	2,052	2,844	619	5,921	4,639	4,382	67	45	7,459
S. LOWER PENINSULA										
Allegan	6,928	0	0	0	0	0	81	0	0	651
Barry	7,641	0	0	0	0	0	0	0	0	657
Berrien	1,880	0	0	0	0	0	0	0	0	163
Branch	2,024	0	0	0	0	0	0	0	0	138
Calhoun	11,082	0	0	0	0	0	0	0	0	874
Cass	3,902	0	0	0	0	0	0	0	0	69
Clinton	2,607	0	0	0	0	0	0	0	0	103
Eaton	4,274	0	0	0	0	0	0	0	0	324
Genessee	880	0	0	0	0	0	0	0	0	60
Gratiot	3,880	0	0	0	0	0	0	0	0	209
Hillsdale	3,241	0	0	0	0	0	0	0	0	259
Huron	1,615	0	0	0	0	0	0	0	0	110
Ingham	4,414	0	0	0	0	0	0	0	0	226
Ionia	7,485	0	0	0	0	0	0	0	0	741
Jackson	6,114	0	0	0	0	0	0	0	0	461
Kalamazoo	911	0	0	0	0	0	0	0	0	7
Kent	10,336	0	0	0	0	29	36	0	0	652
Lapeer	3,624	0	0	0	0	0	0	0	0	348
Lenawee	2,559	0	0	0	0	0	0	0	0	294
Livingston	608	0	0	0	0	0	0	0	0	69
Macomb	250	0	0	0	0	0	0	0	0	30
Monroe	1,864	0	0	0	0	0	0	0	0	120
Montcalm	9,600	0	0	0	0	25	85	0	0	556
Muskegon	4,476	0	0	0	0	0	180	0	0	200
Oakland	1,285	0	0	0	0	0	0	0	0	100
Ottawa	852	0	0	0	0	0	14	0	0	50
Saginaw	4,027	0	0	0	0	0	15	0	0	350
St. Clair	6,427	0	0	0	0	0	0	0	0	545
St. Joseph	3,280	0	0	0	0	0	0	0	0	119
Sanilac	1,765	0	0	0	0	0	0	0	0	200
Shiawassee	2,589	0	0	0	0	0	0	0	0	134
Tuscola	2,846	0	0	0	0	0	10	0	0	144
Van Buren	4,814	0	0	0	0	65	7	0	0	327
Washtenaw	3,419	0	0	0	0	0	0	0	0	286
Wayne	57	0	0	0	0	0	0	0	0	7
Total	133,556	0	0	0	0	119	428	0	0	9,583
State total	563,323	5,498	3,396	8,907	9,821	13,231	22,276	1,770	221	18,664

[1] International 1/4-inch rule.

ty and species, Michigan, 1978

eet)[1/]

cies group												
Bass-wood	Beech	White birch	Yellow birch	Cotton-wood	Elm	Hickory	Hard maple	Soft maple	Red oak	White oak	Walnut	Other hard-woods
252	3,961	50	554	0	881	0	10,411	1,841	54	0	0	135
414	300	283	11	0	221	0	1,100	129	10	0	0	0
201	47	331	161	0	455	0	934	192	12	0	0	22
85	2,952	46	534	0	305	0	6,202	1,069	150	0	0	63
263	330	328	65	0	521	0	2,120	537	0	0	0	0
847	169	845	348	0	1,099	0	3,559	512	27	0	0	13
112	2,247	373	369	0	393	0	4,936	1,296	33	0	0	32
2,174	10,006	2,256	2,042	0	3,875	0	29,262	5,576	286	0	0	265
266	5	29	723	0	758	0	4,149	495	155	0	0	16
178	0	295	92	0	513	0	664	72	52	0	0	0
684	0	228	702	0	921	0	5,774	316	54	0	0	0
492	0	390	804	0	306	0	6,122	1,163	1,242	85	0	5
656	0	172	956	0	2,670	0	3,997	375	102	0	0	62
105	0	0	630	0	190	0	3,006	628	509	0	0	0
701	476	271	1,405	0	1,083	0	10,856	1,200	257	8	0	24
453	0	75	570	0	720	0	4,720	728	91	0	0	16
3,535	481	1,460	5,882	0	7,161	0	39,288	4,977	2,462	93	0	123
80	31	127	0	0	11	0	64	286	1,572	227	0	0
0	8	28	0	0	16	0	69	1,054	505	53	0	0
802	154	104	0	0	422	0	1,920	310	800	0	0	8
19	0	54	0	260	5	0	88	588	816	85	0	2
4	0	0	0	5	0	0	54	130	199	70	0	0
497	159	9	0	0	0	0	940	65	61	0	0	157
460	93	0	0	0	136	0	1,529	155	0	0	0	0
1,137	467	426	80	0	230	0	1,471	657	79	0	0	9
125	10	40	0	100	0	0	488	905	1,415	134	0	0
135	135	104	0	0	67	0	211	172	3,081	27	0	0
962	555	80	5	0	86	0	1,522	267	59	20	0	15
59	0	118	0	315	1	0	171	813	1,377	348	0	0
180	30	0	0	0	0	0	340	75	50	0	0	60
9	5	80	0	235	13	0	110	452	788	142	0	1
242	84	5	0	151	0	18	826	790	929	358	0	0
0	159	4	0	0	13	0	561	166	1,415	250	0	0
232	143	0	0	0	0	0	344	431	3,684	1,000	0	24
304	110	13	0	0	108	0	1,298	466	782	0	0	58
55	0	0	0	0	0	0	144	73	546	0	0	27
224	269	0	0	0	0	0	517	532	1,357	400	0	12
215	160	14	0	81	9	21	988	952	2,464	848	0	0
286	109	158	0	952	0	18	500	1,782	2,072	931	0	0
223	164	8	0	0	2	0	233	182	423	250	0	32
200	182	385	0	0	54	0	175	450	736	111	0	0
249	161	0	0	31	0	18	973	1,301	7,761	1,062	0	0
595	395	0	0	0	0	0	2,050	1,475	3,182	850	0	0
142	35	240	0	0	0	0	72	216	1,191	100	0	0
297	329	35	0	16	18	18	871	493	4,219	738	0	15
85	0	131	0	0	0	0	46	92	1,415	0	0	0
512	356	288	50	0	166	0	924	407	925	0	0	2
524	117	182	0	0	8	0	185	187	9	69	0	0
9	10	33	0	0	4	0	90	179	1,492	50	0	0
61	70	12	0	0	3	0	174	219	223	0	0	21
8,924	4,500	2,678	135	2,146	1,372	93	19,948	16,322	45,627	8,123	0	443
159	79	0	0	6	0	39	1,021	831	2,659	930	19	432
220	128	0	0	6	0	53	994	1,059	2,810	1,135	12	555
69	84	46	0	32	1	33	228	229	604	90	137	90
57	62	46	0	18	0	17	252	276	682	329	137	9
148	579	0	0	15	0	162	951	1,983	4,051	1,804	3	512
122	155	0	3	50	7	99	304	291	2,511	173	4	108
113	43	0	0	32	0	41	338	288	1,452	187	0	10
124	69	0	0	7	0	39	629	788	1,299	593	4	398
60	0	0	0	60	0	0	125	205	260	110	0	0
242	59	0	0	91	0	18	615	690	863	543	0	0
111	47	46	0	33	0	35	369	507	1,110	554	152	11
50	0	0	0	320	0	0	200	400	250	160	0	0
220	145	0	0	6	0	94	742	830	1,413	690	7	36
242	169	0	0	52	0	46	1,270	1,289	2,354	895	1	426
81	156	46	0	0	0	72	436	972	1,864	1,800	143	76
22	7	0	0	3	0	3	166	237	367	94	1	4
326	228	0	0	13	0	32	1,245	1,230	4,580	1,467	1	455
183	0	0	0	483	4	30	296	697	742	788	0	28
105	44	22	0	240	0	41	166	358	753	480	18	21
14	124	0	0	0	0	14	14	138	207	0	0	28
10	0	0	0	10	0	0	0	50	50	100	0	0
70	20	0	0	44	14	44	90	242	685	505	13	10
402	163	0	0	230	0	32	1,278	1,159	3,113	1,092	1	14
28	45	0	0	25	0	0	375	510	2,033	562	13	0
65	0	0	0	0	0	0	205	310	315	290	0	0
21	89	0	0	0	0	0	125	110	286	137	0	0
301	64	0	0	410	0	14	561	788	805	569	0	0
300	0	0	25	495	0	0	440	1,166	1,019	2,312	0	0
216	215	0	0	39	11	80	445	398	1,198	478	0	68
60	0	0	0	340	0	0	115	350	275	375	0	0
200	87	0	0	106	0	32	503	339	762	426	0	0
61	0	0	0	362	0	0	215	857	310	185	0	0
172	82	46	0	75	4	3	789	537	2,104	394	168	25
157	57	0	0	70	25	262	75	476	1,328	641	21	21
0	0	0	0	29	7	7	0	0	6	1	0	0
4,731	3,000	252	28	3,702	73	1342	15,577	20,590	45,120	20,889	855	3,337
19,364	17,987	6,646	8,087	5,848	12,481	1,435	104,075	47,465	93,495	29,105	855	4,168

Table 2.--Saw log production by species and State of destination, Michigan, 1978

(In thousand board feet)[1]

Species	All States	Michigan	Wisconsin	Indiana	Kentucky
SOFTWOODS					
Cedar	5,498	5,496	2	0	0
Balsam fir	3,396	3,355	41	0	0
Hemlock	8,907	7,059	1,848	0	0
Jack pine	9,821	6,740	3,081	0	0
Red pine	13,231	8,913	4,318	0	0
White pine	22,276	16,135	6,141	0	0
Spruce	1,770	1,546	224	0	0
Tamarack	221	221	0	0	0
Total	65,120	49,465	15,655	0	0
HARDWOODS					
Ash	18,664	18,437	59	168	0
Aspen	127,078	108,176	18,890	12	0
Balsam poplar	1,450	1,450	0	0	0
Basswood	19,364	18,657	587	120	0
Beech	17,987	17,738	0	249	0
Paper birch	6,646	6,068	578	0	0
Yellow birch	8,087	7,695	389	3	0
Cottonwood	5,848	5,735	0	113	0
Elm	12,481	11,357	1,108	16	0
Hickory	1,435	1,220	0	215	0
Hard maple	104,075	102,167	1,610	298	0
Soft maple	47,465	46,892	215	358	0
Red oak	93,495	91,528	253	1,714	0
White oak	29,105	28,653	0	452	0
Walnut	855	806	0	14	35
Other species	4,168	3,947	28	193	0
Total	498,203	470,526	23,717	3,925	35
All species	563,323	519,991	39,372	3,925	35

[1] International 1/4-inch rule

plied more than four-fifths of these exports. Pine and aspen comprised three-fourths of the export volume.

Compared to 1977, saw log output rose 68 million board feet in the Lower Peninsula (LP) and fell 19 million board feet in the UP. The northern LP supplied more than two-thirds of the aspen and continued to be the leading saw log producing region. UP producers cut two-thirds of the hard maple; LP loggers cut 97 percent of the red oak.

Producers harvested more than 20 million board feet of saw logs in each of four UP Counties—Houghton, Marquette, Gogebic, and Alger (table 3).

Michigan's 341 active sawmills (21 more than in 1977) received 525 million board feet of saw logs, up 15 percent from 1977. Only 5 million board feet came from other States (table 4). Average annual lumber production per mill continued to climb, reaching 1.54 million board feet. Nineteen mills each sawed more than 5 million board feet and 127 others sawed between 1 and 5 million board feet.

All active sawmills using Michigan logs and bolts were canvassed by means of a formal questionnaire. Canvassing in Michigan was supervised by the Michigan Department of Natural Resources (DNR) with personal contacts at sawmills by DNR personnel and forestry consultants. For a few Michigan mills that did not furnish complete data, DNR wood utilization specialists provided estimates based on prior knowledge and contacts. The North Central Forest Experiment Station canvassed out-of-State sawmills using Michigan logs and edited and compiled the data.

Table 4.--Saw log receipts in Michigan by species and State of origin, 1978

(In thousand board feet)[1]

Species	All States	Michigan	Wisconsin	Ohio
SOFTWOODS				
Cedar	5,598	5,496	102	0
Balsam fir	3,361	3,355	6	0
Hemlock	7,077	7,059	18	0
Jack pine	6,740	6,740	0	0
Red pine	8,940	8,913	27	0
White pine	16,313	16,135	178	0
Spruce	1,587	1,546	41	0
Tamarack	227	221	6	0
Total	49,843	49,465	378	0
HARDWOODS				
Ash	18,713	18,437	177	99
Aspen	108,562	108,176	386	0
Balsam poplar	1,450	1,450	0	0
Basswood	19,015	18,657	289	69
Beech	17,760	17,738	3	19
Paper birch	6,136	6,068	68	0
Yellow birch	7,924	7,695	229	0
Cottonwood	5,765	5,735	0	30
Elm	12,508	11,357	1,151	0
Hickory	1,250	1,220	0	30
Hard maple	103,655	102,167	1,458	30
Soft maple	47,214	46,892	123	199
Red oak	91,978	91,528	102	348
White oak	28,802	28,653	0	149
Walnut	816	806	0	10
Other species	3,957	3,947	0	10
Total	475,505	470,526	3,986	993
All species	525,348	519,991	4,364	993

[1] International 1/4-inch rule

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SULFUR CONTENT OF UPLAND AND WETLAND VEGETATION IN NORTH CENTRAL MINNESOTA

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ABSTRACT.—The sulfur concentration in 138 plant taxa is reported. Significant differences in concentration are noted between some plant life forms and between different environments.

KEY WORDS: sulfur cycle, plant life-form, flora, Lake States, acid precipitation.

Industrial and domestic emissions continue to pour into our atmosphere with little understood consequences (Dochinger and Seliga 1976). These emissions contain sulfur and other elements that increase the acidity, or hydrogen ion activity in precipitation. To improve our understanding of how this "acid rain" affects upland and wetland ecosystems in North America, we need to learn more about the sulfur cycle. We also need to identify all related information, and make it readily available. At the Forestry Sciences Laboratory in Grand Rapids, Minnesota, we have been analyzing the sulfur content of vegetation as part of a larger nutrient study. However, because of the urgent need to better understand the sulfur cycle we are publishing this data immediately in its simplest form.

METHODS

The vegetation was collected from seven water impoundments and one natural deep marsh on the Chippewa National Forest in August of 1976, 1977, and 1978. Samples were collected from 24 1-m^2 systematically located plots in each wetland. The plots were located on transects that extended from 90 cm-deep water to a point 60 cm above the normal water level. All vegetation was clipped on each plot (including woody species less than 2.5 cm at the base), placed in a plastic bag, and transported to the laboratory where it was either frozen immediately or kept at about 3°C for up to 2 weeks before sorting by species. The vegetation was sorted and ovendried for 48 hours at 80°C, and then each species was composited. The composited sample was ground in a Wiley mill and thoroughly mixed, then subsampled for analysis. The foliage and wood of woody species were ground together. The analysis was performed at the Research Analytical Laboratory at the University of Minnesota in St. Paul, Minnesota. Digestion was done by nitric and perchloric acids and SO_4 (later converted to S) content determined turbidmetrically with barium chloride (Blanchar *et al.* 1965).

The samples included the natural mineral and biotic material that adheres to submerged plant surfaces. When using and interpreting the data keep in mind this source of sulfur that could not be partitioned.

The species were grouped by life form, and mean sulfur contents were tested for significant differences ($\alpha 0.05$) by analysis of variance and least significant difference methods. Also, values for individual species within life form groups were compared, using simple regression, with values reported for these species by Gerloff *et al.* (1964) in Wisconsin.

DISCUSSION

Differences in mean sulfur content were significant only between woody and nonwoody plants (table 1). In South Carolina, Boyd (1978) grouped wetland species by life form and reported sulfur contents of 0.31, 0.18, and 0.24 percent for submerged, floating-leaved, and emergent life forms, respectively. These values are remarkably similar to ours (0.31, 0.16, and 0.23 percent), suggesting that real differences may exist in these life forms but that more information is needed to increase statistical sensitivity.

Table 1.—*Sulfur content of impoundment vegetation summarized by life form groups*

(In percent)

Life form	Mean sulfur content and 95 percent confidence interval	Species (n)
Nonwoody		
Submergents	0.31 ± 0.06	4
Floating-leaved	0.16	2
Emergents	0.23 ± 0.03	65
Terrestrial	0.21 ± 0.05	27
Woody		
Shrubs	0.10 ± 0.03	25
Trees	0.10 ± 0.02	15

[1] Means are significantly different (α 0.05) between woody and nonwoody groups.

The low sulfur content of shrubs and trees was expected because woody tissue is known for its low sulfur content (Remezov *et al.* 1955). An accurate estimate of sulfur in these species will require partitioning (Young and Carpenter 1967) of the biomass into various components, particularly if they exceed the 2.5 cm basal diameter included in our study.

Our data showed trends similar to those of Gerloff *et al.* in Wisconsin (table 2). Most notable is the indication that emergent species common on submerged to poorly drained soils contain more sulfur than species commonly found on drier sites. Although this observation is supported by Siccama *et al.* (1970) who report a 0.20 percent mean sulfur content for terrestrial vegetation, it must be viewed cautiously in light of Bowen's (1966) report of a 0.34 percent mean for terrestrial vegetation. The values found by Gerloff *et al.* for each life form represented also tend to be higher than the values we found, perhaps because of different analytical methods. When the two data sets were compared species-to-species within groups, no regression coefficient was significantly different from zero (α0.05). This result emphasizes the extreme variability of the data and indicates that use of the life form mean for all species within the group is as reliable as individual species values.

Table 2.—*Sulfur content of species common to both the present study and to the Wisconsin study by Gerloff* et al. *(1964)*

(In percent)

Life form	Mean sulfur content and 95 percent confidence interval		Species (n)
	Knighton	Gerloff	
Nonwoody			
Submergents	-	-	0
floating-leaved	-	-	0
Emergents	0.18 ± 0.10	0.26 ± 0.16	9
Upland[1]	0.12 ± 0.06	0.21 ± 0.05	17
0.06			
Woody			
Shrubs	0.09 ± 0.02	0.11 ± 0.06	10
Trees	0.08 ± 0.02	0.08 ± 0.03	6

[1] Means are significantly different (α 0.05).

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APPENDIX

Sulphur content of plant species in and around water-impoundments of north central Minnesota. Species names are in accordance with Gleason (1968).

(In percent)

	Sulfur			
Species	**1976**	**1977**	**1978**	**Mean**
SUBMERGENTS				
Ceratophyllum demersum L.	0.34	-	0.40	0.37
Myriophyllum exhalbescens Fern.	-	0.29	0.33	0.31
Potamogeton spp. L.	0.29	0.34	0.21	0.28
Utricularia vulgaris L.	0.26	0.25	0.38	0.30
FLOATING-LEAVED				
Nuphar variegatum Engelm.	-	-	0.12	0.12
Nymphaea tuberosa Paine.	0.24	0.23	0.09	0.19
EMERGENTS				
Acorus Calamus L.	0.24	0.19	0.12	0.18
Agrostis ssp. L.	0.23	-	-	0.23
Alopecurus Aequalis Sobol.	0.29	-	-	0.29
Bidens spp. L.	0.23	0.16	0.28	0.22
Calamagrostis canadensis (Michx.) Beauv.	0.13	-	-	0.13
Calamagrostis inexpansa Gray.	0.15	-	-	0.15
Calamagrostis neglecta (Ehrh.) Gaertn.	0.13	-	-	0.13
Campanula aparinoides Pursh.	0.16	-	-	0.16
Carex spp. L	0.16	0.15	0.17	0.16
Carex comosa Boott.	0.17	-	-	0.17
Carex lasiocarpa Ehrh.	0.13	-	-	0.13
Carex Pseudo-Cyperus L.	0.14	-	-	0.14
Carex rostrata Stokes.	0.15	-	-	0.15
Carex suberecta (Olney) Britt.	-	0.16	-	0.16
Chenopodium album L.	0.31	-	-	0.31
Cicuta bulbifera L.	0.32	0.25	-	0.28
Dulichium arundinaceum (L.) Britt.	-	0.20	0.12	0.16
Eleocharis spp. R.Br.	-	0.22	0.12	0.17
Epilobium adenocaulon Haussk.	0.19	0.24	-	0.22
Equisetum fluviatile L.	0.19	-	-	0.19
Equisetum palustre L.	0.27	-	-	0.27
Eupatorium maculatum L.	0.31	-	-	0.31
Eupatorium perfoliatum L.	-	-	0.15	0.15
Galium spp. L.	280.32	0.14	0.25	
Geum spp. L.	0.14	-	-	0.14
Glyceria borealis (Nash) Batchelder	0.21	-	-	0.21
Glyceria canadensis (Michx.) Trin.	0.39	-	-	0.39
Glyceria grandis S.Wats.	0.25	-	-	0.25
Glyceria septentrionalis Hitchc.	0.17	-	-	0.17
Impatiens biflora Willd.	0.30	0.32	0.27	0.30
Iris versicolor L.	0.15	0.13	0.10	0.12
Laportea candensis (L.) Gaud.	0.76	-	-	0.76
EMERGENTS (con't)				
Leersia oryzoides (L.) Sw.	0.20	-	-	0.20
Lycopus americanus Muhl.	0.35	0.36	0.29	0.33
Lycopus uniflorus Michx.	0.27	0.18	0.17	0.24
Mentha arvensis L.	0.36	0.27	0.10	0.24
Naumburgia thyrisiflora L.Duby.	0.19	-	0.15	0.17
Phalaris arundinacea L.	0.14	0.20	0.32	0.22
Phragmites communis Trin.	0.11	-	0.36	0.24
Poa spp. L.	0.09	-	0.18	0.14
Polygonum cilinode Michx.	0.15	0.15	0.13	0.14
Polygonum lapathifolium L.	0.14	0.36	-	0.21
Polygonum natans Eat.	0.24	0.20	0.18	0.21
Potentilla palustris (L.) Scop.	0.13	0.13	0.12	0.13
Ranunculus Gmelini DC.	0.33	0.29	-	0.31
Ranunculus pensylvanicus L.f.	0.20	0.24	-	0.22
Rorippa islandica (Oeder) Borbas.	0.38	-	-	0.38
Rumex spp.L.	-	0.12	-	0.12
Sagittaria latifolia Willd.	0.18	-	0.20	0.19
Scirpus americanus Pers.	-	-	0.17	0.17
Scirpus cyperinus (L.) Kunth.	0.21	0.21	-	0.21
Scirpus subterminalis Torr.	-	0.21	-	0.21
Scirpus validus Vahl.	0.23	-	-	0.23
Scutellaria galericulata L.	0.22	0.27	-	0.24
Scutellaria lateriflora L.	0.26	-	0.22	0.24
Sium suave Walt.	0.65	0.46	0.25	0.45
Solidago spp. L.	0.15	0.12	0.24	0.17
Sparganium fluctuans (Morong.) Robins.	0.29	-	-	0.29
Stachys palustris L.	0.17	0.15	0.19	0.17
Triadenum virginicum (L.) Raf.	0.18	0.35	-	0.27
Typha latifolia L.	0.14	0.18	0.13	0.15
Urtica dioica L.	0.52	0.35	-	0.44
Zizania aquatica L.	0.17	0.09	0.28	0.18
TERRESTRIAL				
Anemone ssp. L.	0.35	0.44	-	0.40
Apocynum androsaemifolium L.	-	0.40	-	0.40
Aralia nuducaulis L.	0.16	0.18	0.14	0.16
Aster spp. L.	0.18	0.09	-	0.13
Aster cordifolius L.	-	0.08	-	0.08
Aster macrophyllus L.	0.14	0.11	0.13	0.12
Athyrium Filix-femina (L.) Roth.	0.19	-	-	0.19
Cirsium arvense (L.) Scop.	0.30	0.56	0.25	0.37

	Sulfur			
Species	**1976**	**1977**	**1978**	**Mean**
TERRESTRIAL (con't)				
Clintonia borealis (Ait.) Raf.	-	-	0.12	0.12
Cornus canadensis L.	0.25	0.25	0.21	0.24
Dryopteris ssp. Adans.	0.25	0.13	-	0.19
Fragaria spp. L.	0.14	0.14	0.09	0.12
Galium triflorum Michx.	0.19	0.19	-	0.19
Geranium Robertianum L.	-	0.44	-	0.44
Heracleum lanatum Michx.	0.56	-	-	0.56
Lactuca canadensis L.	0.14	0.15	-	0.14
Lathyrus spp. L.	0.34	0.17	-	0.26
Lycopodium obscurum L.	0.12	-	0.12	0.12
Maianthemum canadense Desf.	0.17	0.35	0.15	0.22
Osmunda Claytoniana L.	-	-	0.17	0.17
Parthenocissus quinquefolia (L.) Planch.	-	0.13	-	0.13
Pteridium aquilinum (L.) Kuhn.	0.14	0.10	0.06	0.10
Smilacina trifolia (L.) Desf.	0.12	0.11	-	0.12
Streptopus roseus Michx.	-	-	0.24	0.24
Thalictrum dioicum L.	-	0.13	0.20	0.16
Uvularia grandiflora Sm.	0.15	-	-	0.15
Viola spp. L.	0.23	0.16	-	0.19
SHRUBS				
Alnus rugosa (DuRoi) Spreng.	-	0.08	0.08	0.08
Amelanchier spp. Medic.	0.02	0.04	0.05	0.04
Arctostaphylos Uva-ursi (L.) Spreng.	0.14	-	-	0.14
Cornus stolonifera Michx.	0.31	0.12	0.10	0.18
Corylus americana Walt.	0.05	0.05	-	0.05
Corylus cornuta Marsh.	-	0.05	0.02	0.04
Dead shrub	-	0.05	0.02	0.04
Diervilla Lonicera Mill.	0.08	-	-	0.08
Lonicera spp. L.	0.31	-	-	0.31
Ostrya virginiana (Mill.) K. Koch.	0.05	-	-	0.05

	Sulfur			
Species	**1976**	**1977**	**1978**	**Mean**
SHRUBS (con't)				
Rhamnus alnifolius L'Her.	-	0.05	-	0.05
Ribes spp. L.	0.10	0.13	0.12	0.12
Rosa spp. L.	0.10	-	0.04	0.07
Rubus spp. L.	-	0.17	0.07	0.12
Salix spp. L.	0.06	0.14	0.08	0.10
Salix Bebbiana Sarg.	0.05	-	-	0.05
Salix discolor Muhl.	0.12	-	-	0.12
Salix petiolaris Sm.	0.16	-	-	0.16
Salix rigida Muhl.	0.13	-	-	0.13
Spiraea spp. L.	0.08	-	0.06	0.07
Vaccinium myrtilloides Michx.	-	0.12	0.51	0.32
Vaccinium angustfolium Ait.	-	0.12	-	0.12
Viburnum Lentago L.	-	0.06	-	0.06
Viburnum Rafinesquianum Schult.	0.06	0.06	0.07	0.06
Viburnum Opulus L.	0.07	-	-	0.07
TREES				
Abies balsamea (L.) Mill.	-	-	0.06	0.06
Acer rubrum L.	-	0.08	0.10	0.09
Acer saccharum Marsh.	0.03	0.17	0.07	0.09
Acer spicatum Lam.	-	0.07	-	0.07
Betula papyrifera Marsh.	-	0.07	-	0.07
Dead tree	-	0.09	-	0.09
Fraxinus nigra Marsh.	-	0.11	-	0.11
Picea mariana (Mill.) BSP.	0.05	-	-	0.05
Populus balsamifera L.	0.08	0.07	0.05	0.06
Populus tremuloides Michx.	0.08	0.11	0.04	0.08
Prunus pensylvanica L. f.	-	0.08	-	0.08
Prunus virginiana L.	-	0.02	0.33	0.18
Quercus macrocarpa Michx.	-	0.07	-	0.07
Quercus borealis Michx. *f.*	-	0.13	-	0.13
Ulmus americana L.	-	0.11	0.27	0.19

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A TIME STUDY OF PLANTING A SHORT-ROTATION INTENSIVELY CULTURED PLANTATION

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ABSTRACT.—Time study of planting a 3 ha short-rotation intensively cultured plantation on a 1- by 1-m spacing found a productivity of 0.52 ha/hour and planting cost of $97.87/ha.

KEY WORDS: Machine rates, *Populus*, energy plantation, biomass, tree planting

Analyzing the economic feasibility of short-rotation intensively cultured (SRIC) forestry systems requires data on all aspects of establishing, managing, and harvesting such plantations. Because the concept is still being developed and only a few large plantations have been established, accurate data on many of the operations involved have not been available. The USDA Forest Service's Research and Development Program on the Maximum Yield of Wood and Energy from Intensively Cultured Plantations has progressed from small-scale studies of biological principles to larger scale tests of developing technology for establishing SRIC plantations (U.S. Department of Agriculture 1980). Establishment of a 3 ha plantation in May 1980 provided an opportunity to obtain productivity and cost figures for planting a SRIC plantation. Our paper presents the results of a detailed time study of the establishment of that plantation.

The plantation is located on the Harshaw Experimental Farm near Rhinelander, Wisconsin. The farm, a former agricultural site, is now used for research on SRIC plantations. For this study, an area of sandy loam soil approximately 80 m (262 ft) by 372 m (1,220 ft) was selected for planting. Planting conditions were excellent: the terrain was reasonably level, relatively free of rocks that could interfere with machinery, and fairly dry at the time of planting. The long individual planting runs made this operation a good case study for obtaining accurate planting data that could be characteristic of commercial operations. A commercial operation was approximated by using a uniform 1- by 1-m spacing throughout the planting, and also by using the same planting stock, 20cm (8-inch) long hardwood cuttings of *Populus* clone 9922, primarily 6 to 13mm (¼ to ½ inch) in diameter, for the entire operation.

Four planting machines were attached to a common tool bar and towed by a White Field Boss, Model 2-85, 85-horsepower diesel tractor (fig. 1).[1] The units were Mechanical Transplanter, Model CT5, transplanters which utilize chain-driven plant holders to set the planting stock into a continuous furrow. The plant spacing is thus determined by the rotation of the packing wheel that moves the chain holding the

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[1] *The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of a product or service by the United States Department of Agriculture.*

Figure 1.—*Equipment used to plant the 3 ha demonstration plantation.*

plant holders. A five-person crew is needed in the planting—a tractor operator and four planters, one of whom doubles as the field supervisor. Because of the long planting runs in this operation (372 m), only enough cuttings could be carried on the machines to make a run down the field and back. Therefore, the machines required loading each time they returned to the beginning end of the field.

RESULTS

Our time study showed that a total time of 5.59 hours was required to plant the 3 ha. Time spent in productive activities was 4.93 hours, or 88.2 percent, while 0.66 hours, or 11.8 percent, was consumed by delays (table 1).

Measurement of the planted area indicated a total plantation size of 2.92 ha (7.21 acres). We estimated that 30,388 cuttings were planted at an average spacing of 0.96 m (3.15 ft) within the rows. The between-row spacing was 1 m (3.28 ft) as determined by the planting machine position on the tool bar. The measured density was then 10,417 cuttings/ha (4,215 cuttings/acre), very close to the desired density of 10,000 cuttings/ha (4,047/acre). In inspecting the planted area, we saw that the planting was very efficient. We estimated that less than 1 percent of the cuttings were missed, and the cuttings were consistently in the ground to the right depth, covered, and adequately packed with soil.

Based on the time study and measurement of the planted area, the productivity calculated on total elapsed time was 0.52 ha/hour (1.29 acres/hour). Productivity based on actual operating time of the planters was 0.71 ha/hr (1.76 ac/hr). The planting speed was 1.78 km/hour (1.11 miles/hour).

The machine costs for the White 2-85 Field Boss and the Mechanical Transplanter CT5 were calculated as $13.60 and $2.55/hour, respectively, or a combined cost of $16.15/productive hour (table 2) (Miyata 1980). Based on the field study and the machine costs, estimated costs are shown for a typical 8-hour day with 6 productive hours of actual plant-

Table 1.—*Time study results on planting*

Productive time	**Hours**	**Percent**
Productive time		
Planting	4.09	73.2
Turning around	.20	3.6
Loading cuttings	.64	11.4
	4.93	88.2
Delays		
Rearranging cuttings in holding trays	0.16	2.9
Covering cuttings to avoid moisture loss	.02	.4
Rocks stuck in machine	.09	1.6
Changing personnel	.06	1.1
Breaks	.26	4.6
Start-up	.07	1.2
Sub-total (delays)	.66	11.8
TOTALS	5.59	100.0

ing (table 3). Production would be 4.26 ha (10.56 acres) for this typical day.

The results of our study can be used to estimate the potential productivity and cost of planting SRIC plantations at various other spacings. If similar equipment is used, the following assumptions form the basis for calculating the productivity of planting at other spacings. From observing the planting in our study, we estimated that the planting machine operators were working at an optimum rate for this type of work; therefore, the rate observed was assumed to be the maximum allowable. We also assumed that the tractor speed could be increased by a factor of three without affecting the working conditions of the operators. So, for a within-row spacing of 3 meters, the tractor speed could be tripled because the rate at which the operators would be functioning would remain the same. The physical limitations on the equipment indicate that a tool-bar length of 4 meters would be maximum without encountering structural problems or turning difficulties. This restriction defines the number of planting machines that can be used on a given between-row spacing as tabulated below.

Between row spacings (meters)	**Planting machines** (number)	**Strip width planted** (meters)
1	4	4
2	3	4
3	2	3

Table 2.—*Itemized machine rates*
(In January 1981 dollars)

Machine	**Initial cost**	**Cost/hr (without labor)**		
		Fixed	**Operating**	**Total**
White 2-85 Field Boss	29,260	6.53	7.07	13.60
Mechanical Transplanter CT5 (4 units)	2,945	2.32	.23	2.55

We also assumed that the planting machines are in operation 75 percent of the total scheduled time, and the other 25 percent of the time is spent in loading, turning, and various delays. Based on these assumptions, the projected productivity for planting SRIC plantations on various spacings are as follows:

(meters between rows × meters within rows)	**Productivity** hectares/hr	(acres/hr)
1 × 1	0.53	(1.32)
1 × 0.5	.27	(0.66)
2 × 2	1.60	(3.95)
2 × 1	.80	(1.98)
3 × 3	2.41	(5.95)
3 × 2	1.60	(3.95)
3 × 1	.80	(1.98)

The cost of planting SRIC plantations on these spacings, based on the results of our case study, would be as follows (January 1981 dollars):

Spacing	**Cost**	
	dollars/ha	($/acre)
1 × 1	97.87	(39.48)
1 × 0.5	193.00	(78.95)
2 × 2	28.54	(11.56)
2 × 1	57.08	(23.06)
3 × 3	16.27	(6.59)
3 × 2	24.51	(9.93)
3 × 1	49.01	(19.80)

Table 3.—*Planting costs*
(In January 1981 dollars)

	Total	**Cost/ha**	**Cost/acre**	**Percent**
Machine cost	96.90	22.75	9.18	23.3
Labor[1]	224.00	52.58	21.21	53.7
Supervision[1]	96.00	22.54	9.09	23.0
TOTALS	416.90	97.87	39.48	100.0

[1] Labor rates are assumed to be $6/hr for planters, $10/hr for operators, and $12/hr for supervisors all rates including 30 percent for fringe benefits

DISCUSSION

The operation studied was obviously very efficient. The planting machines operated almost 75 percent of the time, and the delays, excluding rest breaks, were only about 7 percent of the total time. This indicates both a well-trained, experienced crew and good field conditions.

Labor was the major cost of this operation, comprising more than 50 percent of the planting cost. For any significant reduction in the planting costs, automated planting equipment would be needed to reduce the number of operators required on the planting machines. In addition to reducing cost, automated planting equipment could increase productivity. There is only about a 2-month season for planting SRIC plantations in the Lake States. Based on our case study, one planting crew could plant only about 180 ha (445 acres) on a 1- by 1-m spacing in this time. If a wider tree spacing, such as 2 by 2 m, proves economically feasible, the planting acreage would increase. However, for planting large acreages per year, such as may be required commercially, planting technology must be improved.

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NORTH CENTRAL FOREST EXPERIMENT STATION

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198.

SEASONAL VARIATIONS IN ASH CONTENT OF SOME MICHIGAN FOREST FLOOR FUELS

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ABSTRACT.—Samples from the forest floor litter layer were collected seasonally from under medium to fully stocked large sapling to sawtimber stands in Lower Michigan to study seasonal ash content changes. The total ash and silica-free ash content of tree foliage in the upper part of the litter layer differed little from season to season. Differences in ash content due to species were generally more important than those due to season. The total ash content of an entire northern hardwood-oak-hickory forest litter layer increased significantly (0.01 level) through the year; however, silica-free ash content did not. Bracken fern did not change significantly in either total ash or silica-free ash content.

KEY WORDS: Fuel modeling, fuel characteristics.

The National Fire-Danger Rating System (Deeming *et al.* 1977) and Albini (1976) fire behavior models are used by fire managers to predict fire behavior. These systems utilize the Rothermel (1972) fire behavior model, which includes total ash and the silica-free ash content of fuel as variables. The ash (or noncombustible) constituents of organic material are of concern to the fire manager because they usually reduce the combustion rate. Not all of them are equally effective, however. And one of them, silica, is completely inert in the combustion process—hence the special interest in silica-free ash.

Forest floor litter (L-layer)[1] is a primary fuel of wildland fires in many ecosystems, so its silica-free and total ash content are needed in using the above systems to predict fire behavior. Further, it is important for the fire manager to know whether ash content of litter varies from season to season. Therefore, we conducted a study of the seasonal influence on ash content for certain forest floor fuels in Lower Michigan.

METHODS

The study was done in Ingham, Roscommon, and Wexford Counties. From the forest floor litter layer we collected leaves of 10 tree species: white oak (*Quercus alba* L.), northern red oak (*Quercus rubra* L.), northern pin oak (*Quercus ellipsoidalis* Hill), American beech (*Fagus grandifolia* Ehrh.), largetoothed aspen (*Populus grandidentata* Michx.), sugar maple (*Acer saccharum* Marsh.), shagbark hickory (*Carya ovata* (Mill.) K. Koch), red pine (*Pinus resinosa* Ait.), white pine (*Pinus strobus* L.), and jack pine (*Pinus banksiana* Lamb.). In addition, bracken fern (*Pteridium aquilina*) and the entire litter layer under a mixed northern hardwood-oak-hickory stand were sampled.

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[1] *The litter, or L-layer, is the uppermost layer of the forest floor and consists of loose, dead needles, leaves, grass, twigs, etc.*

Samples were collected five times between June 1973 and July 1974: in the early summer (June-July), late summer (August-September), fall (October-November), spring (April), and again in early summer (June-July). (Late summer samples were not collected for all species.) Most of the materials collected were less than 1 year old and were at the top of the litter layer.

Each sample consisted of about 10 grams of material; 3 to 10 samples were collected per species at each location. Samples were obtained under medium to fully stocked large sapling to sawtimber stands.

Samples were oven dried for 72 hours at 70°C and then ground in a Wiley Mill to pass a 20-mesh screen. Ash content was determined according to standard methods (American Society for Testing and Materials 1971, Association of Official Analytical Chemists 1965).

Total ash and silica-free ash content were determined by season for (1) tree foliage, by species, found at the top of the litter layer; (2) the entire litter layer of a mixed northern hardwood-oak-hickory stand; and (3) cured bracken fern (table 1).

The t-test was used to examine ash content differences related to species, location, and season.

RESULTS AND DISCUSSION

Silica-free ash content reduces combustion rate and is independent of heat content (Philpot 1968). Total ash increases with time (Kucera 1959) and also reduces combustion rate. As the litter layer merges with the lower forest floor, the ash content generally increases (Hough 1969, Hough and Albini 1978, Roussopoulos[2]).

Table 1.—*Average total and silica-free ash content of certain dead litter fuels in Michigan*[1]

		Fall			Spring			Early summer			Late summer		
Species of leaves	County	Sample size	Ash content	Standard deviation	Sample size	Ash content	Standard deviation	Sample size	Ash content	Standard deviation	Sample size	Ash content	Standard deviation
		No	*Percent*		*No.*	*Percent*		*No.*	*Percent*		*No.*	*Percent*	
White oak	Ingham	5	5.7	0.3	5	6.9	0.3	10	8.1	0.4	4	9.2	0.5
			(3.0)	(0.2)		(3.4)	(0.5)		(3.1)	(0.2)		(4.2)	(0.3)
Northern red oak	Ingham	5	4.3	1.0	5	4.9	.2	10	6.0	.3	5	6.8	.6
			(3.1)	(.9)		(3.0)	(.2)		(3.0)	(.1)		(3.4)	(.5)
	Wexford	5	3.9	.2	10	4.8	.2	10	5.3	.3	—		
			(2.8)	(.2)		(2.8)	(.1)		(2.7)	(.1)			
Northern pin oak	Roscommon	5	3.7	.5	5	3.7	.2	10	3.8	.3	5	4.1	.1
			(2.7)	(.3)		(2.3)	(.2)		(2.1)	(.1)		(2.7)	(.1)
American beech	Ingham	4	7.7	.2	5	8.9	.4	10	11.1	.9	5	10.9	.7
			(2.3)	(.2)		(1.9)	(.3)		(2.6)	(.3)		(2.7)	(.4)
Large-toothed aspen	Roscommon	5	3.7	.6	10	5.4	.3	10	6.2	.5	—		
			(2.0)	(.4)		(2.8)	(.2)		(3.5)	(.3)			
Sugar maple	Wexford	5	7.1	.1	10	9.2	.5	3	10.3	.6	—		
			(4.6)	(.1)		(3.6)	(.2)		(4.0)	(.2)			
	Ingham	3	8.5	.2	3	12.2	1.2	4	13.1	1.2	—		
			(4.6)	(.1)		(5.2)	(.5)		(5.4)	(.4)			
Shagbark hickory	Ingham	3	8.1	.6	3	9.6	.9	—			—		
			(6.9)	(.7)		(7.6)	(.7)	—			—		
Red pine	Roscommon	5	2.1	.1	4	2.3	.1	5	2.3	.1	—		
			(1.6)	(.1)		(1.6)	(.1)		(1.7)	(.1)			
	Wexford	5	2.5	.2	5	3.0	.1	5	2.6	.6	—		
			(2.0)	(.1)		(2.3)	(.1)		(1.6)	(.7)			
White pine	Ingham	5	2.4	.1	5	2.7	.2	5	2.7	.1	3	2.5	.1
			(1.8)	(.0)		(1.8)	(.2)		(1.7)	(.1)		(2.0)	(.2)
Jack pine	Roscommon	3	2.7	.1	3	2.5	.2	3	2.7	.1	3	3.3	.9
			(1.7)	(.1)		(1.3)	(.1)		(1.4)	(.1)		(2.4)	(.9)
Mixed hardwood forest floor (L-layer)	Ingham	5	7.2	.8	5	14.5	1.8	5	11.3	1.7	5	15.6	1.1
			(3.3)	(.6)		(3.7)	(.3)		(3.4)	(.3)		(3.7)	(.4)
Bracken fern (above ground plant parts)	Roscommon	5	5.4	.9	5	5.5	1.1	5	6.2	.8	—		
			(1.6)	(.2)		(1.5)	(.2)		(1.4)	(.2)			

[1] Silica-free ash content values in parentheses.

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[2] *Information on file at the North Central Forest Experiment Station, East Lansing, Michigan.*

Mineral content generally increases with time because breakdown of the organic portion usually proceeds faster than leaching of minerals. Plant material decomposition is controlled by the chemical make-up of the material and by environmental factors. Therefore, many variables and interactions are involved in the process.

Species appear to have more effect than season or location on ash content and thus on fire behavior. T-tests for seasonal differences in ash content for each species by location were inconclusive,[3] but total ash content increased with time since foliage fell more than did silica-free ash. Examination of effects of season, by species of foliage, on predicted fire reaction intensity (Btu/ft^2/min) and rate-of-spread (ft/min) indicated seasonal intensity differences that ranged from 0 to 4 percent for total ash and from 0 to 5 percent for silica-free ash content. Predicted intensity differences due to species differences within seasons ranged from 6 to 10 percent for total ash and from 5 to 12 percent for silica-free ash content.

Total ash content of the combined northern hardwood-oak-hickory litter layer significantly increased from fall to late summer, but the silica-free ash content did not. Bracken fern showed no significant changes in either total or silica-free ash content from fall through early summer.

Total ash content and silica-free ash content, in general, differed between species and increased with passage of time following leaf fall, although not always significantly. Species of foliage litter material is usually more important for predicting fire behavior than seasonal differences in ash content.

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[3] *The t-test would not conclusively justify combining locations when the same species of foliage was involved.*

NORTH CENTRAL FOREST EXPERIMENT STATION Research Note NC-280
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CLASSIFYING WILDFIRE CAUSES IN THE USDA FOREST SERVICE: PROBLEMS AND ALTERNATIVES

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ABSTRACT.—Discusses problems associated with fire-cause data on USDA Forest Service wildfire reports, traces the historical development of wildfire-cause categories, and presents the pros and cons of retaining current wildfire-cause reporting systems or adopting new systems.

KEY WORDS: Wildfire causes, wildfire reports, wildfire prevention.

Wildfire causes, entered on USDA Forest Service fire reports since 1905, are key elements in the development and analysis of Forest Service fire prevention programs. First devised to pinpoint how fires started, fire-cause categories were later expanded to include the persons responsible. The basic objective of these classifications is still to identify major fire causes, thereby helping land managers select fire prevention programs and allocate prevention resources[1]

Due to several problems, however, accurate fire-cause information is often difficult to collect and report. This paper focuses on problems associated with documenting field data on the Forest Service Individual Fire Report, Form 5100-29. Persons making fire-cause entries on this form face two primary obstacles. The first is selecting the best fire-cause and class-of-people classification scheme from a few overlapping categories which are frequently broad and repetitious. The second is reporting the reliability of fire-cause information. The roots of the first problem lie in the historical development and use of fire-cause categories in the Forest Service; the second is a matter of form design.

The current (1970) Forest Service fire report contains four cause-related items (statistical cause, general cause, specific cause, and class-of-people) which evolved from the reporting system implemented in 1905.[2] The first fire-cause classification system used by the Forest Service contained eight general categories: brush burning, campers, incendiary, railroad, sawmills, miscellaneous, lightning, and unknown. These were expanded in the 1920's and 1930's, reflecting a need for greater fire-cause detail (table 1a). Except for a few minor changes, these general-cause categories remained fairly consistent for 40 years. In 1960, general fire-cause classifications were expanded and divided into two lists, statistical and land-use (table 1a, 1b). In 1970, land-use causes were renamed general causes, but both lists were retained

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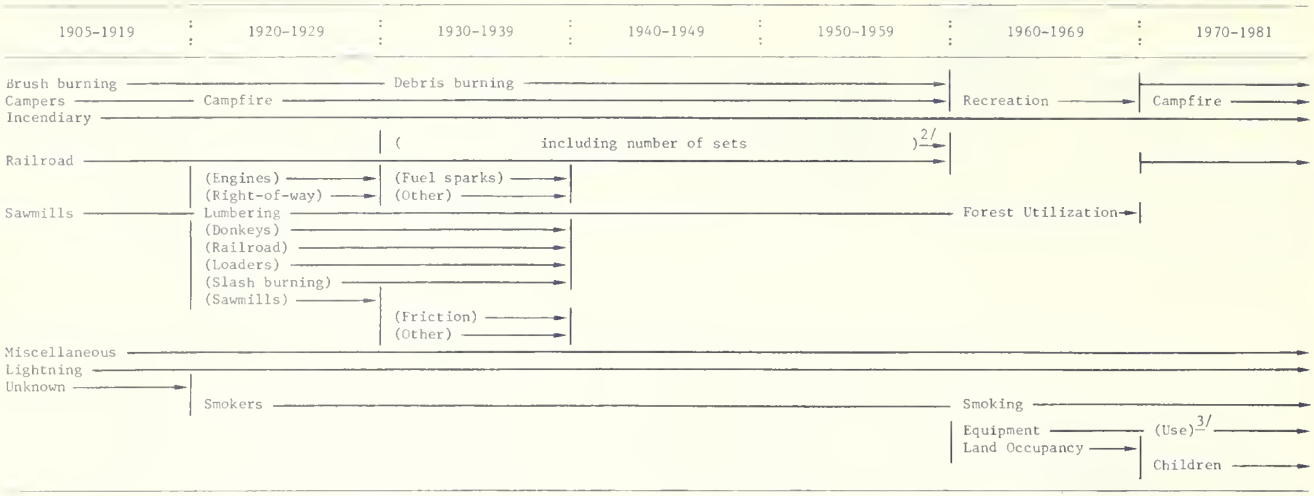
[1] *The focus is on human-caused wildfires because lightning fires are basically not preventable.*

[2] *Statistical causes are used primarily for compiling periodic, general information reports. General causes show the major types of land-use activities responsible for fires, and specific causes show detailed activities or ignition sources of fires. Class-of-people refers to the group of persons to which an individual responsible for a fire ignition belongs.*

Table 1a.--General/statistical cause categories: 1905-1981[1]

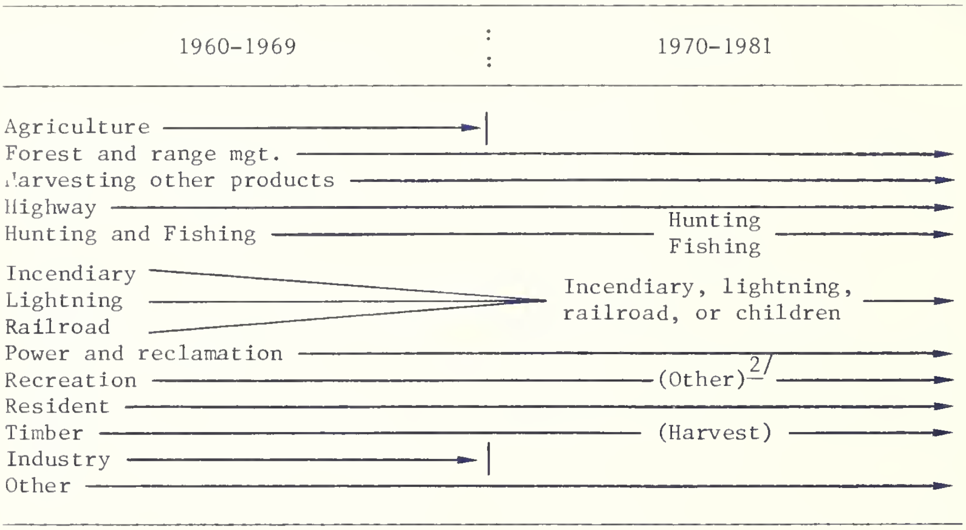


[1] In 1960 general causes were renamed statistical causes.

[2] Parentheses under the line show additional information reported with the primary general cause.

[3] Parentheses on the line show words added later to supplement or clarify the cause classification.

Table 1b.--Land use/general cause categories used in conjunction with statistical cause[1]



[1] Land use categories from the 1960 decade were renamed general causes in 1970.

[2] Parentheses on the line show words added later to supplement or clarify the cause classification.

in a slightly modified form. Even with all these changes since 1920, six of the eight general-cause categories, although slightly modified, are still used today: debris burning, campfire, incendiary, railroads, miscellaneous, and lightning. Approximately three-fourths of the specific-cause categories have been retained, although modified since their introduction in 1940 (table 2).

Instituted in 1920, class-of-people categories remained fairly uniform for 40 years before their extensive revision in 1960 (table 3).

Looking over the past 75 years of changes in fire-cause reporting, however, we can conclude that fire-cause categories have changed little in form. While this lack of change ensured consistency of fire report

Table 2.--Specific cause categories: 1940-1981[1]

1940-1949		1950-1959	1960-1969	1970-1981
Berry land burning	→	→		
Blasting	→	→	→	→
Brake shoe	→	→	→	→
Branding	→	→	→	
Burning building	→	→	→	→
Burning vehicle	→	→	→	→
Cooking fire	→	→	→	→
Exhaust	→	→	→	(power saw)[2] (other) →
Fireworks	→	→	→	→
Fuel sparks	→	→	→	
Fusee	→	→	→	
Glass	→	→	→	
Grudge fire	→	→	→	→
Hot ashes	→	→	→	
House/stove flue sparks	→	→	→	→
Insect/snake control	→	→	→	→
Job fire	→	→	→	→
Land clearing	→	→	→	(burning) →
Lightning	→	→	→	→
Logging line	→	→	→	→
Meadow burning	→	→	→	Field burning →
Moonshine	→	→	→	
Oil/gas well	→	→	→	
Playing with matches	→	→	→	→
Power line	→	→	→	→
Pyromania	→	→	→	→
Range burning	→	→	→	
Refuse burning	→	→	→	Trash burning →
Repelling predatory animals	→	→	→	→
Right-of-way clearing	→	→	→	(burning) →
Rubbish disposal	→	→		Burning dump →
Safety strip burning	→	→	→	
Slash disposal	→	→	→	(burning) →
Smoking	→	→	→	→
Smoking bees/game	→	→	→	→
Spontaneous combustion	→	→	→	
Tie disposal	→	→		
Warming fire	→	→	→	→
Other	→	→	→	→
Unknown	→	→		
		Airplane →	Aircraft →	→
			Burning sawmill →	
			Burning tobacco beds	
			Mill waste →	
			Prescribed burning →	Resource mgt. burning

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[1] Specific causes were not reported from 1905 to 1939.

[2] Parentheses on the line show words added later to supplement or clarify the cause classification.

Table 3.--Class-of-people categories: 1920-1981

1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1981
Fisherman →				Contractor →	
Hunter →				Local permanent →	
Miner →				Owner →	
Rancher →		and Farmer →		Permittee →	
Stockman →				Public employee →	
Timberman →				Seasonal →	
Tourist →	Traveler →			Transient →	
Other(s) →				Other →	
		Camper →			Visitor →
		Construction worker →			Lightning →
		Picnicker →			
		Unknown →			

data, it also created a major problem cited above—overlapping and repetitious fire-cause categories.

Statistical and general fire causes, for instance, include a combination of overlapping categories; as a result, more than one cause class can be assigned to a given fire. These causes include categories of people (children, resident), activities involving intentional use of fire (e.g., camping, debris burning, smoking, incendiarism), and work-related or recreation activities incidentally causing wildfires (e.g., equipment use, timber harvest, fishing, hunting) (table 1a, 1b). In addition, individuals responsible for causing wildfires can be classified in many ways using the current class-of-people categories (table 3). For example, a person could be both an owner and a local permanent or both a permittee and seasonal resident. Such overlapping categories result in multiple classification schemes for a given fire cause and make it difficult to determine from fire-report statistics the actual cause and person responsible for a particular wildfire. To illustrate, a dump fire set by one or more unidentified persons is reported in Region 9 using seven different cause and class-of-people combinations (table 4).

Compounding the problem of overlapping categories is the broad (one category encompasses a host of situations) and repetitious nature of the fire-cause reporting system. A classic example of this problem is the use of the following categories to describe a known fire cause:

Statistical	**General**	**Specific**	**Class-of-People**
Miscellaneous	Other	Other	Other

An investigation revealed that a wildfire was started by an unidentified person who, after lighting a cigarette and falling asleep in bed, ignited the mattress. Upon awakening and finding the mattress on fire, he dragged it out of a bunkhouse and abandoned

Table 4.--Classifications of dump fires in Region 9

	Statistical cause	General cause	Specific cause	Class-of-people
1.	Incendiary	Incendiary	Burning dump	Local permanent
2.	Incendiary	Incendiary	Grudge	Local permanent
3.	Debris burn	Other	Trash burning	Visitor
4.	Debris burn	Resident	Burning dump	Local permanent
5.	Debris burn	Incendiary	Trash burning	Local permanent
6.	Debris burn	Other	Burning dump	Local permanent
7.	Miscellaneous	Resident	Burning dump	Local permanent

it in the woods, starting a wild fire. For lack of a better method, this fire was reported as "Miscellaneous, Other, Other, Other." Although this example may be atypical, it does illustrate the information lost when a reporter classifies a fire-cause using the current system. Even though many fire causes can be pinpointed accurately and facts essential to a sound fire prevention campaign can be assembled, this information is either frequently submerged in a few broad, repetitious fire-cause categories, or it is not recorded at all.

A second major reporting problem is the lack of adequate methods for indicating the reliability of fire-cause data (Main and Haines 1974). Some causes are known with such certainty that legal action can be taken, but others are completely unknown. Once entered on a fire report form, however, reliable causes are indistinguishable from unreliable ones. With no "unknown" category available, an unknown cause is classified typically as a smoking, an incendiary, or a miscellaneous wildfire. Because reporters cannot indicate the reliability of fire causes but must report both known and unknown causes, the accuracy of fire-cause data is often highly questionable, leading to erroneous assumptions about fire prevention problems.

DISCUSSION AND CONCLUSIONS

Decade-to-decade modifications in the Forest Service fire-cause reporting system during the past 75 years brought little more than cosmetic change. As a result, we have inherited a system that has flaws but is relatively simple to use and historically compatible with previous fire report data.

One of the dilemmas facing managers today is whether to maintain the current system, modify it, or replace it.[3] Resolving this dilemma depends, in part, on how the data are used and to whom they are most important. If, for example, upper level managers need general fire-cause information for annual reports and statistics, budgetary and financial assistance requests, or other administrative purposes, the current system is probably adequate with little or no modification. On the other hand, the current system does not provide the data needed to plan, implement, and analyze fire prevention programs in as much detail and as accurately as fire prevention specialists might desire. Two possible remedies would be to modify the current system or adopt a completely new one. Although the first alternative again involves cosmetic change, it does ensure historical data compatibility. With a few improvements (e.g., including "certainty of cause" categories; expanding categories; analyzing and standardizing reporting procedures for a given fire cause such as dump fires), it also eliminates some of the problems cited above, thereby increasing data accuracy and reliability. The second alternative, going to a new and perhaps better reporting system, may also be beneficial. One method, called the "Building Block" system, is currently under consideration by State and Federal land managers.

This system includes multiple categories that classify the form of heat energy (e.g., flames, sparks, and hot surfaces from a variety of sources) that ignited the fire; the equipment that provided the heat that started the fire; the type of material or kindling fuel first ignited; and the reason why the form of heat energy and the material first ignited combined to start a wildfire. It also incorporates into the class-of-people categories the types of persons responsible for fires and the person's age, sex, and primary activity when the fire started. Even though the Building Block system has some drawbacks, such as its lengthiness, it does eliminate the problems with the current system and yet enables statistical fire-cause categories, as we presently know them, to be identified.

No fire-cause reporting system will ever be perfect. But, fire managers, when deciding which system to use, must consider the information they need and the level of resolution, the degree of error they are willing to accept, and the operational simplicity or difficulty of each system. These factors must also be weighed with the current drive to adopt a standardized State and Federal fire-cause reporting system and with the desire to maintain historical data compatibility.

LITERATURE CITED

Main, William A.; Haines, Donald A. The causes of fires on northeastern national forests. Res. Pap. NC-102. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1974. 7 p.

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[3] *Because many State and Federal agency fire-cause reporting systems are similar in many respects to the Forest Service system, this problem also faces fire managers outside the Forest Service.*

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NORTH CENTRAL FOREST EXPERIMENT STATION
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1982

USING A PROGRAMMABLE CALCULATOR TO COMPUTE AND COMPARE THINNING SCHEDULES

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ABSTRACT.—Describes calculator programs that simulate the growth and thinning of a stand. Also includes a method of computing maximum yield, allowing a comparison of potential and actual yields of a stand.

KEY WORDS: Dynamic programming, growth and yield, maximum biomass production.

One decision a forest manager must make is whether to thin a stand of trees now or to wait until the trees have grown more. A decision to thin implies another decision: how much to thin.

To make these decisions easier, the growth and thinning of a stand can be simulated on a programmable calculator by using an equation that predicts basal area growth per acre in a stand. For programs in this paper, we used the equation $\triangle B = aB-bB^m$, where $\triangle B$ is periodic basal area growth per acre, B is basal area per acre, and a, b, and m are numerical constants specific to tree species, location, stand age, and length of growth period. Aided by a calculator, the forest manager can easily compare several thinning schedules before acting.

Figure 1 represents the growth and thinning process over a rotation. The total yield produced is the sum of all the cuts; the final harvest is the clearcut.

FIELD DATA COLLECTION

Information needed to run the program:

1. Age of stand
2. Average height of dominant and codominant trees in the stand
3. Current basal area per acre (ft^2/ac)
4. Site index
5. Age at final harvest
6. Coefficients for basal area growth equation.

Respective sources of information are:

1. Landowner's records or increment boring
2. Field measurements with a hypsometer
3. Field sample with angle gauge or tree measurement
4. Figure 2 (use height and age to read site index)
5. Rotation age chosen by owner (based on management objectives)

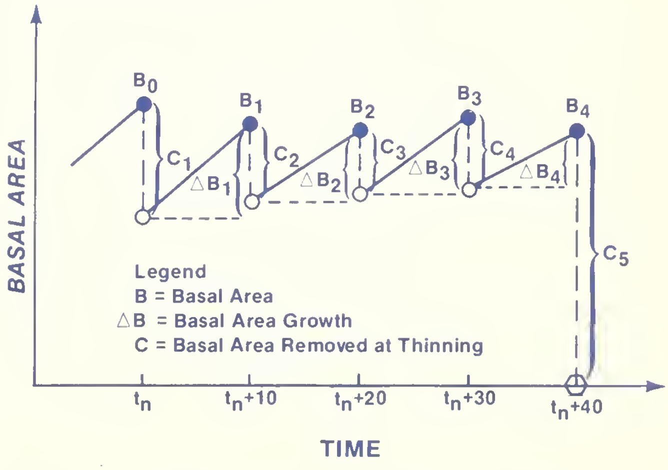

Figure 1.—*Schematic stand development with 4 thinnings prior to a final clearcut.*

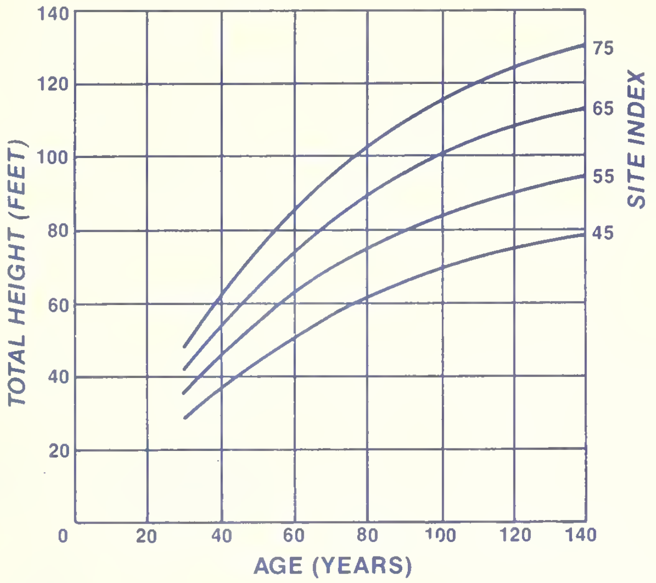

Figure 2.—Red pine site index curves (Lundgren and Dolid 1970).

6. Research that fits the growth equation to observations of stand growth. The growth equation coefficients used in the examples in this paper apply to 10-year periodic basal area growth per acre for red pine plantations in the Lake States.

CALCULATION PROCEDURE

Programs that compute thinning schedules have been designed for the Texas Instruments 59 calculator (with and without a printer) and the Hewlett Packard 67 and 97 calculators[1]. Briefly, the programs operate as follows: After obtaining needed information, the user loads the program into the calculator, enters information into data registers, chooses a thinning schedule, and then presses a series of keys to run the program. Calculations are performed in the following sequence at the beginning of each 10-year period:

1. The desired residual basal area is determined (based on the chosen thinning schedule) and compared to the actual standing basal area.
2. If the desired residual basal area is smaller than the actual standing basal area, the amount to cut is calculated and subtracted from the actual standing basal area.
3. Growth for the next 10-year period is determined and added to the residual basal area.
4. This process is repeated through the rotation to the final harvest.

At the beginning of each period, this calculator provides the following stand information: age, initial basal area (BAI), average height of dominant trees (HT), optimal residual basal area for maximum basal area growth (OPTB), optimal residual basal area for maximum cubic foot volume growth (OPTV), amount to cut in square feet per acre (CUT), cumulative basal area cut plus current residual basal area (CUT/ABA), basal area growth for the next 10 years (GROW), cumulative volume (VOL), and mean annual volume increment (MAI).

COMPARING MANAGEMENT OBJECTIVES

Programs have been designed to compute six thinning schedules that depend on different management objectives: (1) maximize cubic foot volume production, (2) maximize basal area production, (3) make no intermediate cuts, (4) follow the schedule to maximize cubic foot volume production but allow only a minimum feasible cut, (5) cut the same amount at each period, and (6) cut to a chosen residual basal area.

The residual basal area is computed for the first two schedules at the beginning of each 10-year period. These options appear in the tables under the headings OPTV and OPTB, respectively. By producing values that lead to maximum results, these two schedules provide a standard against which other schedules can be compared. The user can run them in addition to the other schedules to compare the potential and the actual yield of a stand. The other four schedules will yield less than the maximum but may be followed due to economic or other considerations.

The age at which mean annual increment reaches a maximum can be determined by finding the highest value in the MAI column (tables 1 and 2) and reading across to the age. This age could be used as the rotation age if compatible with the management plans.

Table 1 illustrates the optimum thinning schedule for maximum volume production and table 2 shows the effects of no intermediate thinning on the same stand. The difference in cubic foot volume production is 1335.3 ft^3. The graph shows the growth pattern and the difference in total volume production.

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[1] *Mention of trade names does not constitute endorsement by the U.S.D.A. Forest Service.*

Table 1.—*Optimal thinning schedule for maximum cubic foot volume production*

AGE	BAI	HT	OPTB	OPTV	CUT	CUT+BA	GROW	VOL	MAI
20	165.0	26.4	110.0	160.3	4.7	165.0	71.8	1,828.5	91.4
30	232.1	40.9	118.9	174.9	57.2	236.8	51.4	4,033.8	134.5
40	226.3	53.9	125.6	182.2	44.0	288.2	41.2	6,159.0	154.0
50	223.4	65.4	131.1	185.7	37.8	329.4	35.0	8,167.7	163.4
60	220.7	75.3	135.7	187.0	33.8	364.4	30.8	10,042.7	167.4
70[1]	217.8	83.6	139.8	187.0	30.7	395.2	27.7	11,780.7	168.3
80	214.7	90.7	—	—	214.7	422.8	—	13,386.5	167.3

[1] Age at which mean annual increment is at a maximum.

Table 2.—*No intermediate thinning*

AGE	BAI	HT	OPTB	OPTV	CUT	CUT+BA	GROW	VOL	MAI
20	165.0	26.4	110.0	160.3	0	165.0	70.1	1,828.5	91.4
30	235.1	40.9	118.9	174.9	0	235.1	30.5	4,032.7	134.4
40	265.6	53.9	125.6	182.2	0	265.6	18.2	6,016.2	150.4
50	283.8	65.4	131.1	185.7	0	283.8	13.2	7,793.7	155.9
60[1]	297.0	75.3	135.7	187.0	0	297.0	10.6	9,384.8	156.4
70	307.6	83.6	139.8	187.0	0	307.6	9.0	10,799.9	154.3
80	316.5	90.7	—	—	316.5	316.5	—	12,051.2	150.6

[1] Age at which mean annual increment is at a maximum.

SAMPLE THINNING SCHEDULES

The sample thinning schedules, illustrated in tables 1 and 2, and figure 3, are geared to a stand having the following characteristics: Age = 20 years

Basal area = 165 ft^2/acre
Site index = 66
Final harvest at 80 years

A more detailed discussion is presented in:
Chen, C. M.; Rose, D. W.; Leary, R. A. How to formulate and solve optimal stand density over time problems for even-aged stands using dynamic programming. Gen. Tech. Rep. NC-56. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1980. 22 p.

Copies of this report, both programs, and complete instructions, are available from:

Publications Room
North Central Forest Experiment Station
1992 Folwell Avenue
St. Paul, Minnesota 55108

Please specify calculator model (and for the TI 59, whether a printer is available).

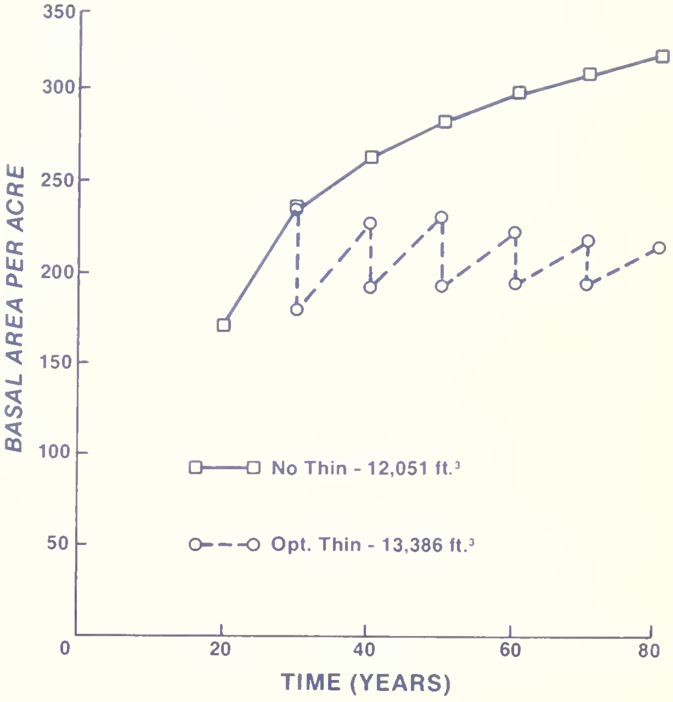

Figure 3.—Comparison of two thinning schedules with initial basal area of 165 ft²/acre.

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TIMBER VOLUME IN EASTERN SOUTH DAKOTA, 1980

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ABSTRACT.—Eastern South Dakota's 113,600 acres of commercial forest land supported 51.9 million cubic.feet of growing stock in 1981. This is a decrease in timber volume of 24 percent since the last inventory in 1965. The decrease was entirely in hardwood species. Cottonwood is the most abundant tree species—it accounts for 33 percent of the growing-stock volume and comprises 44 percent of the sawtimber volume. Shannon County in the southwestern part of the State contains the largest amount of timber volume.

KEY WORDS: Growing stock, sawtimber, species, counties.

Eastern[1] South Dakota's 113,600 acres of commercial forest land supported 51.9 million cubic feet of growing stock[2] in 1980. This is a decrease of 24 percent since the last inventory in 1965. As shown in the following tabulation the decrease was entirely in hardwood species—softwood volume remained the same:

Species group	Growing-stock volume [3]1965	 1980
	(Million cubic feet)	
Softwoods	11.9	11.9
Hardwoods	56.3	40.0
Total	68.2	51.9

The average growing-stock volume per acre increased slightly from 412 cubic feet (3.2 cords per acre) in 1965 to 457 cubic feet (3.6 cords per acre) in 1981. This is due, in part, to increased volume by stand age of commercial forest land base.

Cottonwood is the most abundant tree species in eastern South Dakota and accounts for 33 percent of the growing stock volume (table 1). Its volume, however, has decreased by 3.9 million cubic feet (18 percent) between inventories. Ash, the second most plentiful species in the State, showed a decrease of 3.1 million cubic feet from 1965 to 1980. The third most plentiful species is ponderosa pine, which decreased only 0.6 million cubic feet in the 15 years between inventories. These three species make up about four-fifths of the growing-stock volume in eastern South Dakota. The following tabulation compares growing-stock volumes by species for both surveys.

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[1] *East of the 103rd Meridian (near Rapid City) in South Dakota. The area west of the 103rd Meridian (Harding, Butte, Lawrence, Fall River, Meade, Pennington and Custer Counties) is inventoried by the Intermountain Forest and Range Experiment Station, Ogden, Utah.*

[2] *Net volume of all live merchantable trees 5 inches d.b.h. and larger from the stump to a variable 4-inch top diameter outside bark of the central stem. Does not include limbs or cull tree volume.*

[3] *Figures from the 1967 survey have been adjusted because of changes in survey procedures and definitions.*

Table 1.--Net volume of growing stock on commercial forest land by species group and county, South Dakota, 1980.

(In thousand cubic feet)

County	All species	Softwoods			Hardwoods									
		Ponderosa pine	Juniper/ other softwoods	Total softwoods	Oak	Basswood	Soft maple	Elm	Ash	Cottonwood	Willow	Hackberry	Other hardwoods	Total hardwoods
Aurora	115.8	--	2.2	2.2	7.5	1.1	1.1	10.6	16.6	74.6	0.5	1.1	0.5	113.6
Beadle	585.8	--	8.7	8.7	32.2	7.7	4.2	95.2	168.3	220.0	2.0	4.5	43.0	577.1
Bennet	974.2	683.2	0.9	684.1	56.6	3.4	0.4	26.7	68.6	111.0	9.2	1.7	12.5	290.1
Bon Homme	1,441.6	18.2	26.9	45.1	102.9	15.8	18.8	116.9	400.3	629.9	34.6	10.1	67.2	1,396.5
Brookings	636.3	1.1	13.6	14.7	50.6	7.8	6.6	69.9	109.9	359.3	4.9	7.3	5.3	621.6
Brown	1,168.3	--	26.4	26.4	91.8	13.9	12.9	129.7	191.0	677.2	6.1	13.7	5.6	1,141.9
Brule	194.0	1.1	3.0	4.1	13.7	2.2	1.5	17.8	34.5	112.8	2.5	1.8	3.1	189.9
Buffalo	219.3	1.1	3.6	4.7	15.9	2.5	1.7	20.8	38.2	127.4	2.7	2.1	3.3	214.6
Campbell	56.4	1.1	--	1.1	3.2	0.6	--	3.1	11.6	32.4	1.8	0.2	2.4	55.3
Charles Mix	1,610.3	17.6	30.3	47.9	108.8	17.1	27.4	130.3	417.7	738.0	33.7	11.5	77.9	1,562.4
Clark	192.9	--	4.0	4.0	13.9	2.1	2.0	19.7	29.2	118.2	0.9	2.1	0.8	188.9
Clay	280.8	2.2	4.4	6.6	21.9	3.5	2.1	27.8	55.6	150.0	4.6	2.8	5.9	274.2
Codington	382.4	8.1	21.6	29.7	29.2	5.1	0.7	37.5	102.1	143.7	13.4	2.6	18.4	352.7
Corson	1,847.3	26.5	44.1	70.6	130.0	20.6	26.3	150.3	526.0	764.5	48.5	12.2	98.3	1,776.7
Custer1/	230.7	--	5.3	5.3	18.5	2.8	2.6	26.1	38.3	132.0	1.2	2.8	1.1	225.4
Davison	262.9	--	3.8	3.8	21.7	2.0	1.9	20.4	101.7	103.4	3.2	2.0	2.8	259.1
Day	738.2	7.6	15.4	23.0	41.5	11.5	28.3	51.3	250.1	251.0	14.6	3.1	63.8	715.2
Deuel	278.3	--	6.4	6.4	22.3	3.4	3.1	31.5	46.2	159.2	1.5	3.3	1.4	271.9
Dewey	734.9	13.1	33.1	46.2	54.6	9.3	2.1	69.6	180.7	314.5	22.4	5.2	30.3	688.7
Douglas	4.3	--	--	--	--	--	--	--	0.2	4.1	--	--	--	4.3
Edmunds	20.3	--	0.5	0.5	1.6	0.2	0.2	2.3	3.4	11.7	0.1	0.2	0.1	19.8
Faulk	18.6	--	0.4	0.4	1.5	0.2	0.2	2.1	3.1	10.7	0.1	0.2	0.1	18.2
Grant	939.3	20.0	0.4	20.4	62.2	11.0	0.2	108.2	324.8	288.3	32.9	4.9	86.4	918.9
Gregory	3,111.8	3.2	47.6	50.8	218.6	28.2	68.3	248.1	980.6	1,357.2	29.7	23.8	106.5	3,061.0
Haakon	590.4	1.1	12.7	13.8	39.1	5.6	4.6	51.4	107.0	353.9	4.7	5.2	5.1	576.6
Hamlin	306.9	1.1	6.1	7.2	24.5	3.8	3.0	33.0	56.0	169.0	3.2	3.4	3.8	299.7
Hand	55.5	--	0.9	0.9	3.0	0.5	0.4	4.3	7.1	38.5	0.2	0.4	0.2	54.6
Hanson	121.5	--	1.3	1.3	10.0	0.7	0.6	7.3	58.8	38.7	1.8	0.7	1.6	120.2
Hughes	284.3	--	6.2	6.2	21.7	3.3	3.0	30.6	45.6	168.0	1.4	3.2	1.3	278.1
Hutchinson	272.9	--	3.0	3.0	21.8	1.6	1.5	16.9	122.2	97.2	3.8	1.6	3.3	269.9
Hyde	18.8	--	0.4	0.4	1.5	0.2	0.2	2.1	3.1	10.9	0.1	0.2	0.1	18.4
Jackson	211.5	--	4.1	4.1	14.1	2.1	2.0	19.9	29.4	136.0	0.9	2.1	0.9	207.4
Jerauld	126.8	2.2	0.9	3.1	9.6	1.6	0.4	10.4	29.9	62.0	3.8	0.9	5.1	123.7
Jones	377.9	--	6.5	6.5	25.6	3.5	3.2	32.6	72.7	226.1	2.3	3.4	2.0	371.4
Kingsbury	327.8	--	7.2	7.2	24.9	3.8	3.5	35.2	52.3	194.1	1.6	3.7	1.5	320.6
Lake	177.8	--	3.0	3.0	13.1	1.6	1.4	15.1	46.3	93.1	1.4	1.5	1.3	174.8
Lincoln	630.0	--	10.8	10.8	45.9	5.7	12.1	55.4	175.3	298.8	4.8	5.6	15.6	619.2
Lyman	761.9	2.3	12.9	15.2	54.7	8.0	6.3	70.5	143.7	440.3	7.5	7.2	8.5	746.7
Marshall	1,035.3	21.4	1.3	22.7	69.5	12.3	0.6	114.8	343.7	342.2	35.4	5.6	88.5	1,012.6
McCook	364.0	1.1	5.6	6.7	28.6	3.6	2.8	31.9	103.0	174.6	4.6	3.2	5.0	357.3
McPherson	8.9	--	--	--	--	--	--	--	0.4	8.5	--	--	--	8.9

(Table 1 continued on next page)

(Table 1 continued)

County	All species	Softwoods: Ponderosa pine	Softwoods: Juniper/ other softwoods	Softwoods: Total softwoods	Hardwoods: Oak	Hardwoods: Basswood	Hardwoods: Soft maple	Hardwoods: Elm	Hardwoods: Ash	Hardwoods: Cottonwood	Hardwoods: Willow	Hardwoods: Hackberry	Hardwoods: Other hardwoods	Hardwoods: Total hardwoods
Meade[1]	1,705.1	33.7	44.9	78.6	168.7	137.8	11.4	249.5	556.6	431.8	24.2	6.9	39.6	1,626.5
Mellette	2,020.2	78.9	33.0	111.9	127.3	26.0	26.9	212.0	501.4	901.6	16.5	15.2	81.4	1,908.3
Miner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Minnehaha	401.1	6.6	3.0	9.6	33.3	5.2	1.5	34.2	118.1	167.8	12.2	3.1	16.1	391.5
Moody	604.3	8.8	0.9	9.7	29.7	5.2	7.2	78.7	227.2	157.3	14.6	2.5	72.2	594.6
Pennington[1]	368.3	6.5	2.6	9.1	28.7	4.9	1.2	31.2	90.5	173.4	11.3	2.8	15.2	359.2
Perkins	516.8	--	16.4	16.4	34.6	5.2	4.8	51.3	74.8	320.2	2.3	5.1	2.1	500.4
Potter	40.0	1.2	--	1.2	3.5	0.6	--	3.3	12.4	14.2	1.9	0.3	2.6	38.8
Roberts	2,587.4	26.2	22.4	48.6	167.9	78.2	90.9	203.5	930.5	793.8	52.0	9.4	212.6	2,538.8
Sanborn	160.9	2.2	1.7	3.9	12.7	2.1	0.8	14.9	36.8	79.0	4.0	1.4	5.3	157.0
Shannon	11,505.9	7,760.7	22.7	7,783.4	288.7	24.8	115.6	311.2	1,290.7	1,338.3	69.5	14.4	269.3	3,722.5
Spink	543.9	4.4	8.8	13.2	32.9	5.3	16.3	43.1	135.3	251.8	8.5	2.9	33.6	530.7
Stanley	325.9	3.2	4.7	7.9	26.2	4.2	2.3	32.3	68.9	166.2	6.4	3.2	8.3	318.0
Sully	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Todd	3,992.6	2,313.5	39.2	2,352.7	185.7	19.4	8.6	198.1	404.1	728.9	35.4	13.5	46.2	1,639.9
Tripp	761.4	8.8	11.8	20.6	62.4	18.4	4.2	79.9	165.7	364.8	16.4	6.5	21.5	740.8
Turner	321.0	--	5.2	5.2	26.7	2.8	2.6	27.3	113.1	134.0	3.5	2.7	3.1	315.8
Union	1,032.0	2.2	11.9	14.1	61.9	7.5	32.6	70.7	322.8	450.5	10.1	6.7	55.1	1,017.9
Walworth	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Washabaugh	1,213.4	222.8	5.2	228.0	53.5	8.6	0.6	149.1	377.6	251.4	24.1	4.1	116.4	985.4
Yankton	1,556.4	--	17.3	17.3	114.0	9.2	29.0	97.8	669.8	541.3	18.6	9.0	50.4	1,539.1
Ziebach	533.3	11.1	4.1	15.2	36.6	6.4	7.3	37.9	151.9	220.3	18.3	3.0	36.4	518.1
All counties	51,906.8 [2]	11,324.1	641.3	11,965.4	3,023.3	601.7	622.0	3,873.3	11,744.4	17,229.6	698.4	280.8	1,867.9	39,941.4

[1] Only the portions of these counties east of the 103rd meridian are included in the area surveyed by the North Central Forest Experiment Station.

[2] Sampling error is estimated to be 40 percent.

Species group	Growing-stock volume [3]1965	1980
	(million cubic feet)	
SOFTWOODS		
Ponderosa pine	11.9	11.3
Other softwoods[4]	—	0.6
Total	11.9	11.9
HARDWOODS		
Oak	2.8	3.0
Basswood	1.6	0.6
Soft maple	0.8	0.6
Hard maple	0.2	—
Elm	11.8	3.9
Ash	14.8	11.7
Cottonwood	21.1	17.2
Willow	1.3	0.7
Hackberry	0.1	0.3
Black walnut	0.1	—
Other hardwoods[5]	1.7	2.0
Total	56.3	40.0

Included in the growing-stock volume are 176 million board feet in sawtimber trees.[6] The average sawtimber volume per acre is 1,552.8 board feet. As with growing stock, cottonwood is by far the leading sawtimber species in eastern South Dakota and comprises 44 percent of the volume. Ponderosa pine is ranked second and accounts for 22 percent of the total sawtimber volume. Ash, oak, and elm account for most of the remaining sawtimber volume as shown in the following tabulation:

Species	Sawtimber (Thousand board feet)[7]
Cottonwood	77,328
Ponderosa pine	38,644
Ash	31,936
Oak	9,832
Elm	7,833
Other species	10,827
Total	176,400

Timber is concentrated primarily in the major river basins of Southwestern, Western, and Southern regions of eastern South Dakota. Shannon County in the southwestern part of the State contains the largest amount of timber volume (22 percent of the total), with 11.5 million cubic feet of growing stock and 38.5 million board feet of sawtimber volume (table 2). Sixty-nine percent of the total ponderosa pine growing-stock volume and 8 percent of the total cottonwood volume is found in Shannon County.

These statistics are based on results from the forest inventory conducted by the North Central Forest Experiment Station. Fieldwork for the inventory was completed in July 1980. This is one of a number of reports that will be prepared presenting resource statistics for Eastern South Dakota.

Sampling error for eastern South Dakota's total growing-stock volume of 51.9 million cubic feet is estimated to be ±40 percent. Sawtimber sampling error is estimated to be ±30 percent for the total of 176.4 million board feet.

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[4] *Other softwoods are Rocky Mountain juniper and eastern red cedar.*

[5] *Other hardwoods are honey locust, red mulberry, eastern hophornbeam, chokecherry, Canada plum, wild plum, and aspen.*

[6] *Net volume of live merchantable sawtimber trees (softwoods 9.0 inches d.b.h. or larger and hardwoods 11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn products is limited by large branches, forks, or other defects, or by a top diameter outside bark of 7.0 inches for softwoods and 9.0 inches for hardwoods.*

International ¼-inch rule.

Table 2.--Net volume of sawtimber on commercial forest land by species group and county, South Dakota, 1980.

(In thousand board feet)[1]

County	All species	Softwoods			Hardwoods									
		Ponderosa pine	Juniper/ other softwoods	Total softwoods	Oak	Basswood	Soft maple	Elm	Ash	Cottonwood	Willow	Hack-berry	Other hardwoods	Total hardwoods
Aurora	380.5	--	--	--	22.1	2.2	3.9	14.3	23.4	313.5	--	--	1.1	380.5
Beadle	1,572.8	--	--	--	94.6	19.5	15.7	170.1	219.8	1,048.5	--	--	4.6	1,572.8
Bennet	3,003.5	2,093.5	--	2,093.5	83.6	6.2	1.6	93.5	147.4	545.5	33.5	--	8.7	910.0
Bon Homme	4,950.2	106.2	39.7	145.9	350.6	29.1	92.3	240.6	1,044.5	2,813.9	127.4	--	105.9	4,804.3
Brookings	2,200.2	6.3	--	6.3	151.8	14.7	24.6	97.5	172.3	1,717.6	6.6	--	8.8	2,193.9
Brown	4,029.3	--	--	--	270.9	26.5	47.8	174.7	286.6	3,208.9	--	--	13.9	4,029.3
Brule	650.1	6.4	--	6.4	43.0	4.1	5.4	27.4	57.4	496.6	6.6	--	3.2	643.7
Buffalo	712.1	6.6	--	6.6	49.5	4.7	6.5	31.5	64.7	538.1	6.9	--	3.6	705.5
Campbell	154.3	6.2	--	6.2	12.1	1.0	--	7.5	24.6	94.8	6.5	--	1.6	148.1
Charles Mix	5,468.7	102.9	40.8	143.7	365.4	31.4	136.6	257.2	1,039.1	3,235.1	118.9	--	141.3	5,325.0
Clark	637.3	--	--	--	41.1	4.0	7.2	26.5	43.4	513.0	--	--	2.1	637.3
Clay	951.5	13.0	--	13.0	69.9	6.5	7.9	44.3	98.2	692.4	13.6	--	5.7	938.5
Codington	1,305.5	47.1	51.2	98.3	105.3	9.2	2.5	115.2	199.3	713.6	49.2	--	12.9	1,207.2
Corson	6,381.7	155.2	82.1	237.3	450.7	37.6	132.6	343.2	1,339.1	3,506.1	179.2	--	155.9	6,144.4
Custer[2]	800.0	--	--	--	54.6	5.3	9.6	35.2	57.7	634.8	--	--	2.8	800.0
Davison	1,013.2	--	--	--	67.9	3.9	7.0	25.4	396.0	488.8	16.6	--	7.6	1,013.2
Day	2,574.5	44.6	32.3	76.9	142.9	31.4	150.9	123.8	758.3	1,079.4	57.7	--	153.2	2,497.6
Deuel	964.9	--	--	--	65.8	6.4	11.6	42.4	69.6	765.7	--	--	3.4	964.9
Dewey	2,472.2	76.5	72.8	149.3	192.4	17.0	7.8	190.7	346.2	1,466.8	80.0	--	22.0	2,322.9
Douglas	10.9	--	--	--	--	--	--	--	--	10.9	--	--	--	10.9
Edmunds	70.4	--	--	--	4.8	0.5	0.8	3.1	5.1	55.9	--	--	0.2	70.4
Faulk	64.6	--	--	--	4.4	0.4	0.8	2.8	4.7	51.3	--	--	0.2	64.6
Grant	2,824.0	116.8	--	116.8	231.3	19.9	0.8	244.3	588.9	1,469.4	122.2	--	30.4	2,707.2
Gregory	11,346.8	18.9	8.0	26.9	677.0	58.3	333.3	335.3	3,331.7	6,161.0	124.0	--	299.3	11,319.9
Haakon	1,880.1	6.4	8.2	14.6	119.2	10.6	17.2	78.3	247.4	1,372.0	12.3	--	8.5	1,865.5
Hamlin	1,062.1	6.5	--	6.5	75.0	7.2	11.0	48.0	91.3	811.5	6.7	--	4.9	1,055.6
Hand	175.5	--	--	--	8.9	0.9	1.6	5.7	9.4	148.5	--	--	0.5	175.5
Hanson	488.1	--	--	--	32.3	1.3	2.3	8.5	250.8	177.4	11.1	--	4.4	488.1
Hughes	972.7	--	--	--	64.0	6.2	11.3	41.3	67.7	778.9	--	--	3.3	972.7
Hutchinson	1,072.3	--	--	--	69.5	3.0	5.5	20.0	511.1	431.7	22.4	--	9.1	1,072.3
Hyde	65.3	--	--	--	4.5	0.4	0.8	2.9	4.7	51.8	--	--	0.2	65.3
Jackson	659.1	--	--	--	41.6	4.1	7.3	26.8	44.1	533.1	--	--	2.1	659.1
Jerauld	417.8	12.7	--	12.7	33.4	3.0	1.5	20.8	59.1	270.3	13.3	--	3.7	405.1
Jones	1,221.1	--	--	--	76.8	6.5	11.8	43.2	191.6	880.2	5.7	--	5.3	1,221.1
Kingsbury	1,120.1	--	--	--	73.4	7.2	13.0	47.4	77.6	897.7	--	--	3.8	1,120.1
Lake	621.3	--	--	--	39.9	3.0	5.4	19.7	149.7	394.7	5.5	--	3.4	621.3
Lincoln	2,277.5	--	--	--	139.5	10.8	56.4	71.4	555.6	1,381.3	16.8	--	45.7	2,277.5
Lyman	2,490.2	13.2	--	13.2	168.2	15.2	23.4	101.3	315.3	1,821.8	19.6	--	12.2	2,477.0
Marshall	3,159.5	125.3	--	125.3	256.2	22.1	2.3	256.4	626.8	1,706.2	131.1	--	33.1	3,034.2
McCook	1,305.1	6.5	--	6.5	89.7	6.7	10.2	45.0	326.5	794.1	18.0	--	8.4	1,298.6
McPherson	22.5	--	--	--	--	--	--	--	--	22.5	--	--	--	22.5

(Table 2 continued on next page)

(Table 2 continued)

County	All species	Softwoods			Hardwoods									
		Ponderosa pine	Juniper/ other softwoods	Total softwoods	Oak	Basswood	Soft maple	Elm	Ash	Cottonwood	Willow	Hack-berry	Other hardwoods	Total hardwoods
Meade[2/]	5,643.1	142.4	89.5	231.9	524.2	469.8	54.0	676.7	1,578.4	1,927.3	109.5	--	71.3	5,411.2
Mellette	6,449.4	297.4	26.8	324.2	392.3	63.9	123.1	351.0	1,163.5	3,885.4	49.0	--	97.0	6,125.2
Miner	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Minnehaha	1,417.5	38.5	--	38.5	115.4	9.4	5.5	66.0	303.2	820.2	45.9	--	13.4	1,379.0
Moody	1,660.0	51.4	--	51.4	108.7	9.4	38.4	168.0	416.1	766.0	53.8	--	48.2	1,608.6
Pennington[2/]	1,261.2	38.1	--	38.1	100.2	8.9	4.6	62.4	177.1	818.9	39.8	--	11.2	1,223.1
Perkins	1,664.5	--	16.3	16.3	101.9	10.0	18.0	81.7	107.8	1,323.6	--	--	5.2	1,648.2
Potter	141.1	6.7	--	6.7	13.1	1.1	--	8.0	26.4	77.1	7.0	--	1.7	134.4
Roberts	8,995.4	153.0	40.4	193.4	566.9	245.9	487.3	484.2	2,891.9	3,404.4	215.6	--	505.8	8,802.0
Sanborn	554.0	12.9	--	12.9	42.8	3.9	3.1	26.9	69.4	377.2	13.5	--	4.3	541.1
Shannon	38,526.6	24,888.2	24.5	24,912.7	1,019.0	45.2	615.6	995.0	4,463.4	5,543.6	292.2	--	639.9	13,613.9
Spink	1,860.8	25.7	8.1	33.8	107.4	9.9	83.8	75.7	322.2	1,122.7	26.9	--	78.4	1,827.0
Stanley	1,114.5	19.0	--	19.0	84.9	7.9	8.5	53.7	125.2	788.0	19.9	--	7.4	1,095.5
Sully	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Todd	15,104.2	9,196.6	88.1	9,284.7	653.4	35.9	32.0	486.0	989.1	3,464.3	119.5	--	39.3	5,819.5
Tripp	2,539.7	51.3	8.1	59.4	204.4	49.4	15.6	159.4	294.6	1,685.5	53.6	--	17.8	2,480.3
Turner	1,221.2	--	--	--	82.9	5.2	9.5	34.7	418.8	644.7	17.0	--	8.4	1,221.2
Union	3,664.2	12.7	--	12.7	194.2	14.1	166.7	94.0	1,084.3	1,902.9	40.9	--	154.4	3,651.5
Walworth	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Washabaugh	3,179.6	675.1	18.3	693.4	180.7	15.5	2.4	330.5	603.9	1,241.6	88.9	--	22.7	2,486.2
Yankton	6,032.2	--	--	--	361.6	17.4	142.6	114.9	2,711.0	2,429.2	106.9	--	148.6	6,032.2
Ziebach	1,820.8	64.6	8.2	72.8	134.3	11.6	38.6	90.9	343.4	1,009.8	67.6	--	51.8	1,748.0
All counties	176,399.5	[3/]38,644.4	663.4	39,307.8	9,832.1	1,482.4	3,037.5	7,832.9	31,936.4	77,327.7	2,578.9	--	3,063.8	137,091.7

[1/] International 1/4-inch rule.

[2/] Only the portions of these counties east of the 103rd meridian are included in the area surveyed by the North Central Forest Experiment Station.

[3/] Sampling error estimated to be 30 percent.

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A TECHNIQUE FOR TRAPPING FUNGAL SPORES

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ABSTRACT.—Describes a technique for using petroleum jelly-coated microscope slides to determine the spore dispersal patterns of fungi that cause diseases of nursery, plantation and forest trees.

KEY WORDS.—Disease, pest management, infection, trees, phenology, spore traps.

Early detection, identification, and study of a forest pathogen is essential to prevent a potential epidemic and subsequent economic loss. The biology and life history of a disease-causing organism should be understood, if its controls are to be effective. Spore traps have been used to study the life cycles of fungi and also can be used as a forecasting tool to monitor the presence of certain tree pathogens. The information gained from these traps is extremely useful for planning the control of many forest pathogens. We have successfully used Vaseline[1] petroleum jelly-coated microscope slide spore traps to determine the timing of spore release and dissemination for several serious fungal pathogens in the Lake States. Timing of spore release is particularly important for applying chemical sprays. Knowledge of proper spray timing eliminates extra sprays, which are costly and introduce needless pesticides into the environment.

SPORE TRAP OPERATION

Spore traps are placed in and around infected trees at various heights and distances. These traps are then changed at weekly intervals throughout the season. All slides should be changed on the same day for easy comparison. Potted seedlings, used as exposure trees, can also be placed under infected trees and changed at weekly intervals to determine exact timing of infection. After exposure, the trees are moved to an area free of the disease and observed for the occurrence of disease symptoms. Data from the spore traps and exposure trees can be used to determine when spores are released and when host trees are infected. By graphing spore dispersal data it can be determined when peak amounts of spore inoculum are present (fig. 1-3). Control measures can then be applied prior to and during these peaks to ensure complete protection. Most chemical controls are preventative so must be applied before spores are released to be effective.

The following methods are used to prepare vaseline spore traps for the field and to examine them in the laboratory.

METHODS FOR MAKING VASELINE SPORE TRAP SLIDES

1. Obtain slides that have one frosted end.
2. Fill 2 or more 300 ml beakers two-thirds full of water and place an amount of vaseline in the water so that when it melts there will be approximately a 1-inch layer floating on top. SLOWLY heat the beakers on separate hot plates until vaseline melts to a clear, yellow color. This is usu-

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[1] *Mention of trade names does not endorse the products by the USDA Forest Service.*

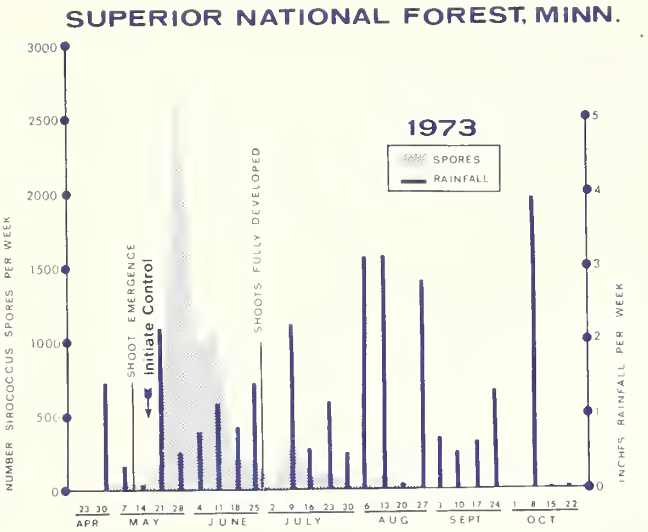


Figure 1.—Sirococcus strobilinus *spore dispersal from red pine correlated with rainfall, Superior National Forest, Minnesota, 1973.*

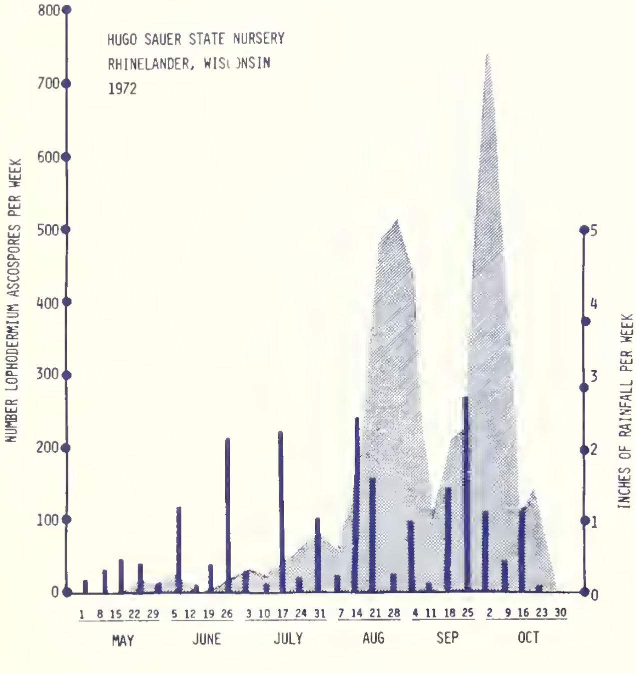


Figure 2.—Lophodermium *needlecast spore dispersal from red pine nursery seedlings correlated with rainfall, Hugo Sauer State Nursery, Rhinelander, Wisconsin, 1972. Note that the major spore dispersal peak for* Sirococcus *shoot blight (fig. 1) is in the early part of the growing season and that for Lophodermium occurs in the latter part of the growing season. Therefore, timing of control measures are different for the two diseases.*

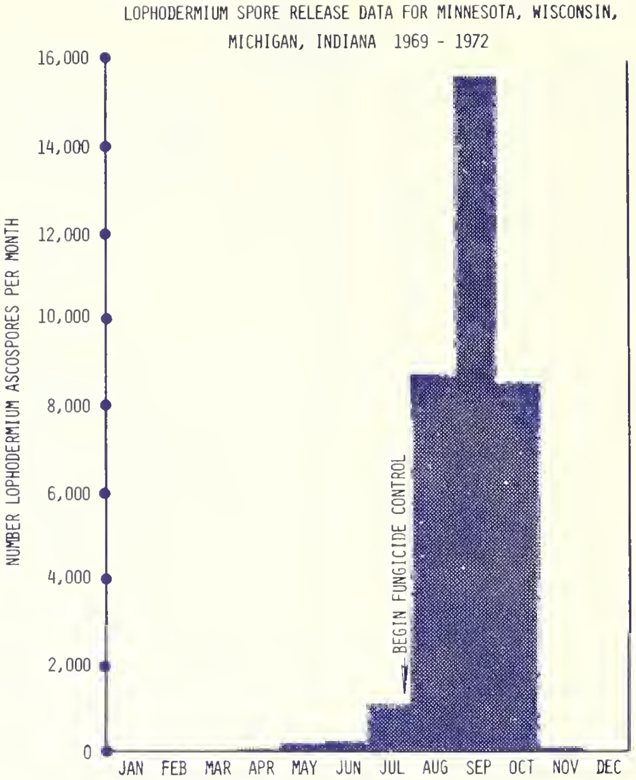


Figure 3.—Lophodermium *spore release data for Minnesota, Wisconsin, Michigan, and Indiana showing how data can be combined to produce a regional spore dispersal graph that can help forest manager's initiate controls at the proper times.*

ally between 65 and 80° C. DO NOT BOIL. Temperature is critical—if it is too cool, vaseline will not adhere smoothly to slides; if it is too hot, vaseline will melt off the sides of slides as they are being dipped. Use several beakers because the water temperature will drop as slides are dipped. Also, more vaseline must be added and melted when the level in the beaker is less than inch thick.

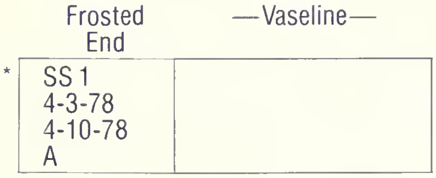
3. Dip two slides at a time. Apply a drop of water to the back of one slide and place it back to back (FROSTED SIDES *OUT)* with another. Holding onto the frosted end, dip the slides into the beaker of melted vaseline using a SMOOTH, vertical motion up to about 1/8-inch from the frosted end. Do not let frosted ends become covered with vaseline. Separate slides and place on a paper towel to cool. Use a spatula to scrape excess vaseline off edges of slides and remove approximately 1/8-inch of vaseline from the end so that it will not smear when the slide is placed in a slide box. The finished slide should have a smooth surface. If it does not, refer to the following trouble shooting guide to determine the cause of the problem.

TROUBLE SHOOTING GUIDE

Problem	**Cause**	**Solution**
Vaseline surface lumpy, irregular	Water/Vaseline too cool, jerky motion in dipping slides	Reheat water; dip slides using a smooth, nonstop motion
Vaseline surface too thin or melted off near the edges of slide	Water/Vaseline too hot, dipping too slow so that water heats the slide & melts Vaseline as slide is dipped	Let water/Vaseline cool, dip slides faster
Bubbles on Vaseline surface of slide	Water/Vaseline boiling	Use lower heat setting, let water/ Vaseline cool before using

CAUTION: Do not leave heating beakers unattended; do not boil; use care in handling hot, slippery beakers; do not allow Vaseline to spill onto heating coils. When reheating a beaker of water with Vaseline that has solidified, break up the surface to prevent a boil-over.

4. Label the Slides
The following is an example of a method that can be used to code exposure slides. Use a hard (4H) lead pencil to avoid smearing.



KEY
* Solon Springs, Wisconsin, Week 1
Exposed from 4-3-78 to 4-10-78
Spore Trap Location A

5. Keep coated slides in a cool place. They can be stored at room temperature or, preferably, in a refrigerator.
Exposed slides placed in slide boxes can be sent from field locations to laboratories using carefully padded mailing boxes to avoid breakage.
6. Make Spore trap holders.
They can be made from aluminum clothesline or similar wire. Bend one length of wire to shape and hold the frosted end of the slide in place by two bends in the wire and by a spring clothespin (fig. 4). For best results in the field, keep slides horizontal and keep vegetation away from the slides. Place slides in and around the areas being monitored. Slides should be positioned under infected trees to ensure trapping spores, especially rain-splash disseminated spores when they are produced. To determine the source or spread of inoculum place slides at known distances in the cardinal directions from infected trees.

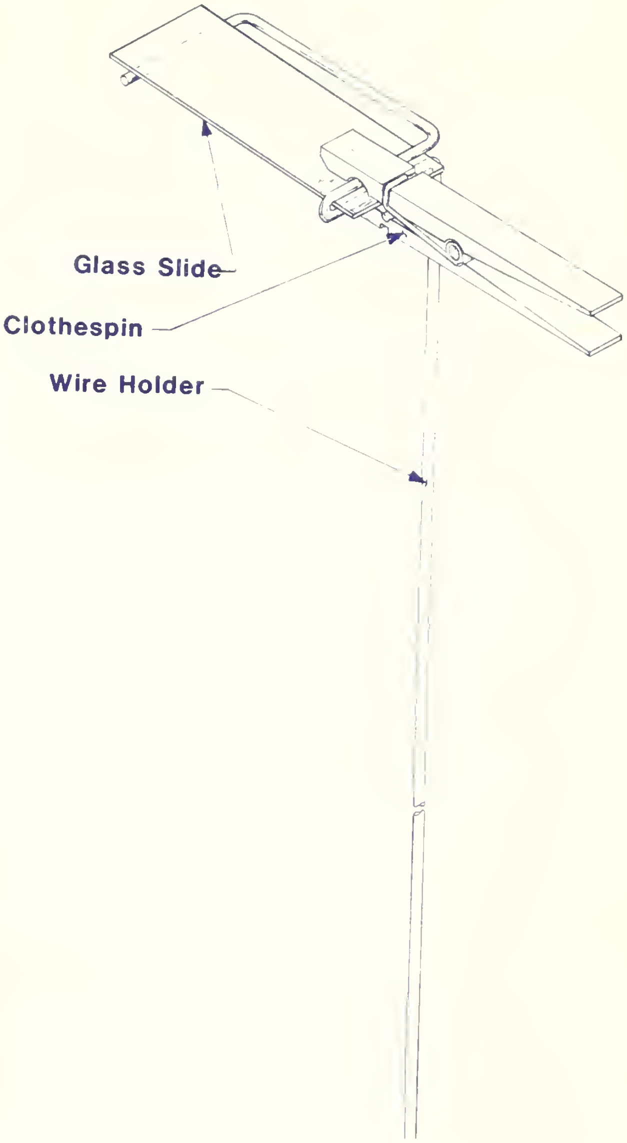


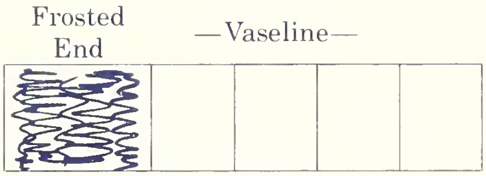
Figure 4.—*Spore trap holder.*

7. Read the slide with a microscope.
A cover slip is not necessary if a stain is not used except at high magnifications where it is helpful in preventing vaseline from accidently smearing the objective. The use of a stain is necessary when counting hyaline or other light-colored spores. Staining can usually be done by placing one drop of lactophenol and one drop of stain in the middle of each transect to be counted. Then gently place

a 24x50mm cover slip on the vaseline and allow the stain to disperse. Avoid using extensive amounts of stain or lactophenol.

The size of spore being counted will determine the magnification needed but it should be the same throughout the study for comparison purposes. For example, we generally use 430X for counting *Diplodia*, *Sirococcus*, and *Gremmeniella* spores.

Make three transects at predetermined locations across the width of each slide as shown below. Then count and total all spores in each transect.



Spore Count Transects

MONITORING WEATHER AND PHENOLOGY

The development and severity of disease is greatly affected by weather conditions. To study this, we maintain weather stations at each study site where spore traps are located. Each station consists of a weather shelter containing a temperature-relative humidity 7-day recording hygrothermograph and a rain gauge. The phenological development of parasite and host are monitored at weekly intervals using a standard field form. Shoot and foliage elongation and presence of fruiting bodies or needlespots are recorded and correlated with weather and spore release data.

CONCLUSION

The techniques described in this paper can be used to inexpensively provide knowledge on the biology of a fungus pathogen that is needed to help make accurate control judgments. Control recommendations for one part of the country may not necessarily work for the same species in other areas because of climatic or physiological and genetic differences in hosts and pathogens. Therefore, it may be necessary to adjust timing of control practices for different areas. These adjustments can be made easily and quickly by obtaining the necessary information using these techniques.

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THE HYBRID WHITE SPRUCE X HIMALAYAN SPRUCE

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ABSTRACT.—*Picea glauca* and *P. smithiana* were successfully crossed. Crossability ranged from 2 to 30 percent depending on the female *P. glauca* parent tree. Early characteristics and growth in Wisconsin and in New Brunswick are described. *P. smithiana* relatedness in the genus is discussed.

KEY WORDS: Crossability, seedling characteristics, hybridity, phylogeny.

Species hybridization creates new genotypes that may be superior to the parental species; it can also be used to help determine intrageneric relations among species (Wright 1955).

Himalayan spruce, *Picea smithiana* (Wall.) Boise., is a high elevation (2,000-4,000 m), commercially important species. It extends from eastern Afghanistan southeastward to central Nepal, a distance of approximately 2,000 km. Himalayan spruce is one of the largest spruce species with heights of up to 50 m (Schmidt-Vogt 1977). The species has been planted on a small scale as an ornamental in Great Britain (Streets 1962) and in eastern North America (Wright 1956).

White spruce, *Picea glauca* (Moench) Voss, is the most widely distributed conifer in North America. The species has been extensively planted throughout the north-central and northeastern United States and adjacent Canada during the last 40 years. White spruce is known to be highly variable with a great potential for genetic improvement (Nienstaedt and Teich 1971).

Mergen *et al.* (1965) were the first to attempt to cross white spruce and Himalayan spruce. They obtained 852 seeds from 32 cones but provided no information on proportions of full seed or on germinations. At least 40 seeds germinated and survived for 4 years in a nursery. At the end of the first growing season, the hybrids were not significantly different from white spruce. At the end of the fourth growing season in the nursery, their heights were intermediate between white spruce seedlings obtained from self- and from wind-pollinations.

Fowler *et al.* (1973) reported obtaining 144 full seeds from 443 cones from crosses of three white spruce with pollen of Himalayan spruce. Later Fowler *et al.* (1975) obtained 14 full seeds from 310 cones from this same cross on nine additional white spruce at the Acadia Forest Experiment Station (AFES) near Fredericton, New Brunswick. The same cross using 42 female strobili on three trees was reported as successful by Hoffman and Kleinschmit (1979).

We present additional information on some crosses reported by Fowler *et al.* (1975) and on crosses made at the Forestry Sciences Laboratory (FSL) in Rhinelander, Wisconsin.

MATERIALS AND METHODS

In the spring of 1971, an attempt was made to cross three white spruce trees growing at the AFES with pollen from a single Himalayan spruce growing in the Yale Brett Arboretum in Fairfield, Connecticut. This same combination, as well as intraspecific white spruce crosses, was attempted again in 1973 using nine other white spruces at the AFES, one at Taymouth, N.B., and four white spruces at the FSL.

The pollination techniques used were essentially the same as those described for white spruce by Nienstaedt and Teich (1971). The general procedures used for seed cleaning and germination and for raising and testing seedlings at the AFES and the FSL are described by Fowler (1980) and Nienstaedt (1979) respectively. One deviation, however, should be mentioned: At the FSL seedlings in the greenhouses were transplanted progressively to larger containers; at no time were they rootbound.

RESULTS

Ten of the 17 attempts to cross white spruce and Himalayan spruce produced at least a few full seeds. The seven unsuccessful crosses occurred at the AFES in 1973 when Himalayan spruce pollen known to have low *in vitro* germination was used. Seed yields from both hybrid and control crosses were considerably higher at the FSL than at the AFES (table 1).

Germination of hybrid seeds was variable. Two AFES crosses failed to germinate; otherwise, the germination of hybrid seed was similar to that of comparable white spruce. The frequency of abnormal germination, e.g., seeds with reverse embryos, was higher among the hybrids than among the parental species. It was especially high for one cross (#7583) in which 15 of 38 germinants had reverse embryos.

Estimates of crossability, based on the yield of sound, germinable seed from crosses between two species, expressed as a percentage of the seed yield from within species crosses, provide a measure of relation between species (Critchfield 1973). However, for such estimates to be meaningful, comparable information should be available from intra- and interspecific crosses made on the same mother trees. Only six of the attempted crosses reported here meet this requirement. Crossability estimates based on these crosses range from 1.7 to 30 percent and average 9.1 percent (table 1).

The hybrid families can be distinguished from parental species on the basis of needle length and stem form and in some cases on the basis of number of cotyledons and needle serrulations. Variation in respect to hypocotyl color and foliage color is too great to be of diagnostic value, at least for young seedlings.

Table 1.—Crossability estimates for the cross Picea glauca x P. smithiana—full seeds and germination percentages[1]

Identification Number	Parentage ♀	♂	Cones	Full Seed	Germination	Crossability[2]
			No.	No.	Percent	Percent
		1971 CONTROLLED POLLINATIONS (NEW BRUNSWICK)				
2220	glauca #556	smith	166	20	20.0	
--	glauca #561	smith	234	3	0	No estimates possible
2224	glauca #558	smith	43	119	53.8	
2226	glauca AFES	open[3]	--	250	88.0	
2227	smith India	open	--	200	37.0	
2228	smith India	open		200	80.0	
		1973 CONTROLLED POLLINATIONS (NEW BRUNSWICK)				
2860	glauca 73-6	smith	48	13	61.5	6.08
2863	glauca 73-6	glauca	54	266	55.6	
--	glauca T-3	smith	27	12	[4]	7.56
--	glauca T-3	glauca	32	188	[4]	
2867	glauca 73-2	smith	16	1	0	
2892	smith India	open		100	19.0	
		1972 CONTROLLED POLLINATIONS (WISCONSIN)				
7579	glauca 1885	smith	165	902	21.8	30.42
7123	glauca 1885	glauca 1887	52	1,164	17.5	
7584	glauca 1888	glauca 1889	43	1,931	41.5	2.42
7583	glauca 1888	smith	51	63	36.5	6.52
7585	glauca 1888	glauca 1887	52	1,285	28.0	
7586	glauca 1889	smith	28	29	48.3	1.67
7127	glauca 1889	glauca 1885	36	2,182	48.0	
7582	glauca 1887	smith	49	120	58.5	

[1] Only the 10 hybrid combinations that yielded full seeds are included.

[2] $$\frac{\text{Germinated hybrid seed/cone}}{\text{Germinated control-cross seed/cone}} \times 100.$$

[3] "Open" indicates open pollinated seed collected in native stands.

[4] Seeds not germinated.

The hybrid seedlings are clearly distinguishable from white spruce (table 2).

The performance of hybrid families in respect to that of both parents or to white spruce alone was highly variable (table 2, 3). Seedlings from the two hybrid families from the 1971 pollinations at the AFES were smaller than seedlings of either parent species after 5 months in the greenhouse (table 2). After 2 years in the nursery, the hybrids and Himalayan spruce seedlings were somewhat taller than white spruce. However, the Himalayan spruce seedlings had lower survival (80 percent) than the hybrid and white spruces (100 percent) and showed winter damage, i.e., shoot tips killed back and desiccated needles. After 5 growing seasons in the field, all the Himalayan spruce seedlings had died and the hybrids had poorer survival (71 percent) than white spruce (94 percent). The hybrids showed winter damage and were shorter than white spruce.

After two growth cycles in the greenhouse, 15-month-old seedlings of hybrid family 2860 (1973 pollination, AFES) were intermediate in height between Himalayan (44 cm) and white spruce (34 cm). After 2 years in the nursery, the hybrids were shorter than either parent species. Six of the ten Himalayan spruce seedlings and one of the four hybrid seedlings suffered some winter damage. White spruce seedlings were undamaged.

The hybrids produced at the FSL generally performed better in terms of height growth than those produced at the AFES. Two of the three hybrid families were as tall or taller than the best white spruce after 5, 10, and 19 months. The other hybrid family was shorter than the shortest white spruce family at 10 and 19 months. However, after one winter's exposure, all hybrids showed much winter damage.

DISCUSSION

Our estimates of crossability for white x Himalayan spruce are tentative. Although the cross has been attempted on more than 17 different white spruces, all the Himalayan pollen came from a single non-native source (Brett Arboretum) and possibly from a single tree. It is highly probable that different Himalayan spruces used as either male or female parents would have yielded somewhat different estimates of crossability.

Attempts have been made to cross Himalayan spruce with eight other spruce species (and one hybrid), but apparently the species has never been used as female parent in any attempted crosses. In table 4, we have listed all recorded attempts to cross Himalayan and other spruce species as well as unpublished information on crosses made at the FSL. More detailed information is needed on the Hoffman-Kleinschmit crosses, some of which were made using mentor pollen. It appears that Himalayan spruce is closely related to white spruce, distantly related to *P. mariana* (Mill.) Brit., and only very distantly related to *P. abies* (L.) Karst. and *P. asperata* Mast. It is also probable that Himalayan spruce can be crossed with reasonable ease with other white spruce-related species, i.e., *P. engelmannii* (Parry) Engelm., *P. sitchensis* (Bong.) Carr., *P. jezoensis* (Sieb. et Zucc.) Carr.

Table 2.--Seedling characteristics of the cross *Picea glauca* x *P. smithiana* and of the parent species to age 5 months

(In percent)[1]

Identification Number	Parentage		Cotyledon	Needle length	Needle Percent with serration	Stem[2] form	Height 5 mon.	Seedlings
			No.	mm			cm	No.
	1971 CONTROLLED POLLINATIONS (NEW BRUNSWICK)							
2226	Glauca means		7.40	13.2	100	1.08	6.2	
2220	glauca #556	smith	105	131	100	185	85	3
2224	glauca #558	smith	105	120	96	168	74	24
2226	glauca AFES	open[3]	100	100	100	100	100	24
2227	smith, India	open	131	202	79	269	90	24
2228	smith, India	open	123	180	79	267	97	24
	1973 CONTROLLED POLLINATIONS (WISCONSIN)							
	Glauca means		5.81	13.1	99	1.00	5.1	
7123	glauca 1885	glauca 1887	97	97	101	100	92	40
7583	glauca 1888	smith	107	117	80	189	106	18
7585	glauca 1888	glauca 1887	103	103	99	100	108	40
7586	glauca 1889	smith	90	136	101	225	106	5
7582	glauca 1887	smith	103	111	79	175	96	40

[1] Expressed as percent of *P. glauca* mean values.

[2] Numerical rating: 1 = orthotropic; 2 = intermediate; 3 = plagiotropic.

[3] "Open" indicates open pollinated seed collected in native stands.

Table 3.--Growth beyond 5 months, winter damage, and survival of the cross *Picea glauca* x *P. smithiana* and of the parent species

(In percent)[1]

Identification Number	Parentage ♀	♂	Seedlings	Heights: Months 10	15	19	Nursery	Plantation	Survival[2] Nursery	Plantation	Winter damage[2] Nursery	Plantation
			No.	cm	cm	cm	cm	cm				
1971 CONTROLLED POLLINATIONS (NEW BRUNSWICK)												
2226	Glauca means						23.9	88.7	100	93.8	0	0
2220	glauca #556	smith	3				142	98	100	67	0	0
2224	glauca #558	smith	32				105	63	100	72	0	0
2226	glauca AFES	open[3]	32				100	100	100	94	0	0
2228	smith, India	open	16				114	--	80	0	100	(100)
1973 CONTROLLED POLLINATIONS (NEW BRUNSWICK)												
2863	Glauca means				33.8		48.4		100		0	
2860	glauca 73-6	smith	5		113		97		80		25	
2863	glauca 73-6	glauca	10		100		100		100		0	
2892	smith, India	open	10		129		113		60		67	
1973 CONTROLLED POLLINATIONS (WISCONSIN)												
	Glauca means			15.5		66.7			100		10.7	
7579[4]	glauca 1885	smith	40			84						
7173	glauca 1885	glauca 1887	40	180		104			100		15	
7583	glauca 1888	smith	18	88		70			100		49	
7584	glauca 1888	glauca 1889	40	88		96			100		7	
7585	glauca 1888	glauca 1887	40	102		87			100		9	
7586	glauca 1889	smith	5	122		118			100		75	
7127	glauca 1889	glauca 1885	40	102		113			100		12	
7582	glauca 1887	smith	40	107		106			100		69	

[1] Expressed as percent of *P. glauca* mean values.

[2] Data recorded as percentages - therefore not converted.

[3] "Open" indicates open pollinated seed collected in native stands.

[4] This hybrid was not grown with other hybrids and white spruce. The value is computed using other *P. glauca* mean values.

At this time, the value of the hybrid, white x Himalayan, for direct use in reforestation is questionable. In eastern Canada, the hybrids have not performed as well as native white spruce. In Wisconsin, early growth of some hybrid families exceeds that of white spruce, but the hybrids are not adapted to the severe continental climate. However, they are promising enough to warrant further testing. Available hybrids should be vegetatively propagated and small tests outplanted in less extreme north temperate climates. At the same time, if possible, the cross should be repeated on a larger scale with pollen representing a wide array of Himalayan spruce provenances.

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Table 4.--Summary of interspecific hybridization attempted with *Picea smithiana* as pollen parent

Female Parent	Reference[1/]	Results	
P. abies	1	1 Attempt, 0 full seeds.	Fail
"	2	1 Attempt, 0 full seeds.	Fail
"	3	3 Attempts, No other information.	Hybrid
P. asperata	4	1 Attempt, 0 full seeds.	Fail
"	3	No information.	Hybrid?
P. glauca	4	?, full seeds.	Hybrid
"	3	3 Attempts, No other information.	Hybrid
"	This study	17 Attempts, 1.7 - 30.4% crossability.	Hybrid
P. glehnii	3	3 Attempts, 0 full seeds.	Fail
P. mariana	5	7 Attempts, 1 yielded 34 full seeds.	Probable hybrid.
"	1	14 Attempts, 1 yielded 3 full seeds, 0.1% crossability.	Hybrid
"	3	3 Attempts, No other information.	Hybrid
P. omorika	3	3 Attempts, 0 full seeds.	Fail
(*P. mariana* x *P. omorika*)	2	4 Attempts, 20 full seeds, no germination.	Fail
P. orientalis	3	3 Attempts, No other information.	Hybrid
P. sitchensis	3	3 Attempts, No other information.	Hybrid

[1/] 1. Fowler, *et al.*, 1975.
2. Nienstaedt, unpublished data on file, FSL, Rhinelander, WI.
3. Hoffman and Kleinschmit, 1979.
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ESTIMATING SITE INDEX IN EVEN-AGED NORTHERN HARDWOOD STANDS

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ABSTRACT. — Describes two methods for improving site index estimates in diffuse porous even-aged northern hardwood stands.

KEY WORDS: Stem analysis, diffuse, porous, *Acer saccharum* Marsh., *Acer rubrum* L., *Betula alleghaniensis* Britton.

Foresters need to know how good their land is for growing trees. They can estimate the quality of a site by measuring the heights and ages of the dominant and codominant trees on it.

Common practice has been to measure a tree's age with an increment core and its height with a hypsometer. This practice has been useful for estimating ages of conifers and ring porous hardwoods, but has often led to misleading or imprecise results in diffuse porous hardwoods because annual growth rings are more difficult to distinguish. Foresters can increase the accuracy of these estimates and eliminate age and height measurement errors by using a different technique, stem analysis.

Here, we explain how to use stem analysis to estimate the site quality for even-aged, second-growth northern hardwood stands. We describe the field and office procedures to use in developing height-age curves for a specific site. These curves provide the best estimates of the site's quality, because they are based on the past growth of trees there.

We also present an easy way to improve site estimates from existing site curves.

DEVELOPING YOUR OWN TREE HEIGHT AGE CURVE

Select a Suitable Stand to Measure

Suitable stands are:

1. Even-aged with less than a 10-year age difference among the overstory trees (excluding residuals). Although stem analysis techniques can *only* be used to estimate site quality in even-aged stands, the information obtained can be applied to uneven-aged stands growing on comparable sites nearby.
2. Fully stocked with closed canopy.
3. Unaffected by excessive mortality caused by wind, insects, or disease; not disturbed by fire, grazing, or heavy thinnings from above since establishment.
4. At least 20 and preferably more than 50 years old measured at ground line. Site index estimates in younger stands are not as valid because of large variations in tree heights and growth rates in young stands.

5. Often composed of mixtures of hardwood species. The widely distributed sugar and red maples provide the best source of information for comparisons among northern hardwood species in the Lake States. However, when suitable maples are not present, reliable SI estimates can be obtained with other hardwood species.
6. At least 40 acres in size.

Choose high quality sample trees. They must be:

1. Dominants or strong codominants.
2. Above average diameter (considering all trees over 5 inches at breast height).
3. Single-stemmed — not from a sprout clump.
4. No more than 6 years old at breast height (free from evidences of past suppression).
5. Without serious insect, disease, and fire injuries. Don't use trees with rotten cores to determine age unless all rings are still evident.
6. At least their own height away from the influence of residual trees.
7. Straight, without crooks or pronounced lean.
8. Clean-stemmed, without many epicormic branches, bumps, dead branch stubs, or other surface defects. A few small surface wounds, bark scrapes, and scars are acceptable.
9. Full-crowned, without dead tops or large forks. Small (1 inch in diameter) correcting forks are permissible.

Fell, Measure, and Section Sample Trees

Horizontally mark selected trees (3 or more) at stump and breast height. Measure diameters and then record them on the stem analysis data form (fig. 1).

Figure 1.—*Sample stem analysis data form.*

Location: T47N, R25W, Sec. 36, NE1/4 of SW1/4 Date November 5, 1979

Compartment 5, Stand 3. Crew R. Oberg & R. Peterson

AGE COUNTS FROM CROSS-SECTIONAL DISKS

Tree 1 cc Codom Species Red maple			Tree 2 cc Codom Species Red maple			Tree 3 cc Condom Species Red maple		
1 Sectioning height above ground line	2 Tree age at section height	3 Number of rings counted	1 Sectioning height above ground line	2 Tree age at section height	3 Number of rings counted	1 Sectioning height above ground line	2 Tree age at section height	3 Number of rings counted
Feet	Years	Years	Feet	Years	Years	Feet	Years	Years
0(GL)	0	57	0	0	53	0	0	53
1-foot stump	1	56	1	1	52	1	1	52
4.5	4	53	4.5	3	50	4.5	3	50
9.3	9	48	9.3	8	45	9.3	7	46
17.6	16	41	17.6	12	41	17.6	12	41
25.9	21	36	25.9	17	36	25.9	19	34
34.2	25	32	34.2	24	29	34.2	25	28
42.5	33	24	42.5	32	21	42.5	32	21
50.8	41	16	50.8	36	17	50.8	38	15
59.1	48	9	59.1	44	9	59.1	45	8
67.4	54	3[1]	67.4	51	2[1]	67.4	50	2[1]
Total Tree Height (feet)		68.2			69.2			69.2

HEIGHT AND AGE VALUES FROM INTERNODE MEASUREMENTS

Height	Age	Year[2]	Annual leader growth	Height	Age	Year[2]	Annual leader growth	Height	Age	Year[2]	Annual leader growth
Feet	Years		Feet	Feet	Years		Feet	Feet	Years		Feet
68.2	57	0		69.2	53	0		69.2	53	0	
68.0	56	1	0.2	68.6	52	1	0.6	68.2	52	1	1.0
67.8	55	2	0.2	67.4	51	2	1.2	66.0	51	2	2.2
67.3	54	3	0.5	65.6	50	3	1.8	64.5	50	3	1.5
66.5	53	4	0.8	64.3	49	4	1.3	62.5	49	4	2.0
65.0	52	5	1.0	62.5	48	5	1.8	61.3	48	5	1.2
64.1	51	6	1.1	61.3	47	6	1.2				

Soil type Rousseau fine sand Aspect east Slope position: ridge, slope, [✓ bottom,] cove (circle)
Slope steepness (%) 0-6 Total length of slope (feet) 1200
Slope shape: convex (linear), concave Distance to ridge (feet)

[1] Disk ring count overlaps annual leader growth measurements below.

[2] Year 0 represents tree total height at ground line at the end of the 1979 growing season; tree heights for preceding years are obtained by subtracting annual leader growth values from the previous years total tree height.

Carefully undercut the trees above stump height and fell them to avoid tip breakage, hang-ups, and splitting. Remove all limbs. If any broken stem sections cannot be accurately joined together, discard the entire tree. Next, mark sectioning points at ground line, 1 foot, 4.5 feet, 9.3 feet, and then at 8-foot intervals up the stem (column 1). Measure total tree height to the nearest tenth of a foot and record it before sectioning the tree.

Measure down from the tree's tip between apical bud scars to find the annual height growth during the last 6 to 10 years; record on the same form (fig. 1). Take care in identifying bud scars beyond the sixth growth period where they may be obscured by diameter growth. Beginning as near the ground line as possible, cut 1- to 2-inch disks at each of the sectioning points. Cut high enough to overlap the measurements between apical bud scars. The overlapping section serves as a check on ages in plotting individual tree height-growth curves. Label (with red grease pencil or crayon) each disk according to the stand, tree, and sectioning height where it was taken. (A suitable label might be: 3-2-4.5—a disk sampled in stand 3 from tree number 2 at 4.5 feet above ground line.) Be sure to record tree location, date of sectioning, crew members, tree number, crown position (as dominant or strong codominant), species, and other pertinent soil information on the stem analysis form. If you desire, collect other information such as Girard form class, merchantable stem lengths, and diameters inside and outside bark for volume determinations.

Counting the Rings

To help distinguish annual growth rings, use an electric planer or belt sander to smooth disk surfaces. Usually rings can be distinguished easily a few days after planing, but magnification, ample lighting, and staining (phloroglucinol in hydrochloric acid and Bismark brown stains) can be used to bring out growth rings on difficult disks. Record ring counts from disks taken at various sectioning points in column 3 on the stem analysis form (fig. 1). Count rings from the pith toward the perimeter of each disk and mark at 10-year intervals for easy checks. Take care to count every ring in periods of slow growth where they are closely spaced and avoid counting false (incomplete) rings.

Make Tree Height-Age Curves

Make a height-age curve for each sample tree (fig. 2) by plotting measured height (column 1) over the corresponding age (column 2) from the stem analysis data (fig. 1). Height is the distance in feet above ground line to a particular sectioning point; age is the number of years required for the tree to reach that point (or the difference between the tree's total age at ground line and the ring count (column 3) at that sectioning point). Then connect lines through the plotted height-age values for each sample tree height-age curve. Next compare the individual height growth patterns of all sample trees within the stand and discard trees that took more than 6 years to reach d.b.h. or that have grown irregularly because of top breakage or dieback.

After this, read heights at 5-year intervals and heights at the greatest common age from the height-age curves for each sample tree. Combine and average the data (table 1). Add a correction of one-half the average annual leader growth to each mean sectioning height to remove the bias caused by sectioning points not being cut exactly on the tips of terminal leaders. Obtain an average site index curve for your stand by plotting mean total height values over age values with the correction for bias added in table 1 and drawing a smooth freehand through the plotted values. Read your site index directly from the combined curve at index age 50 (65.0 in the example).

Some foresters prefer to fix d.b.h. height as the 0-age starting point, so they can save sample trees that suffered from early suppression but grew like free-growing trees after reaching breast height. This procedure brings all tree height-age curves to the same starting point. The average height-age curve is then determined and *then 4 years is added to the ring count at breast height to get total age.*

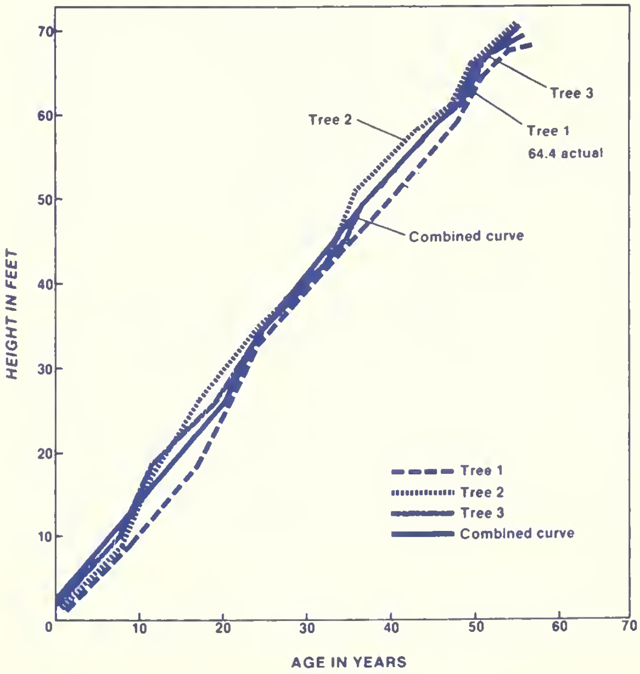

Figure 2.—*Height-age curves and a combined curve for three red maple trees.*

Table 1.--Red maple heights read from free hand sample-tree curves

(In feet)

Tree number	Total height at age (years)											
	5	10	15	20	25	30	35	40	45	50	53[1]	57[2]
1	5.2	10.2	16.4	24.3	31.4	38.3	44.6	50.2	55.9	63.0	66.5	68.2
2	6.0	13.4	22.5	29.4	35.3	40.6	48.3	55.0	59.8	65.6	69.2	
3	6.8	14.4	21.2	26.3	34.2	40.0	46.7	53.0	59.1	64.5	69.2	
Mean height	6.0	12.7	20.0	26.7	33.6	39.5	46.5	52.7	58.3	64.4	68.3[4]	
Correction to mean height[3]	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.6	[4]	
Mean height with correction added	6.6	13.3	20.7	27.3	34.2	40.2	47.1	53.3	58.8	65.0		

Mean leader growth by periods										
1-5	5-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-53
1.0	1.2	1.3	1.2	1.3	1.1	1.3	1.1	1.0	1.1	1.3

[1] Height at greatest common age.
[2] Height of oldest tree.
[3] A correction of ½ the average annual leader growth is added to each mean sectioning height to remove the bias caused by sectioning points not being cut exactly on tips of terminal leaders.
[4] No correction is needed because total height measurements were taken from the apical bud tip down the stem between annual terminal bud scars.

Ideally, foresters should compare stand yields from different areas at rotation age so they can maximize returns on their investments or at least be able to identify their most productive areas and work on them first. High quality northern hardwood saw logs can be produced in about 75 to 80 years in managed even-aged stands growing on good sites in the Lake States. It would be better to develop your own curves in stands near rotation age than to use Carmean's (1978) curves, which are based on reference age 50 and are most accurate for stands between 35 and 65 years old.

DETERMINING SITE INDEX FROM EXISTING CURVES

Select 5 or more well formed trees from representative portions of older stands. Ten or more trees are needed in young (20- to 30-year-old) stands where growth is more irregular. Fell each sample tree carefully to avoid breaking the top or losing the tip. Measure the total tree height to the nearest foot. Cut a 1- to 2-inch cross-section (disk) from the tree at breast height and label it. Estimate total age by counting the rings on the disk and adding 4 years. Use Carmean's (1978) polymorphic site index curves to determine the site index for each tree and then calculate an average site index estimate for the stand. You can use Carmean's (1979) site index comparisons for estimating site indices of other species.

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NORTH CENTRAL FOREST EXPERIMENT STATION
Research Note NC-286
1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.
1981

PULPWOOD PRODUCTION[1] IN THE LAKE STATES BY COUNTY, 1980

James E. Blyth, *Principal Market Analyst*,

and W. Brad Smith, *Associate Mensurationist*

ABSTRACT.--Pulpwood production in the Lake States--Michigan, Minnesota, and Wisconsin--advanced to 5.66 million cords in 1980. Pulpwood production is shown by county and species group for these three States.

KEY WORDS: Residue, Michigan, Minnesota, Wisconsin.

Lake States pulpwood production climbed to 5.66 million cords in 1980. Wisconsin produced 2.36 million cords, Michigan 1.97 million cords, and Minnesota 1.33 million cords.

Nine out of 10 cords came from roundwood (including chips); the remainder came from mill residue such as slabs, edgings, veneer cores, and chips from these materials. Production from softwood and hardwood residue by State was:

	Softwood	Hardwood
	(Hundred standard cords, unpeeled)	
Michigan	152	1,380
Minnesota	339	628
Wisconsin	395	2,493

Principal species harvested were aspen (2,278,000 cords), pine (805,000 cords), maple (482,000 cords), balsam fir (322,000 cords), and birch (304,000 cords).

Wisconsin imported 30 percent of its pulpwood requirements, including 490,000 cords from Michigan, 216,000 cords from Minnesota, 170,000 cords from other (primarily western) States, and 92,000 cords from Canada.

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[1] Includes logs, bolts, and wood residue used in manufacturing particleboard and waferboard.

Counties cutting more than 100,000 cords were Delta, Marquette, Iron, and Menominee in Michigan; St. Louis, Koochiching, and Itasca in Minnesota; and Marinette, Oneida, Forest, and Price in Wisconsin. These counties furnished 36 percent of the pulpwood produced from roundwood in the Lake States in 1980.

Table 1.--Lake States pulpwood production by county and species, 1980

(In hundred standard cords, unpeeled)

MICHIGAN

Unit[1] and county	All species	Pine	Spruce	Balsam fir	Hemlock	Tamarack	Cedar	Aspen	Birch	Oak	Maple	Other hardwoods
E. UPPER PENINSULA												
Alger	398	94	23	32	42	3	4	38	19	2	89	52
Chippewa	315	113	52	60	20	3	3	33	6	1	14	10
Delta	1,500	123	80	163	89	10	12	443	127	9	242	202
Luce	390	128	51	55	51	3	2	42	10	1	29	18
Mackinac	431	40	47	63	22	2	8	106	26	4	65	48
Menominee	1,095	51	52	143	59	5	5	395	74	10	222	79
Schoolcraft	563	151	32	57	42	4	7	106	24	2	80	58
Total	4,692	700	337	573	325	30	41	1,163	286	29	741	467
W. UPPER PENINSULA												
Baraga	635	29	15	27	35	3	6	95	79	5	234	107
Dickinson	601	12	24	64	14	3	2	340	36	5	61	40
Gogebic	448	24	25	38	37	3	4	125	24	2	98	68
Houghton	335	44	10	28	24	2	3	75	35	2	79	33
Iron	1,377	94	69	141	36	6	5	539	117	8	260	102
Keweenaw	11	0	2	2	3	0	0	0	1	0	2	1
Marquette	1,478	317	72	148	96	9	12	423	74	15	194	118
Ontonagon	777	11	8	16	11	2	X[2]	490	37	1	125	76
Total	5,662	531	225	464	256	28	32	2,087	403	38	1,053	545
N. LOWER PENINSULA												
Alcona	569	28	1	X	0	0	0	363	26	74	51	26
Alpena	436	21	6	7	0	0	0	231	19	50	75	27
Antrim	122	1	0	0	0	0	0	69	6	22	20	4
Arenac	11	0	0	0	0	0	0	7	0	0	4	0
Benzie	130	X	0	0	0	0	0	52	2	17	47	12
Charlevoix	50	X	X	5	0	0	0	33	2	1	9	0
Cheboygan	412	38	1	13	0	0	0	247	33	17	35	28
Clare	248	0	0	0	0	0	0	184	13	26	18	7
Crawford	251	102	1	1	0	0	0	94	10	16	22	5
Emmet	135	12	0	0	0	0	0	91	11	7	13	1
Gladwin	60	X	0	0	0	0	0	46	4	3	7	X
Grand Traverse	65	16	0	0	0	0	0	31	1	4	5	8
Iosco	174	82	0	X	0	0	0	46	5	19	18	4
Isabella	179	7	0	0	0	0	0	111	2	17	28	14
Kalkaska	64	35	0	0	0	0	0	24	3	1	1	0
Lake	526	182	0	0	0	0	0	110	3	117	99	15
Leelanau	5	3	0	0	0	0	0	X	0	X	1	1
Manistee	249	8	0	0	0	0	0	100	10	43	71	17
Mason	264	21	0	0	0	0	0	96	9	80	51	7
Mecosta	88	11	0	0	0	0	0	61	2	5	8	1
Midland	47	0	0	0	0	0	0	37	3	0	6	1
Missaukee	211	5	X	4	0	0	0	139	11	21	27	4
Montmorency	286	69	X	2	0	0	0	138	23	16	28	10
Newaygo	264	83	0	0	0	0	0	100	1	66	11	3
Oceana	175	46	0	0	0	0	0	51	2	48	26	2
Ogemaw	164	8	0	X	0	0	0	100	11	32	11	2
Osceola	244	34	0	0	0	0	0	123	3	60	23	1
Oscoda	502	89	X	1	0	0	0	266	26	61	47	12
Otsego	497	124	0	X	0	0	0	280	33	27	33	0
Presque Isle	401	20	4	24	X	0	0	234	49	4	44	22
Roscommon	258	55	0	0	0	0	0	167	15	9	11	1
Wexford	357	139	0	0	0	0	0	103	8	26	61	20
Total	7,444	1,239	13	57	X	0	0	3,734	346	889	911	255
S. LOWER PENINSULA												
Allegan	15	5	0	0	0	0	0	9	0	X	1	0
Barry	11	3	0	0	0	0	0	5	X	3	X	X
Berrien	2	2	0	0	0	0	0	0	0	0	0	0
Cass	1	1	0	0	0	0	0	0	0	0	0	0
Ingham	5	5	0	0	0	0	0	0	0	0	0	0
Kalamazoo	1	1	0	0	0	0	0	X	0	0	0	0
Kent	17	4	0	0	0	0	0	8	0	5	0	0
Montcalm	73	16	0	0	0	0	0	31	X	18	5	3
Muskegon	94	48	0	0	0	0	0	8	X	38	X	X
Ottawa	119	113	0	0	0	0	0	2	0	4	0	0
Van Buren	4	4	0	0	0	0	0	0	0	0	0	0
Washtenaw	4	4	0	0	0	0	0	0	0	0	0	0
Total	346	206	0	0	0	0	0	63	X	68	6	3
State total	18,144	2,676	575	1,094	581	58	73	7,047	1,035	1024	2,711	1,270

(Table 1 continued on next page)

(Table 1 continued)

MINNESOTA

Unit[1] and county	All species	Pine	Spruce	Balsam fir	Hemlock	Tamarack	Cedar	Aspen	Birch	Oak	Maple	Other hardwoods
NORTHERN ASPEN-BIRCH												
Carlton	180	8	21	9	0	2	0	117	2	0	0	21
Cook	587	47	149	219	0	0	0	171	0	0	0	1
Koochiching	2,242	109	644	228	0	179	0	946	10	0	4	122
Lake	705	136	184	58	0	1	0	281	39	0	0	6
St.Louis	2,700	355	267	215	0	37	0	1,616	59	0	1	150
Total	6,414	655	1,265	729	0	219	0	3,131	110	0	5	300
NORTHERN PINE												
Aitkin	445	3	14	8	0	25	0	376	1	0	0	18
Becker	23	13	0	1	0	X	0	9	0	0	0	X
Beltrami	891	136	119	102	0	61	0	444	4	X	2	23
Cass	666	111	5	9	0	14	0	491	29	0	X	7
Clearwater	299	34	21	15	0	28	0	193	2	0	1	5
Crow Wing	115	60	3	1	0	0	0	47	2	0	0	2
Hubbard	446	66	6	8	0	7	0	334	1	0	0	24
Itasca	2,079	104	108	235	0	23	0	1,537	5	0	3	64
Lake of the Woods	320	68	123	3	0	15	0	100	0	0	0	11
Mahnomen	15	3	0	0	0	0	0	11	0	0	0	1
Roseau	86	38	30	1	0	3	0	13	0	0	0	1
Wadena	140	121	X	X	0	0	0	16	0	0	0	3
Total	5,525	757	429	383	0	176	0	3,571	44	X	6	159
CENTRAL HARDWOOD												
Chisago	3	3	0	0	0	0	0	0	0	0	0	0
Goodhue	X	X	0	0	0	0	0	0	0	0	0	0
Hennepin	1	0	0	0	0	0	0	0	0	0	0	1
Isanti	19	19	0	0	0	0	0	0	0	0	0	0
Kanabec	37	0	0	0	0	0	0	34	X	0	0	3
Mille Lacs	91	1	1	0	0	2	0	87	0	0	0	X
Morrison	56	3	0	0	0	0	0	53	0	0	0	0
Otter Tail	1	0	0	0	0	0	0	1	0	0	0	X
Pine	129	6	2	0	0	X	0	113	1	0	0	7
Ramsey	1	0	0	0	0	0	0	0	0	0	0	1
Sherburne	45	45	0	0	0	0	0	0	0	0	0	0
Todd	13	12	0	0	0	0	0	1	0	0	0	X
Total	396	89	3	0	0	2	0	289	1	0	0	12
PRAIRIE												
Polk	34	0	2	0	0	29	0	3	0	0	0	X
Total	34	0	2	0	0	29	0	3	0	0	0	X
State total	12,369	1,501	1,699	1,112	0	426	0	6,994	155	X	11	471

(Table 1 continued on next page)

(Table 1 continued)

WISCONSIN

Unit[1] and county	All species	Pine	Spruce	Balsam fir	Hemlock	Tamarack	Cedar	Aspen	Birch	Oak	Maple	Other hardwoods
NORTHEASTERN												
Florence	599	22	20	30	7	1	0	360	55	9	63	32
Forest	1,362	61	73	189	23	2	0	596	122	8	178	110
Langlade	853	28	21	46	3	3	0	405	66	8	184	89
Lincoln	906	37	9	32	6	2	X	362	63	14	177	204
Marinette	1,925	302	58	75	21	3	0	1,146	158	32	79	51
Menominee	423	28	0	X	149	0	0	167	3	3	42	31
Oconto	600	166	15	13	5	3	0	303	56	5	18	16
Oneida	1,612	158	57	184	31	3	0	685	229	43	152	70
Shawano	330	54	0	2	6	X	0	177	6	11	33	41
Vilas	863	92	22	82	8	1	X	389	152	22	70	25
Total	9,473	948	275	653	259	18	X	4,590	910	155	996	669
NORTHWESTERN												
Ashland	893	41	14	130	5	1	X	406	113	15	106	62
Barron	15	5	0	0	0	0	0	8	X	X	1	1
Bayfield	923	182	2	24	2	X	0	538	142	6	15	12
Burnett	401	192	0	X	0	0	0	201	3	1	3	1
Oouglas	968	426	1	4	0	1	0	493	36	1	4	2
Iron	592	15	4	28	6	1	0	176	51	10	149	152
Polk	12	6	0	0	0	0	0	6	X	X	X	X
Price	1,231	28	9	62	22	7	1	351	177	47	244	283
Rusk	423	3	0	2	5	1	0	184	66	22	82	58
Sawyer	861	34	5	66	12	X	0	417	110	15	127	75
Taylor	757	14	6	30	11	2	0	271	74	20	162	167
Washburn	451	186	2	5	0	0	0	212	22	3	16	5
Total	7,527	1,132	43	351	63	13	1	3,263	794	140	909	818
CENTRAL												
Adams	459	364	X	X	0	1	0	5	2	75	6	6
Chippewa	270	38	X	1	2	0	0	111	35	27	28	28
Clark	422	50	0	X	6	X	0	185	34	86	30	31
Eau Claire	121	54	X	0	0	0	0	27	6	16	10	8
Jackson	290	178	X	0	0	1	0	34	9	55	7	6
Juneau	303	184	0	0	0	0	0	19	10	68	14	8
Marathon	405	59	2	9	11	X	0	211	21	18	40	34
Marquette	85	36	0	0	0	X	0	1	4	30	8	6
Monroe	150	119	0	0	0	1	0	4	2	14	6	4
Portage	199	110	X	X	1	1	0	37	4	32	8	6
Waupaca	138	44	0	X	X	0	0	71	2	11	5	5
Waushara	134	125	0	0	0	0	0	1	1	4	2	1
Wood	370	132	3	0	X	0	0	142	14	55	10	14
Total	3,346	1,493	5	10	20	4	0	848	144	491	174	157
SOUTHWESTERN												
Buffalo	13	8	0	0	0	0	0	5	0	0	0	0
Crawford	17	0	0	0	0	0	0	2	1	9	2	3
Dunn	113	111	0	0	0	0	0	X	X	X	1	1
Grant	17	X	0	0	0	0	0	2	1	9	2	3
Iowa	X	X	0	0	0	0	0	X	0	0	0	0
La Crosse	10	10	0	0	0	0	0	0	0	0	0	0
Pepin	21	18	1	0	0	0	0	1	1	X	X	X
Pierce	3	3	X	0	0	0	0	X	X	0	X	X
Richland	X	X	0	0	0	0	0	0	0	0	0	0
St.Croix	1	0	0	0	0	0	0	1	0	0	0	0
Sauk	53	47	0	0	0	0	0	0	1	1	3	1
Trempealeau	24	24	0	0	0	0	0	X	X	0	X	X
Vernon	1	1	0	0	0	0	0	0	X	0	X	X
Total	273	222	1	0	0	0	0	11	4	19	8	8
SOUTHEASTERN												
Brown	10	5	0	0	0	0	0	5	X	0	X	0
Columbia	64	46	0	0	0	0	0	1	4	6	4	3
Oane	1	1	0	0	0	0	0	0	0	0	0	0
Door	X	X	0	0	0	0	0	0	0	0	0	0
Green	3	3	0	0	0	0	0	0	0	0	0	0
Green Lake	8	7	0	0	0	0	0	0	X	0	X	1
Outagamie	17	3	X	0	0	0	0	14	0	0	X	0
Waukesha	11	11	0	0	0	0	0	0	X	X	X	X
Winnebago	X	X	0	0	0	0	0	0	0	0	0	0
Total	114	76	X	0	0	0	0	20	4	6	4	4
State total	20,733	3,871	324	1,014	342	35	1	8,732	1,856	811	2,091	1,656

[1] Includes only those counties that supplied pulpwood in 1980.
[2] X=Less than 50 cords.

NORTH CENTRAL FOREST EXPERIMENT STATION 1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.

Research Note NC-287

1982

Pulpwood Production[1] in the Lake States by County, 1981

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Abstract.--Lake States pulpwood production fell to 5.60 million cords in 1981. Pulpwood production is shown by county and species group in Michigan, Minnesota, and Wisconsin.

KEY WORDS: Residue, Michigan, Minnesota, Wisconsin

Pulpwood production in the Lake States--Michigan, Minnesota, and Wisconsin--dipped to 5.60 million cords in 1981: Wisconsin produced 2.39 million cords, Michigan 1.84 million cords, and Minnesota 1.37 million cords.

Ninety percent came from roundwood (including chips from roundwood); the remainder came from mill residue, such as slabs, edgings, veneer cores, and chips from these materials. Production from softwood and hardwood residue by State was:

State	Softwood	Hardwood
	(Hundred standard cords, unpeeled)	
Michigan	146	1,515
Minnesota	387	615
Wisconsin	466	2,440

Major species harvested were aspen (2,419,000 cords), pine (803,000 cords), maple (421,000 cords), balsam fir (309,000 cords), and birch (275,000 cords).

Wisconsin imported 26 percent of its pulpwood requirements, including 419,000 cords from Michigan, 177,000 cords from Minnesota, 164,000 cords from other (primarily western) States, and 75,000 cords from Canada.

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[1] Includes logs, bolts, and wood residue used in manufacturing particleboard, waferboard, and oriented strand board.

Counties cutting more than 100,000 cords were Delta, Menominee, Iron, and Marquette in Michigan; Koochiching, St. Louis, Beltrami, and Itasca in Minnesota; and Marinette, Oneida, Forest, Bayfield, Douglas, Price, and Sawyer in Wisconsin. These 15 counties contributed 44 percent of the pulpwood produced from roundwood in the Lake States in 1981.

Table 1.--Lake States pulpwood production from roundwood by county and species, 1981

(In hundred standard cords, unpeeled)

MICHIGAN

Unit[1] and county	All species	Pine	Spruce	Balsam fir	Hemlock	Tamarack	Cedar	Aspen	Birch	Oak	Maple	Other hardwoods
E. UPPER PENINSULA												
Alger	447	41	12	41	38	1	10	45	52	7	111	89
Chippewa	344	102	30	53	25	5	1	42	23	2	32	29
Delta	1000	102	89	153	48	10	36	247	94	7	110	104
Luce	235	54	27	33	38	1	1	22	11	1	25	22
Mackinac	353	60	35	61	7	3	3	65	26	0	51	42
Menominee	1128	79	29	151	42	5	11	365	95	16	201	134
Schoolcraft	631	118	22	76	28	1	8	108	59	8	108	95
Total	4138	556	244	568	226	26	70	894	360	41	638	515
W. UPPER PENINSULA												
Baraga	408	33	8	22	25	4	1	119	39	2	104	51
Dickinson	668	24	17	63	13	4	4	339	50	4	85	65
Gogebic	273	4	4	12	5	0	0	124	26	X[2]	67	31
Houghton	262	48	10	26	21	10	0	67	23	1	40	16
Iron	1409	89	77	128	46	3	2	572	104	15	263	110
Keweenaw	4	X	3	1	X	0	0	0	X	0	X	X
Marquette	1451	256	67	167	43	11	36	300	159	13	235	164
Ontonagon	703	X	3	2	6	0	0	493	36	X	113	50
Total	5178	454	189	421	159	32	43	2014	437	35	907	487
N. LOWER PENINSULA												
Alcona	445	30	X	1	0	0	0	277	24	56	36	21
Alpena	271	3	2	2	0	0	0	172	12	35	30	15
Antrim	12	1	0	0	0	0	0	7	X	0	4	X
Arenac	19	0	0	0	0	0	0	9	1	0	7	2
Benzie	143	3	0	0	0	0	0	64	3	22	45	6
Charlevoix	69	0	0	0	0	0	0	42	9	1	14	3
Cheboygan	381	15	X	3	0	0	0	243	29	10	65	16
Clare	121	X	0	0	0	0	0	98	2	18	3	X
Crawford	272	194	0	7	0	0	0	50	1	8	11	1
Emmet	107	6	0	0	0	0	0	70	5	3	19	4
Gladwin	43	1	0	0	0	0	0	35	2	3	1	1
Grand Traverse	62	14	0	0	0	0	0	31	2	4	6	5
Iosco	192	80	0	0	0	0	0	58	6	20	19	9
Isabella	148	5	0	0	0	0	0	109	0	11	12	11
Kalkaska	103	19	0	0	0	0	0	58	3	9	12	2
Lake	395	113	0	0	0	0	0	118	4	118	37	5
Leelanau	10	7	0	0	0	0	0	3	X	X	0	0
Manistee	360	10	0	0	0	0	0	147	10	91	93	9
Mason	315	29	0	0	0	0	0	131	8	64	75	8
Mecosta	159	17	0	0	0	0	0	108	2	23	9	X
Midland	63	0	0	0	0	0	0	45	11	0	7	X
Missaukee	213	7	0	0	0	0	0	138	12	25	26	5
Montmorency	345	36	2	2	0	0	0	191	24	25	49	16
Newaygo	426	93	0	0	0	0	0	200	2	116	14	1
Oceana	182	59	0	0	0	0	0	64	2	41	13	3
Ogemaw	227	80	0	0	0	0	0	93	6	24	17	7
Osceola	231	3	0	0	0	0	0	154	8	54	10	2
Oscoda	498	153	1	7	2	0	0	242	13	38	30	12
Otsego	192	49	0	1	1	0	0	87	8	10	32	4
Presque Isle	399	24	10	23	X	0	0	238	38	5	38	23
Roscommon	187	34	0	4	0	0	0	109	6	26	5	3
Wexford	336	87	0	0	0	0	0	104	3	56	73	13
Total	6926	1172	15	50	3	0	0	3495	256	916	812	207
S. LOWER PENINSULA												
Allegan	125	11	0	0	0	0	0	25	0	72	13	4
Barry	25	8	0	0	0	0	0	11	X	5	1	X
Berrien	2	2	0	0	0	0	0	0	0	0	0	0
Calhoun	X	X	0	0	0	0	0	0	0	0	0	0
Cass	X	X	0	0	0	0	0	0	0	0	0	0
Clinton	X	0	0	0	0	0	0	X	0	0	0	0
Eaton	1	1	0	0	0	0	0	0	0	0	0	0
Kalamazoo	2	2	0	0	0	0	0	X	0	0	0	0
Kent	9	8	0	0	0	0	0	1	0	0	0	0
Montcalm	90	6	0	0	0	0	0	51	X	28	5	X
Muskegon	93	36	0	0	0	0	0	27	X	26	4	X
Ottawa	106	102	0	0	0	0	0	X	X	4	X	X
St.Joseph	1	1	0	0	0	0	0	0	0	0	0	0
Tuscola	2	1	0	0	0	0	0	1	0	0	0	0
Van Buren	15	3	0	0	0	0	0	3	0	4	5	0
Washtenaw	5	5	0	0	0	0	0	0	0	0	0	0
Total	476	186	0	0	0	0	0	119	X	139	28	4
State total	16718	2368	448	1039	388	58	113	6522	1053	1131	2385	1213

(Table 1 continued on next page)

(Table 1 continued)

MINNESOTA

Unit[1/] and county	All species	Pine	Spruce	Balsam fir	Hemlock	Tamarack	Cedar	Aspen	Birch	Oak	Maple	Other hardwoods
NORTHERN ASPEN-BIRCH												
Carlton	194	7	8	9	0	4	0	139	2	0	0	25
Cook	585	35	140.	203	0	0	0	200	1	0	0	6
Koochiching	2038	216	427	168	0	92	0	1031	6	0	3	95
Lake	600	72	135	50	0	3	0	297	38	0	0	5
St.Louis	2937	375	218	263	0	15	0	1850	40	0	1	175
Total	6354	705	928	693	0	114	0	3517	87	0	4	306
NORTHERN PINE												
Aitkin	460	7	4	9	0	22	0	370	2	0	0	46
Becker	35	20	0	0	0	0	0	14	0	0	0	1
Beltrami	1001	113	97	72	0	78	0	599	10	0	1	31
Cass	915	158	5	19	0	10	0	708	4	X	X	11
Clearwater	266	20	21	11	0	23	0	179	2	0	1	9
Crow Wing	151	67	0	0	0	0	0	84	X	0	X	X
Hubbard	562	32	8	7	0	5	0	486	2	0	0	22
Itasca	2132	102	72	194	0	30	0	1667	4	0	1	62
Lake of the Woods	227	56	105	4	0	5	0	53	0	0	0	4
Mahnomen	27	2	0	0	0	0	0	23	X	0	0	2
Roseau	72	21	31	X	0	3	0	15	0	0	0	2
Wadena	121	99	0	0	0	0	0	21	0	0	0	1
Total	5959	697	343	316	0	176	0	4219	24	X	3	191
CENTRAL HARDWOOD												
Chisago	3	3	0	0	0	0	0	0	0	0	0	0
Goodhue	X	X	0	0	0	0	0	0	0	0	0	0
Isanti	3	3	0	0	0	0	0	0	0	0	0	0
Kanabec	24	0	0	0	0	0	0	24	0	0	0	0
Mille Lacs	31	2	1	0	0	2	0	26	0	0	0	X
Morrison	92	2	X	0	0	0	0	90	0	0	0	0
Otter Tail	2	0	0	0	0	X	0	2	0	0	0	0
Pine	166	12	0	0	0	0	0	128	1	0	0	25
Scott	1	1	0	0	0	0	0	0	0	0	0	0
Sherburne	34	34	0	0	0	0	0	0	0	0	0	0
Todd	5	3	0	0	0	0	0	2	0	0	0	0
Wabasha	1	1	0	0	0	0	0	0	0	0	0	0
Total	362	61	1	0	0	2	0	272	1	0	0	25
PRAIRIE												
Cottonwood	1	1	0	0	0	0	0	0	0	0	0	0
Kandiyohi	1	1	0	0	0	0	0	0	0	0	0	0
Polk	12	0	1	0	0	7	0	4	0	0	0	0
Red Lake	1	1	0	0	0	0	0	0	0	0	0	0
Total	15	3	1	0	0	7	0	4	0	0	0	0
State total	12700	1466	1273	1009	0	299	0	8012	112	X	7	522

(Table 1 continued on next page)

(Table 1 continued)

WISCONSIN

Unit[1] and county	All species	Pine	Spruce	Balsam fir	Hemlock	Tamarack	Cedar	Aspen	Birch	Oak	Maple	Other hardwoods
NORTHEASTERN												
Florence	563	39	18	53	8	2	0	326	41	8	48	20
Forest	1281	67	72	227	22	1	0	499	114	16	173	90
Langlade	841	30	11	66	3	1	0	411	64	9	164	82
Lincoln	907	72	9	36	6	3	0	470	70	20	119	102
Marinette	1594	292	39	116	12	1	0	883	76	38	96	41
Menominee	512	33	X	0	163	0	0	209	9	9	53	36
Oconto	542	216	4	16	7	0	0	236	27	6	20	10
Oneida	1472	171	42	207	7	5	0	635	194	41	122	48
Shawano	278	71	0	1	5	X	0	120	8	9	32	32
Vilas	813	118	19	67	8	X	0	364	137	20	63	17
Total	8803	1109	214	789	241	13	0	4153	740	176	890	478
NORTHWESTERN												
Ashland	964	117	23	97	5	3	0	424	93	11	111	80
Barron	19	2	0	0	0	0	0	11	3	1	1	1
Bayfield	1361	209	2	12	4	1	0	842	127	12	75	77
Burnett	499	217	X	X	0	X	0	268	3	2	7	2
Douglas	1161	472	X	5	0	0	0	643	32	X	4	5
Iron	553	8	1	12	3	X	0	375	47	9	53	45
Polk	19	19	0	X	0	0	0	0	0	0	0	0
Price	1110	37	14	47	7	11	0	378	159	37	180	240
Rusk	657	10	0	X	2	1	0	352	79	38	100	75
Sawyer	1154	72	7	45	7	7	0	752	98	14	106	46
Taylor	656	22	3	22	10	3	0	308	63	14	113	98
Washburn	549	129	3	12	0	X	0	339	26	7	22	11
Total	8702	1314	53	252	38	26	0	4692	730	145	772	680
CENTRAL												
Adams	460	379	0	0	0	0	0	4	1	66	6	4
Chippewa	255	22	0	0	1	1	0	127	31	20	28	25
Clark	407	47	X	0	2	0	0	203	32	75	25	23
Eau Claire	189	129	X	0	0	0	0	24	4	21	7	4
Jackson	267	162	0	0	0	X	0	29	5	60	6	5
Juneau	306	205	0	0	0	0	0	17	5	64	10	5
Marathon	416	50	4	5	5	X	0	220	24	34	37	37
Marquette	69	41	0	0	0	X	0	4	2	15	5	2
Monroe	137	96	0	0	0	0	0	9	3	15	9	5
Portage	182	101	X	X	1	7	0	44	2	21	4	2
Waupaca	131	80	X	X	X	X	0	32	2	7	6	4
Waushara	135	134	0	0	0	0	0	X	0	1	X	0
Wood	188	56	1	0	0	X	0	81	5	32	6	7
Total	3142	1502	5	5	9	8	0	794	116	431	149	123
SOUTHWESTERN												
Buffalo	X	X	0	0	0	0	0	0	0	0	0	0
Crawford	15	0	0	0	0	0	0	2	1	7	2	3
Dunn	126	125	X	X	0	0	0	1	X	X	X	X
Grant	16	0	0	0	0	0	0	2	1	8	2	3
La Crosse	4	3	0	0	0	0	0	1	X	0	X	X
Pepin	2	2	X	0	0	0	0	0	0	X	0	0
Pierce	1	1	0	0	0	0	0	X	0	0	0	0
Sauk	60	51	0	0	0	0	0	0	1	4	3	1
Trempealeau	22	21	0	0	0	0	0	0	X	1	X	X
Vernon	1	1	0	0	0	0	0	0	0	0	0	0
Total	247	204	X	X	0	0	0	6	3	20	7	7
SOUTHEASTERN												
Brown	8	5	0	0	0	0	0	3	0	0	0	0
Columbia	61	43	0	0	0	0	0	1	2	8	3	4
Door	X	X	0	0	0	0	0	0	0	0	0	0
Green Lake	2	2	0	0	0	0	0	0	0	0	0	0
Kenosha	X	0	0	0	0	0	0	X	0	0	0	0
Kewaunee	X	X	0	0	0	0	0	0	0	0	0	0
Outagamie	3	1	0	0	0	0	0	2	0	0	0	0
Rock	X	0	0	0	0	0	0	0	0	0	X	X
Walworth	11	11	0	0	0	0	0	0	0	0	0	0
Waukesha	2	2	0	0	0	0	0	0	0	0	0	0
Total	87	64	0	0	0	0	0	6	2	8	3	4
State total	20981	4193	272	1046	288	47	0	9651	1591	780	1821	1292

[1] Includes only those counties that supplied pulpwood in 1981.

[2] X=Less than 50 cords.

NORTH CENTRAL FOREST EXPERIMENT STATION
Research Note NC-288
1992 FOLWELL AVE ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.
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TIMBER VOLUME IN NORTH DAKOTA COUNTIES, 1980

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ABSTRACT. — The second forest inventory of North Dakota shows growing-stock volume reaching 207 million cubic feet in 1980. Hardwoods make up more than 99 percent of this total.

KEY WORDS: Growing stock, sawtimber, softwoods, hardwoods.

North Dakota's 300,000 acres of commercial forest land supported 207 million cubic feet in growing-stock trees in 1980. Included in the total volume of growing stock are 510 million board feet of saw log material.

Additional volume in live rough, rotten, and short-log trees (nongrowing stock) is 89 million cubic feet.

Hardwoods make up more than 99 percent of the growing-stock volume North Dakota. Quaking aspen accounts for 29 percent of the total. More than 40 percent of the growing stock volume is in the elm-ash-cottonwood[1] forest type (bottomland hardwoods).

North Dakota is divided into East and West inventory units. Eighty-six percent of growing-stock volume is in the eastern unit.

The sampling error of volume for the survey was ± 8.17 percent for 207 million cubic feet of growing stock in the State.

The second forest inventory of North Dakota was conducted in 1978 and 1979 by the North Central Forest Experiment Station with cooperation from the North Dakota Forest Service. Aerial photography was provided by the North Dakota Office of the Agricultural Stabilization and Conservation Service.

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[1] *Forests in which elm, ash, or cottonwood, singly or in combination, comprise a plurality of the stocking. Common associates include willow, sycamore, and maple.*

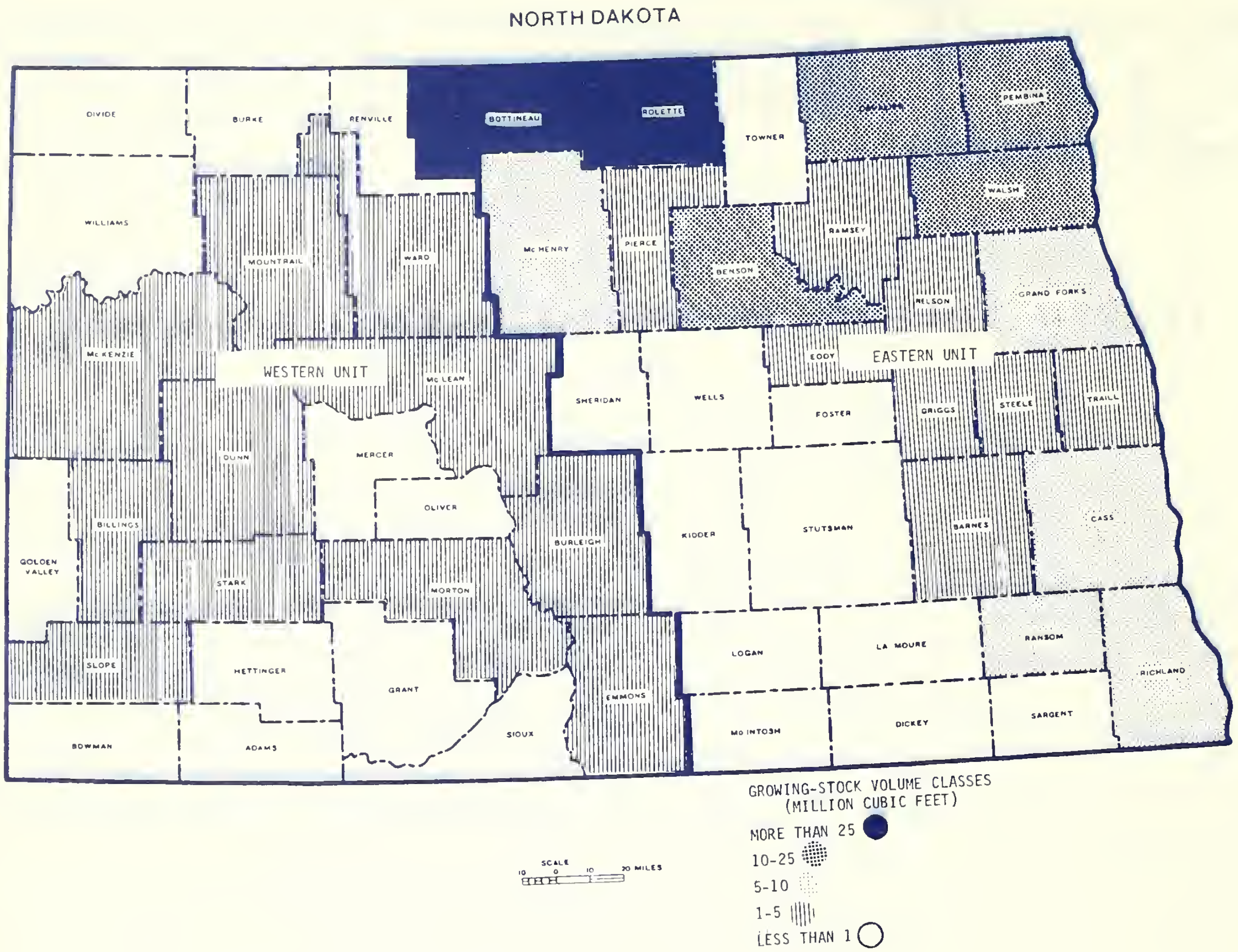

Figure 1. *Growing-stock volume in North Dakota counties, 1980.*

Table 1.--Net volume of growing stock and sawtimber on commercial forest land by county species category and Survey Unit, North Dakota, 1980

EAST UNIT

County	Growing stock[1]						Sawtimber[2]					
	All species	Softwoods	Elm	Ash	Aspen	Other hardwoods	All species	Softwoods	Elm	Ash	Aspen	Other hardwoods
	Thousand cubic feet						Thousand board feet[3]					
Barnes	2,350.5	--	741.2	487.0	61.7	1,060.6	9,300.0	--	3,230.2	1,649.3	68.5	4,132.0
Benson	14,633.4	--	1,522.4	1,371.5	6,898.4	4,841.1	20,536.9	--	7,068.2	3,107.4	2,168.3	6,173.0
Bottineau	26,990.0	--	866.5	2,482.0	15,467.0	8,172.5	31,368.4	--	2,674.9	2,040.3	14,624.7	11,828.5
Cass	5,382.5	--	1,538.2	1,241.2	166.9	2,436.2	20,510.0	--	6,651.2	4,430.1	138.6	9,290.1
Cavalier	23,471.3	--	4,087.0	4,392.5	5,966.3	9,025.5	64,482.2	--	17,262.5	12,875.2	6,041.6	28,302.9
Dickey	442.4	--	134.0	96.1	13.3	199.0	1,715.7	--	577.1	349.4	14.6	774.6
Eddy	2,011.6	--	461.2	440.5	209.9	900.0	6,694.2	--	2,114.2	1,600.8	53.4	2,925.8
Foster	143.4	--	36.7	39.1	5.6	62.0	542.3	--	159.3	135.1	1.4	246.5
Grand Forks	5,768.8	--	1,501.8	1,314.9	373.2	2,578.9	20,623.8	--	6,536.9	4,589.4	156.8	9,340.7
Griggs	1,777.9	--	499.7	432.4	60.9	784.9	6,815.9	--	2,158.7	1,530.9	39.4	3,086.9
Kidder	--	--	--	--	--	--	--	--	--	--	--	--
LaMoure	620.6	--	172.5	153.2	21.6	273.3	2,379.4	--	745.7	540.6	12.8	1,080.3
Logan	49.3	--	16.0	9.4	1.3	22.6	193.3	--	68.8	35.3	2.2	87.0
McHenry	6,601.0	--	2,180.0	1,990.4	315.9	4,114.7	30,769.1	--	9,651.0	7,026.7	155.3	13,936.1
McIntosh	100.4	--	32.7	19.1	2.6	46.0	393.9	--	140.2	71.9	4.4	177.4
Nelson	3,048.8	--	803.2	751.8	81.1	1,412.7	11,478.2	--	3,594.2	2,729.0	46.6	5,106.4
Pembina	13,180.6	--	2,219.1	2,160.7	2,432.1	6,368.7	31,310.8	--	9,682.3	6,345.5	534.6	14,748.4
Pierce	1,152.8	--	315.8	290.2	41.1	505.7	4,402.9	--	1,365.8	1,019.5	21.5	1,996.1
Ramsey	1,362.0	--	230.6	165.2	474.4	471.6	2,995.2	--	1,031.1	562.8	123.1	1,278.2
Ransom	6,958.3	--	1,818.1	1,585.9	366.7	3,187.6	24,917.4	--	7,672.4	5,597.2	139.1	11,308.7
Richland	6,102.1	--	1,594.6	1,546.4	181.1	2,760.0	22,997.1	--	7,085.0	5,538.9	67.3	10,285.9
Rolette	36,895.4	--	940.0	2,716.5	23,635.4	9,601.5	38,985.9	--	3,406.1	1,409.3	21,747.5	12,423.0
Sargent	400.0	--	130.2	76.1	10.4	163.3	1,569.3	--	556.8	286.6	17.6	706.3
Steele	1,332.5	--	413.8	277.4	36.3	603.0	5,187.9	--	1,779.6	1,019.6	40.8	2,339.9
Stutsman	936.8	--	295.0	190.1	26.2	425.5	3,655.5	--	1,267.9	703.5	36.3	1,647.8
Towner	50.1	--	16.3	9.5	1.3	23.0	196.4	--	69.9	55.9	2.2	66.4
Traill	3,366.3	--	1,015.3	736.4	102.4	1,512.2	13,044.8	--	4,371.9	2,673.5	108.6	5,890.8
Walsh	11,072.0	--	2,431.7	2,241.9	1,147.9	5,250.5	34,877.0	--	11,146.5	7,925.7	346.4	15,456.4
Wells	545.5	--	157.3	126.0	18.0	242.2	2,099.0	--	678.5	456.9	14.0	949.6
Unit total	176,746.3	--	26,172.9	27,367.4	58,121.0	67,065.0	414,042.5	--	113,148.9	76,486.3	46,797.6	177,609.7

WEST UNIT

County	Growing stock						Sawtimber					
	All species	Softwoods	Elm	Ash	Aspen	Other hardwoods	All species	Softwoods	Elm	Ash	Aspen	Other hardwoods
	Thousand cubic feet						Thousand board feet[3]					
Adams	13.7	--	--	0.6	0.8	12.3	29.3	--	--	2.0	1.8	25.5
Billings	1,680.9	--	56.9	221.2	73.4	1,329.4	6,145.0	--	235.8	399.0	48.5	5,461.7
Bowman	48.9	--	--	2.3	3.1	43.5	116.5	--	--	7.9	7.2	101.4
Burke	180.4	--	28.3	36.8	5.9	109.4	655.7	--	109.9	65.4	--	480.4
Burleigh	3,630.8	--	258.9	346.6	72.5	2,952.8	15,625.9	--	1,012.1	640.5	46.3	13,927.0
Divide	5.5	--	--	--	--	5.5	--	--	--	--	--	--
Dunn	4,544.0	151.0	139.7	389.5	1,023.1	2,840.7	9,960.3	281.0	645.3	716.0	433.3	7,884.7
Emmons	2,286.9	--	78.7	235.1	34.2	1,938.9	9,889.5	--	312.1	432.1	42.9	9,102.4
Golden Valley	268.8	--	30.6	39.9	9.1	189.2	798.5	--	123.3	74.8	7.2	593.2
Grant	301.8	--	4.0	14.2	19.2	264.4	754.3	--	27.4	49.2	44.6	632.9
Hettinger	27.2	--	--	1.1	1.5	24.6	58.3	--	--	4.0	3.6	50.7
McKenzie	1,801.1	157.5	61.4	587.4	157.4	837.4	4,688.6	293.0	245.2	1,017.6	16.4	3,114.2
McLean	2,628.4	--	269.3	357.1	73.0	1,929.0	10,409.6	--	1,057.7	657.2	42.5	6,652.2
Mercer	715.5	--	85.7	120.3	30.0	479.5	2,445.2	--	332.0	229.1	26.6	1,855.5
Morton	1,199.8	--	114.1	171.3	54.9	859.5	3,825.8	--	442.0	343.7	73.1	2,967.0
Mountrail	2,238.7	--	306.7	407.0	82.8	1,442.2	7,783.5	--	1,202.9	748.5	47.5	5,784.6
Oliver	455.1	--	12.6	30.7	26.9	384.9	1,184.1	--	56.1	85.7	56.2	962.1
Renville	174.6	--	19.5	27.6	7.2	120.3	569.5	--	75.5	53.0	7.3	433.7
Slope	1,487.4	1,385.7	9.6	12.5	2.0	77.6	2,801.0	2,578.5	37.3	22.2	--	163.0
Sheridan	25.6	--	0.8	1.1	1.5	22.2	63.4	--	5.5	3.9	3.6	50.4
Sioux	422.0	--	50.7	67.2	14.9	289.2	1,324.9	--	201.3	125.3	11.0	987.3
Stark	1,239.9	--	137.5	426.2	37.6	638.6	3,911.3	--	544.7	752.3	23.3	2,591.0
Ward	2,637.9	--	172.9	232.0	45.8	2,187.2	11,639.6	--	670.2	424.8	23.4	10,521.2
Williams	353.4	--	47.6	64.1	12.9	228.6	1,216.6	--	184.4	117.7	7.1	907.4
Unit total	28,368.3	1,694.2	1,885.5	3,791.8	1,789.7	19,207.1	95,896.4	3,152.5	7,522.7	6,972.1	979.6	77,269.5
All units	207,114.6	1,694.2	28,058.4	31,159.2	59,910.7	86,292.1	509,938.9	3,152.5	120,671.6	83,458.4	447,777.2	254,879.2

[1] The volume of sound wood in the bole of growing-stock trees 5.0 inches d.b.h. and larger, from a 1-foot stump to a minimum of 4.0 inch top diameter outside bark, or to the point where the central stem breaks into limbs. Growing stock volumes are shown in cubic feet.

[2] Net volume of the saw log portion of live sawtimber trees (softwoods 9.0 inches d.b.h. and larger and hardwoods 11.0 inches d.b.h. and larger) from stump to a minimum 7 inches top diameter outside bark for softwoods and 9 inches for hardwoods.

[3] International 1/4-inch rule.

Table 2.--Net volume of growing stock, sawtimber, short-log, and rough and rotten trees on commercial forest land by individual species, North Dakota, 1980

Species	Total all live	Growing[1] stock	Short[2] log	Rough and[3] rotten	[4] Sawtimber
	Thousand cubic feet				Thousand board feet[5]
SOFTWOODS:					
Ponderosa pine	1,792.3	1,694.2	--	98.1	3,152.5
Total	1,792.3	1,694.2	--	98.1	3,152.5
HARDWOODS:					
Boxelder	18,968.6	5,320.7	2,019.1	11,628.8	9,456.7
River birch	74.9	--	--	74.9	--
Paper birch	7,141.1	6,038.3	335.1	767.7	9,303.7
Hackberry	343.4	178.6	98.0	66.8	621.7
Black ash	932.6	118.8	--	813.8	--
Green ash	46,814.4	31,040.4	1,518.5	14,255.5	83,458.4
Balsam poplar	12,599.7	12,006.8	136.2	456.7	13,510.6
Eastern cottonwood	22,636.1	17,038.5	1,834.8	3,762.8	73,058.2
Plains cottonwood	7,399.1	6,359.4	637.6	402.1	32,729.4
Quaking aspen	76,658.4	59,910.7	489.8	16,257.9	47,777.2
Bur oak	39,935.6	29,229.6	1,749.7	8,956.3	66,082.6
American basswood	11,971.3	10,120.2	406.1	1,445.0	50,116.3
American elm	44,019.9	27,861.3	5,756.1	10,402.5	120,671.6
Slippery elm	197.1	197.1	--	--	--
Noncommercial species	4,618.8	--	--	4,618.8	--
Total	294,311.0	205,420.4	14,981.0	73,909.6	506,786.4
All species	296,103.3	207,114.6	14,981.0	74,007.7	509,938.9

[1] The volume of sound wood in the bole of growing-stock trees 5.0 inches d.b.h. and larger, from a 1-foot stump to a minimum of 4.0-inch top diameter outside bark, or to the point where the central stem breaks into limbs. Growing-stock volumes are shown in cubic feet.

[2] Any live sawtimber size tree of commercial species which has at least one 8-foot log, but less than a 12-foot log that meets minimum log grade specifications.

[3] Net volume of live trees 5.0 inches d.b.h. and larger that do not contain at least one merchantable 12-foot saw log or two noncontiguous 8-foot or longer saw logs, now or prospectively, because of roughness and poor form or because of rot (that is, when more than 50 percent of the cull volume of the tree is rotten).

[4] Net volume of the saw log portion of live sawtimber trees (softwoods 9.0 inches d.b.h. and larger and hardwoods 11.0 inches d.b.h. and larger) from stump to a minimum 7 inches top diameter outside bark for softwoods and 9 inches for hardwoods.

[5] International 1/4-inch rule.

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FOREST AREA IN MICHIGAN, 1980

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ABSTRACT.—In 1980 Michigan's forests covered 18.4 million acres, a decline of 5.2 percent from the 19.4 million acres reported in 1966. Commercial forest land dropped to 17.5 million acres.

KEY WORDS: Forest inventory, commercial forest land, noncommercial forest land.

One out of every 2 acres in Michigan is forested. These forested acres total 18.4 million acres in the State. Forest land covers more than four-fifths of the total land area in the Upper Peninsula, three-fifths of the land area in the northern half of Lower Michigan, but less than one-fifth of the land area in the southern half of the Lower Peninsula. Keweenaw County in the Western Upper Peninsula Unit is 97 percent forest, the most heavily forested county in the State (table 1).

Forest land Statewide declined one million acres or 5.2 percent between 1966 and 1980 inventories. A comparison of areas from the two inventories by geographical regions shows that the greatest reduction in forest area—almost 11 percent—occurred in the southern half of the Lower Peninsula (table 2).

Commercial forests (land suitable for growing crops of wood and not reserved from utilization) now occupy 17.5 million acres or 95 percent of Michigan's forest land. Since 1966, commercial forests have declined almost 1.4 million acres from 18.9 to 17.5 million acres a 7.3 percent reduction (table 3).

In looking at the State in sections, we can note the different rates of change in the commercial forest land base (table 3). As with total forest land, the greatest reduction occurred in the Southern Lower Michigan Unit where commercial timber land decreased by 12.4 percent. In the Upper Peninsula commercial forest land decreased by 8.4 percent. The Northern Lower Michigan Unit had the smallest decrease—3.7 percent or 260 thousand acres (table 3).

Only 5 percent or 879,000 acres of Michigan's forests are classified as noncommercial. Of this, 622,000 acres are productive forest land, but reserved for uses other than timber production such as parks and other reserved recreation areas. The remaining 257,000 acres are forest land too poor to grow timber crops. The 363,000-acre increase in noncommercial forest land between inventories is the result of additions to the productive reserved forest base (table 4). These additions primarily include National Lakeshore Areas, State Parks, State Sharptail Grouse Management Areas, and State Recreation Areas.

The sampling error for the 17.5 million acres of commercial forest area for this inventory was ±.33 percent.

This forest inventory was conducted by the North Central Forest Experiment Station. More intensified field sampling was made possible by additional funding and personnel provided by the Michigan Legislature through the State's Department of Natural Resources and by interested forest industry companies.

Table 1.—*Area of land and forest land by county, Michigan, 1980*

		Forest land[2]				
County	All land[1]	All forest	Non commercial[3]	Commercial[4]	Commercial forest as a percent of land area	All forest as a percent of land area
	Thousand acres				*Percent*	
EASTERN UPPER PENINSULA UNIT						
Alger	578.9	530.7	38.8	491.9	85	92
Chippewa	1,017.6	757.5	51.6	705.9	69	74
Delta	753.0	596.8	22.3	574.5	76	79
Luce	580.1	496.5	28.1	468.4	81	86
Mackinac	649.1	565.0	40.7	524.3	81	87
Menominee	664.3	496.2	2.8	493.4	74	75
Schoolcraft	56.0	588.9	45.7	543.2	72	78
Total	4,999.0	4,031.6	230.0	3,801.6	76	81
WESTERN UPPER PENINSULA UNIT						
Baraga	576.5	539.8	26.6	513.2	89	94
Dickinson	484.6	381.0	4.4	376.6	78	79
Gogebic	708.4	654.6	34.7	619.9	88	92
Houghton	650.9	533.7	20.0	513.7	79	82
Iron	749.5	664.7	10.7	654.0	87	89
Keweenaw	344.1	333.1	126.0	207.1	60	97
Marquette	1,170.4	1,026.9	56.5	970.4	83	88
Ontonagon	842.0	724.7	50.0	674.7	80	86
Total	5,526.4	4,858.5	328.9	4,529.6	82	88
NORTHERN LOWER PENINSULA UNIT						
Alcona	433.6	318.9	12.4	306.5	71	74
Alpena	361.3	222.6	4.9	217.7	60	62
Antrim	304.3	159.9	3.3	156.6	51	53
Arenac	235.2	94.4	1.7	92.7	39	40
Bay	286.2	20.1	2.3	17.8	6	7
Benzie	201.9	131.0	9.9	121.1	60	65
Charlevoix	265.1	139.1	0.5	138.6	52	52
Cheboygan	461.2	383.0	16.4	366.6	79	83
Clare	365.4	219.9	4.2	215.7	59	60
Crawford	359.3	304.8	31.9	272.9	76	85
Emmet	294.7	202.2	7.0	195.2	66	69
Gladwin	322.2	193.1	0.3	192.8	60	60
Grand Traverse	295.8	154.4	2.2	152.2	51	52
Iosco	347.9	231.9	7.3	224.6	65	67
Isabella	365.9	78.4	—	78.4	21	21
Kalkaska	362.0	275.3	22.0	253.3	70	76
Lake	365.3	300.0	0.2	299.8	82	82
Leelanau	220.5	94.1	18.3	75.8	34	43
Manistee	353.9	225.7	0.2	225.5	64	64
Mason	313.4	156.0	8.0	148.0	47	50
Mecosta	358.4	125.2	2.5	122.7	34	35
Midland	332.7	149.8	2.3	147.5	44	45
Missaukee	361.3	212.5	8.1	204.4	57	59
Montmorency	355.2	302.3	0.3	302.0	85	85
Newaygo	543.7	316.3	6.3	310.0	57	58
Oceana	343.2	160.0	11.7	148.3	43	47
Ogemaw	365.7	235.3	15.8	219.5	60	64
Osceola	371.8	158.5	1.7	156.8	42	43
Oscoda	360.2	309.9	2.7	307.2	85	86
Otsego	337.5	262.9	2.1	260.8	77	78
Presque Isle	414.6	277.6	10.7	266.9	64	67
Roscommon	333.4	252.8	6.1	246.7	74	76
Wexford	357.9	261.7	11.4	250.3	70	73
Total	11,350.7	6,929.6	234.7	6,694.9	59	61

(table 1 continued)

(Table 1 continued)

SOUTHERN LOWER PENINSULA UNIT

County	All land[1]	Forest land[2]			Commercial forest as a percent of land area	All forest as a percent of land area
		All forest	Non commercial[3]	Commercial[4]		
	Thousand acres				*Percent*	
Allegan	528.6	137.4	—	137.4	26	26
Barry	354.7	119.9	8.7	111.2	31	34
Berrien	371.0	67.3	1.2	66.1	18	18
Branch	323.8	44.1	—	44.1	14	14
Calhoun	453.9	76.6	0.5	76.1	17	17
Cass	314.0	54.0	—	54.0	17	17
Clinton	366.0	31.0	0.5	30.5	8	8
Eaton	365.5	45.5	—	45.5	12	12
Genesee	410.9	44.0	—	44.0	11	11
Gratiot	361.9	27.4	—	27.4	8	8
Hillsdale	384.3	45.6	0.6	45.0	12	12
Huron	524.2	57.4	1.3	56.1	11	11
Ingham	357.7	42.1	—	42.1	12	12
Ionia	367.8	38.6	1.4	37.2	10	10
Jackson	446.8	87.4	4.0	83.4	19	20
Kalamazoo	359.5	73.4	6.8	66.6	19	20
Kent	548.5	123.6	1.0	122.6	22	23
Lapeer	420.8	83.5	2.5	81.0	19	20
Lenawee	481.9	48.2	0.5	47.7	10	10
Livingston	366.0	78.1	9.0	69.1	19	21
Macomb	307.3	46.2	1.2	45.0	15	15
Monroe	356.5	35.2	0.1	35.1	10	10
Montcalm	455.9	145.3	—	145.3	32	32
Muskegon	320.9	165.8	1.2	164.6	51	52
Oakland	554.7	104.3	22.1	82.2	15	19
Ottawa	360.4	77.7	0.2	77.5	22	22
Saginaw	520.7	82.7	—	82.7	16	16
St. Clair	469.6	89.0	1.1	87.9	19	19
St. Joseph	323.6	59.9	—	59.9	19	19
Sanilac	615.0	50.2	0.1	50.1	8	8
Shiawassee	345.4	52.8	—	52.8	15	15
Tuscola	521.5	83.7	—	83.7	16	16
Van Buren	385.6	106.2	4.2	102.0	26	28
Washtenaw	454.7	82.8	10.8	72.0	16	18
Wayne	387.2	42.2	6.7	35.5	9	11
Total	14,486.8	2,549.1	85.7	2,463.4	17	18
State Total	36,362.9	18,368.8	879.3	17,489.5	48	51

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[1] 1970 Bureau of the Census estimates.

[2] Land at least 16.7 percent stocked by forest trees of any size, or formerly having such tree cover; excludes land currently developed for nonforest use such as urban or heavily settled residential or resort area, city parks, orchards, improved roads, or improved pasture land. The minimum forest area classified was 1 acre. Classified as forest were roadside, streamside, and shelterbelt strips of timber with a crown width of at least 120 feet and unimproved roads and trails, streams, and clearings in forested areas if less than 120 feet wide.

[3] Unproductive forest land incapable of yielding crops of industrial wood because of adverse site conditions, and productive public forest land withdrawn from commercial timber production through statute or administrative regulation.

[4] Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation.

Table 2.—*Area of forest land by forest survey unit for 1966 and 1980, Michigan*

Unit	Survey year 1966[1]	Survey year 1980	Change since 1966	Change since 1966
	Thousand acres			*Percent*
Eastern Upper Peninsula	4,281.3	4,031.6	-249.7	-5.8
Western Upper Peninsula	5,183.3	4,858.5	-324.8	-6.3
Northern Lower Peninsula	7,051.7	6,929.6	-122.1	-1.7
Southern Lower Peninsula	2,857.1	2,549.1	-308.0	-10.8
State total	19,373.4	18,368.8	-1,004.6	-5.2

[1] Figures have been adjusted from those published after the 1966 survey to conform to 1980 areas because of changes in survey procedure and definitions.

Table 3.—*Area of commercial forest land by forest survey unit for 1966 and 1980, Michigan*

Unit	Survey year 1966[1]	Survey year 1980	Change since 1966	Change since 1966
	Thousand acres			*Percent*
Eastern Upper Peninsula	4,169.1	3,801.6	-367.5	-8.8
Western Upper Peninsula	4,920.9	4,529.6	-391.3	-8.0
Northern Lower Peninsula	6,955.1	6,694.9	-260.2	-3.7
Southern Lower Peninsula	2,812.2	2,463.4	-348.8 -12.4	
State total	18,857.3	17,489.5	-1,367.8	-7.3

[1] Figures have been adjusted from those published after the 1966 survey to conform to 1980 areas because of changes in survey procedure and definitions.

Table 4.—*Area of noncommercial forest land by forest survey unit for 1966 and 1980, Michigan*

Unit	Survey year 1966[1]	Survey year 1980	Change since 1966	Change since 1966
	Thousand acres			*Percent*
Eastern Upper Peninsula	112.2	230.0	+117.8	+105.0
Western Upper Peninsula	262.4	328.9	+ 66.5	+ 25.3
Northern Lower Peninsula	96.6	234.7	+138.1	+143.0
Northern Lower Peninsula	44.9	85.7	+ 40.8	+ 90.9
State total	516.1	879.3	+363.2	+ 70.4

[1] Figures have been adjusted from those published after the 1966 survey to conform to 1980 areas because of changes in survey procedure and definitions.

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TIMBER VOLUME IN MICHIGAN, 1980

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ABSTRACT.—The fourth inventory of Michigan's forest resources shows a 27 percent increase in growing-stock volume between 1966 and 1980, from 15.0 to 19.1 billion cubic feet.

KEY WORDS: Timber resource, statistics, growing stock, sawtimber.

Volume of growing stock[1] on commercial forest land in Michigan increased from 15.0 billion cubic feet in 1966 to 19.1 billion cubic feet in 1980, a 27 percent gain:

Growing stock	Survey year [2]1966	1980
	(Million cubic feet)	
Softwoods	4,001	5,356
Hardwoods	11,049	13,748
Total	15,050	19,104

Softwood growing stock volume increased by 34 percent while hardwood volume grew by 24 percent.

These volume gains were made despite a 7.3 percent decline in commercial forest area. These increased volumes reflect an increase in average growing-stock volume per acre from 798 cubic feet per acre in 1966 to 1,092 cubic feet per acre in 1980.

Growing stock volume did not increase uniformly throughout the State (table 1). The largest total volume and greatest percent increase were in the Northern Lower Peninsula Unit, and the smallest percent gains were in the Eastern Upper Peninsula (fig. 1).

The hard maple species group, primarily sugar maple, is the most abundant species group in Michigan and accounts for more than 14 percent of the growing-stock volume. Its volume increased by 20 percent between surveys. Aspen, the second most plentiful species group in the State, makes up another 14 percent. The soft maple group, primarily red maple, is the third most abundant species in Michigan and showed a dramatic increase of 78 percent in growing-stock volume between inventories. As shown in the following tabulation other prominent species include the oak and pine groups:

Species group	Growing stock (Million cubic feet)
Hard maple	2,749
Aspen	2,617
Soft maple	2,253
Oak	2,019
Pine	1,886
Other hardwoods	4,110
Other softwoods	3,470
Total	19,104

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[1] *Net volume in cubic feet of growing stock trees 5 inches d.b.h. and larger from the stump to a variable 4-inch top diameter.*

[2] *Figures have been adjusted from those published after the 1966 survey to conform to 1980 volumes because of changes in survey procedure and definitions.*

Table 1.--Net volume of growing stock in 1966 and 1980 by Forest Inventory Unit and Change Since 1966, Michigan

Forest Inventory Unit	1966 Growing-stock volume	1980 Growing-stock volume	Change since 1966
	Million cubic feet		Percent
Eastern Upper Peninsula	3,403	4,035	+19
Western Upper Peninsula	4,757	5,785	+22
Northern Lower Peninsula	4,945	6,825	+38
Southern Lower Peninsula	1,945	2,459	+26
Total	15,050	19,104	+27

Included in the growing stock volume are 47.7 billion board feet of sawtimber.[3] As with growing stock, hard maple leads other species groups in volume. We then find a slightly different order from growing stock for the other prominent sawtimber species, with the oak group second, pine third, and aspen and soft maple rounding out the top five:

Species group	Sawtimber (Million board feet)[4]
Hard maple	6,998
Oak	6,626
Pine	5,798
Aspen	5,303
Soft maple	4,813
Other hardwoods	9,983
Other softwoods	8,148
Total	47,669

The major concentrations of timber are found in the Upper Peninsula:

Forest inventory unit	Growing-stock volume Softwoods	Growing-stock volume Hardwoods
	(Million cubic feet)	
Eastern Upper Peninsula	1,748	2,287
Western Upper Peninsula	1,729	4,056
Northern Lower Peninsula	1,707	5,118
Southern Lower Peninsula	172	2,287
Total	5,356	13,748

This area contains less than 30 percent of the State's land area but more than 50 percent of it's growing-stock volume. Marquette County, in the Upper Peninsula, has the most growing-stock and sawtimber volume of any county in the State (tables 2 and 3). Sugar maple and lowland conifers are well represented in this part of the State. The Northern Lower Peninsula Unit contains an additional 36 percent of the State's volume. This area contains more than 50

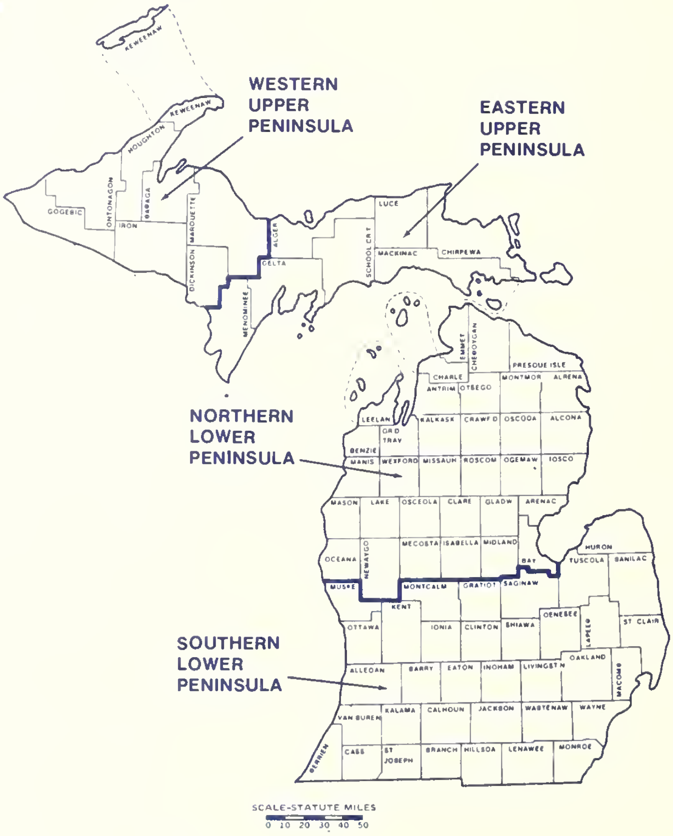

Figure 1.—*Michigan's four Forest Inventory Units.*

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[3] *Net volume of the saw log portion of live sawtimber trees (softwoods 9.0 inches d.b.h. or larger and hardwoods 11.0 inches d.b.h. and larger) from the stump to a point in the central stem at which utilization for sawn products is limited by large branches, forks, or other defects, or by a diameter outside bark 7.0 inches for softwoods and 9.0 inches for hardwoods.*

[4] *International -inch rule.*

percent of the pine growing-stock volume and 57 percent of the oak growing-stock volume in the State.

The sampling error was ± 0.7 percent for the 19.1 billion cubic feet of growing stock material in the State.

This forest inventory was conducted by the North Central Forest Experiment Station. More intensified field sampling was made possible by additional funding and personnel provided the North Central Station by the State Legislature through the Michigan Department of Natural Resources and by interested forest industry companies.

Table 2.--Net volume of growing stock on commercial forest land by species groups1/ and county, Michigan, 1980

(In thousand cubic feet)

		Softwoods				Hardwoods				
County	All Species	Pine	Spruce and balsam fir	Northern white cedar	Other softwoods	Oaks	Hard maple	Soft maple	Aspen	Other hardwoods
				EASTERN UPPER PENINSULA						
Alger	633,168	47,540	60,111	56,335	39,262	72	154,397	105,298	20,542	149,611
Chippewa	741,628	113,460	126,471	77,642	17,923	6,765	75,681	75,844	109,544	138,298
Delta	595,253	65,627	109,432	81,695	22,391	1,996	49,016	62,394	81,602	121,100
Luce	509,662	80,999	63,782	64,408	32,522	819	69,793	83,532	37,394	76,413
Mackinac	591,900	45,185	108,453	82,242	14,533	1,733	70,754	51,146	86,173	131,681
Menominee	458,744	20,569	40,986	102,783	25,122	10,594	66,268	28,540	54,172	109,710
Schoolcraft	504,389	85,819	69,661	67,743	25,588	86	50,509	70,699	40,979	93,305
Total	4,034,744	459,199	578,896	532,848	177,341	22,065	536,418	477,453	430,406	820,118
				WESTERN UPPER PENINSULA						
Baraga	719,048	21,646	82,015	43,425	62,996	3,190	209,963	112,115	46,468	137,230
Dickinson	383,517	14,604	64,692	40,428	6,425	4,423	58,492	13,579	71,733	109,141
Gogebic	763,990	20,404	97,623	40,629	53,263	6,710	199,816	60,607	96,173	188,765
Houghton	718,181	40,391	59,926	28,043	36,211	10,270	223,250	102,832	83,857	133,401
Iron	785,974	45,338	135,241	25,712	33,593	6,354	185,935	54,797	121,792	177,212
Keweenaw	292,375	14,254	40,931	49,271	671	17,007	62,350	38,908	19,423	49,560
Marquette	1,264,465	139,207	175,883	78,037	76,888	33,636	268,226	164,385	129,608	198,595
Ontonagon	857,481	36,354	93,327	24,504	46,737	4,255	196,678	81,286	178,447	195,893
Total	5,785,031	332,198	749,638	330,049	316,784	85,845	1,404,710	628,509	747,501	1,189,797
				NORTHERN LOWER PENINSULA						
Alcona	313,422	40,462	13,155	16,470	1,183	88,518	7,547	28,078	58,774	59,235
Alpena	229,438	14,294	24,206	30,438	1,662	22,000	2,760	22,506	68,328	43,244
Antrim	204,488	1,861	4,526	10,369	6,025	--	60,526	20,066	34,591	66,524
Arenac	98,882	6,685	1,853	2,299	2,306	10,970	677	15,710	34,975	23,407
Bay	19,562	--	--	--	--	427	--	3,835	5,967	9,333
Benzie	143,591	9,391	779	2,960	6,706	978	47,710	23,314	13,112	38,641
Charlevoix	223,281	10,563	10,741	25,800	3,249	2,808	51,006	10,929	24,654	83,531
Cheboygan	366,166	39,281	28,795	40,998	5,380	12,666	50,720	22,792	81,759	83,775
Clare	198,788	30,218	1,872	9,898	1,814	54,814	1,838	31,427	47,939	18,968
Crawford	229,246	74,347	4,405	6,567	1,342	79,073	10,422	12,344	27,287	13,459
Emmet	256,988	3,249	9,408	12,099	5,102	5,729	77,468	16,725	56,687	70,521
Gladwin	161,384	8,749	1,053	1,184	199	17,458	0	26,163	77,030	29,548
Grand Traverse	164,917	30,698	194	11,306	7,483	20,109	18,654	21,552	36,134	18,797
Iosco	225,748	71,316	7,241	20,134	4,286	28,405	1,464	29,020	32,988	30,894
Isabella	71,290	801	113	4,716	4,750	13,547	530	11,909	24,449	10,475
Kalkaska	190,384	42,266	7,065	8,259	3,292	15,685	38,195	19,439	21,527	34,656
Lake	303,726	78,986	279	12,703	5,811	124,947	3,949	21,004	34,902	21,145
Leelanau	112,604	4,655	395	4,698	2,198	3,315	43,409	2,814	2,390	48,730
Manistee	244,928	32,801	363	6,884	3,340	49,935	41,325	49,949	21,847	38,484
Mason	152,245	18,830	278	4,153	4,634	49,681	6,870	24,836	29,207	13,756
Mecosta	104,234	8,326	938	5,043	3,230	11,495	6,226	12,095	33,967	22,914
Midland	135,485	8,308	--	--	1,234	21,020	211	29,714	48,921	26,077
Missaukee	185,718	16,998	4,046	10,824	4,355	26,936	19,964	32,510	40,245	29,840
Montmorency	229,593	37,289	9,494	14,493	4,604	39,815	18,556	24,287	40,390	40,665
Newaygo	326,936	56,204	358	5,210	7,099	129,375	8,743	49,776	33,858	36,313
Oceana	147,241	13,121	502	3,757	5,806	42,411	6,902	28,501	17,263	28,978
Ogemaw	226,851	22,487	4,600	14,254	404	47,173	5,415	23,790	69,022	39,706
Osceola	196,236	3,963	3,079	17,433	8,845	18,767	29,220	26,357	44,246	44,326
Oscoda	248,446	85,215	5,362	7,553	226	61,780	6,524	13,184	47,587	21,015
Otsego	286,118	41,242	11,361	12,226	1,922	12,777	78,851	18,681	35,522	73,536
Presque Isle	253,992	25,630	22,707	61,444	3,943	17,082	9,654	11,638	51,464	50,430
Roscommon	305,689	51,511	8,558	32,523	1,292	96,221	1,442	31,818	56,411	25,913
Wexford	267,049	75,429	2,860	14,421	6,461	26,890	36,206	31,592	31,139	42,051
Total	6,824,666	965,176	190,576	431,116	120,183	1,152,807	692,984	748,355	1,284,582	1,238,887

(Table 2 continued on next page)

(Table 2 continued)

SOUTHERN LOWER PENINSULA

		Softwoods				Hardwoods				
County	All Species	Pine	Spruce and balsam fir	Northern white cedar	Other softwoods	Oaks	Hard maple	Soft maple	Aspen	Other hardwoods
Allegan	160,301	27,845	--	--	5,245	56,637	1,542	21,681	6,970	40,381
Barry	147,582	3,697	1,082	--	1,009	60,818	17,838	21,122	2,539	39,477
Berrien	84,356	--	--	--	--	10,467	12,285	10,411	1,507	49,686
Branch	55,938	--	--	--	188	9,803	1,329	22,115	1,327	21,176
Calhoun	85,534	1,142	--	--	679	13,569	1,143	17,244	2,036	49,721
Cass	68,751	--	--	--	1,138	10,587	1,665	17,254	1,310	36,797
Clinton	19,817	--	--	--	--	4,507	538	5,533	1,009	8,230
Eaton	41,076	--	--	--	389	3,858	4,601	5,318	414	26,496
Genesee	37,485	--	--	--	--	10,648	4,558	7,753	886	13,640
Gratiot	29,548	1,168	--	--	--	11,819	1,190	7,814	2,247	5,310
Hillsdale	19,791	--	--	--	--	2,246	5,088	1,657	0	10,800
Huron	37,011	--	--	--	233	--	--	1,921	12,350	22,507
Ingham	44,819	135	166	--	--	8,636	3,378	4,774	3,810	23,920
Ionia	26,429	--	--	--	267	6,761	1,249	3,353	2,522	12,277
Jackson	95,732	--	--	--	205	43,985	--	6,930	3,619	40,993
Kalamazoo	47,733	5,412	256	--	5,966	8,737	308	7,611	3,483	15,960
Kent	117,307	1,375	--	--	1,043	50,336	9,246	24,980	5,924	24,403
Lapeer	64,384	2,637	185	--	206	19,783	6,901	11,551	3,315	19,806
Lenawee	44,036	--	--	--	--	8,229	6,598	5,462	1,691	22,056
Livingston	71,575	4,290	--	--	2,479	38,829	--	10,413	1,639	13,925
Macomb	26,901	--	--	662	810	970	3,560	11,309	189	9,401
Monroe	45,275	--	--	--	--	18,170	1,919	4,325	0	20,861
Montcalm	147,371	16,691	--	161	2,246	52,569	1,499	24,139	18,177	31,889
Muskegon	160,911	36,428	--	21	3,501	71,253	662	24,178	13,447	11,421
Oakland	62,889	730	--	--	--	31,024	827	6,571	2,592	21,145
Ottawa	93,034	12,384	--	--	8,220	22,358	3,544	21,360	1,594	23,574
Saginaw	60,154	1,222	--	--	142	21,155	2,739	8,129	8,045	18,722
St. Clair	91,786	7,713	--	--	1,236	27,420	5,114	7,622	3,654	39,027
St. Joseph	74,003	322	214	--	169	19,696	973	10,666	8,332	33,631
Sanilac	21,859	--	--	--	--	542	--	1,758	8,775	10,784
Shiawassee	72,960	--	--	--	--	23,823	2,543	12,426	2,724	31,444
Tuscola	77,239	1,012	--	3,085	330	4,294	5,406	19,149	23,076	20,887
Van Buren	99,113	4,801	--	--	261	22,177	5,117	19,675	2,778	44,304
Washtenaw	83,489	--	--	--	797	41,533	996	7,068	1,911	31,184
Wayne	43,170	--	--	--	--	20,906	304	5,163	1,011	15,786
Total	2,459,359	129,004	1,903	3,929	36,759	758,145	114,660	398,435	154,903	861,621
State Total	19,103,800	1,885,577	1,521,013	1,297,942	651,067	2,018,862	2,748,772	2,252,752	2,617,392	4,110,423

[1] Species groups: other softwoods - primarily hemlock and tamarack; hard maple - sugar maple and black maple; soft maple - red maple and silver maple; other hardwoods - primarily hickory, yellow birch, beech, ash, balsam poplar, cottonwood, basswood, black walnut, black cherry, butternut, elm, and paper birch.

Table 3.--Net volume of sawtimber on commercial forest land by species groups[1] and county, Michigan, 1980

(In thousand board feet)[2]

County	All Species	Softwoods					Hardwoods			
		Pine	Spruce and balsam fir	Northern white-cedar	Other softwoods	Oaks	Hard maple	Soft maple	Aspen	Other hardwoods
EASTERN UPPER PENINSULA										
Alger	1,888,985	171,606	121,978	153,667	201,655	--	452,443	234,842	47,845	504,949
Chippewa	1,659,894	281,372	224,959	158,395	75,491	22,147	162,544	166,851	223,007	345,128
Delta	1,134,546	182,729	192,669	113,780	85,011	8,531	116,505	76,781	108,284	250,256
Luce	1,466,285	307,316	105,318	177,581	148,731	546	223,358	194,900	75,217	233,318
Mackinac	1,240,067	159,628	210,043	132,121	53,326	2,236	177,115	85,204	148,235	272,159
Menominee	833,200	93,829	56,996	150,605	64,384	32,908	109,642	47,813	75,277	201,746
Schoolcraft	1,172,230	297,223	108,744	110,131	101,337	--	124,729	140,652	72,584	216,830
Total	9,395,207	1,493,703	1,020,707	996,280	729,935	66,368	1,366,336	947,043	750,449	2,024,386
WESTERN UPPER PENINSULA										
Baraga	2,253,770	89,154	170,599	163,114	320,593	9,741	700,785	264,384	124,313	411,087
Dickinson	698,953	62,812	103,940	69,513	10,092	18,140	67,583	12,024	123,693	231,156
Gogebic	1,926,524	57,673	190,692	136,366	254,132	20,201	535,635	108,544	202,912	420,369
Houghton	1,995,226	135,297	131,417	101,157	176,776	41,763	664,036	198,769	221,092	324,919
Iron	1,957,638	193,451	278,680	77,832	146,210	20,918	499,633	115,743	251,532	373,639
Keweenaw	830,853	73,835	97,469	155,233	2,570	70,995	171,170	87,305	46,280	125,996
Marquette	3,406,308	601,269	326,287	204,497	366,886	105,533	781,680	266,336	265,560	488,260
Ontonagon	2,176,940	123,108	210,503	86,665	228,793	14,933	589,364	115,604	367,393	440,577
Total	15,246,212	1,336,599	1,509,587	994,377	1,506,052	302,224	4,009,886	1,168,709	1,602,775	2,816,003
NORTHERN LOWER PENINSULA										
Alcona	727,582	142,193	29,762	30,900	5,833	204,917	11,070	55,391	122,631	124,885
Alpena	492,107	57,617	52,600	57,222	4,459	51,746	3,921	45,207	155,184	64,151
Antrim	377,697	8,477	10,577	26,988	21,314	--	88,241	36,428	70,692	114,980
Arenac	199,998	17,707	--	691	2,507	29,977	--	28,175	70,913	50,028
Bay	46,778	--	--	--	--	1,845	--	10,030	14,286	20,617
Benzie	328,817	1,255	--	7,372	19,521	3,756	94,680	44,233	29,987	128,013
Charlevoix	508,496	41,698	19,850	30,721	9,373	11,494	97,973	19,884	87,645	189,858
Cheboygan	732,066	130,777	57,050	60,703	17,418	33,773	48,252	24,600	191,647	167,846
Clare	471,667	67,713	1,453	12,365	5,677	189,492	7,863	49,525	104,096	33,483
Crawford	413,157	195,389	3,834	2,834	6,727	131,191	7,858	4,482	31,319	29,523
Emmet	540,251	8,732	14,337	11,168	14,947	22,032	101,823	16,063	173,728	177,421
Gladwin	329,985	38,721	2,287	2,029	1,074	41,230	--	23,532	180,268	40,844
Grand Traverse	402,688	72,564	--	15,929	17,073	64,670	48,298	49,256	86,919	47,979
Iosco	488,497	170,730	14,932	31,517	20,107	47,785	4,944	61,470	71,113	65,899
Isabella	164,022	2,347	--	3,784	10,434	59,425	1,993	33,275	35,575	17,189
Kalkaska	368,373	112,243	9,748	14,438	6,400	43,997	52,453	23,615	37,899	67,580
Lake	677,970	161,110	--	10,070	6,061	354,939	6,484	26,172	64,503	48,631
Leelanau	334,699	12,647	--	5,051	8,263	15,594	94,814	12,742	7,168	178,420
Manistee	678,216	58,298	--	10,023	8,217	155,141	133,061	156,115	40,566	116,795
Mason	371,064	36,983	--	8,681	8,105	151,874	21,550	74,479	38,601	30,791
Mecosta	255,640	28,469	--	6,551	11,817	47,043	26,285	24,648	76,658	34,169
Midland	317,391	35,636	--	--	5,598	73,929	--	81,598	72,906	47,724
Missaukee	408,816	55,450	6,506	24,512	5,700	103,854	28,855	59,171	66,033	58,735
Montmorency	456,718	111,503	16,412	14,613	5,944	102,817	20,445	21,866	90,239	72,879
Newaygo	869,882	119,322	--	9,388	15,277	412,525	21,731	139,175	53,951	98,513
Oceana	384,521	29,661	--	4,040	13,835	147,203	15,787	76,242	29,552	68,201
Ogemaw	402,505	47,198	5,572	17,659	1,223	88,262	3,256	38,680	141,617	59,038
Osceola	562,103	14,854	3,774	34,045	37,301	63,417	79,125	56,062	147,669	125,856
Oscoda	563,867	242,294	8,969	14,690	749	155,227	6,518	16,373	78,714	40,333
Otsego	564,076	140,038	15,044	18,541	10,378	41,845	89,465	23,082	67,062	158,621
Presque Isle	451,144	77,895	35,563	99,105	8,149	38,859	12,363	13,502	89,192	76,516
Roscommon	680,326	195,916	6,135	51,881	1,967	220,516	--	43,345	124,846	35,720
Wexford	511,063	114,529	1,067	15,695	9,330	109,610	59,467	61,654	52,297	87,414
Total	15,082,182	2,549,966	315,472	653,206	320,778	3,219,985	1,188,575	1,450,072	2,705,476	2,678,652

(Table 3 continued on next page)

(Table 3 continued)

SOUTHERN LOWER PENINSULA

		Softwoods					Hardwoods			
County	All Species	Pine	Spruce and balsam fir	Northern white-cedar	Other softwoods	Oaks	Hard maple	Soft maple	Aspen	Other hardwoods
Allegan	492,180	71,134	--	--	4,995	195,853	6,499	78,264	10,011	125,424
Barry	537,729	9,830	538	--	2,175	264,323	79,424	65,286	1,891	114,262
Berrien	275,389	--	--	--	--	35,117	32,882	24,298	1,642	181,450
Branch	181,734	--	--	--	872	44,207	3,160	76,340	3,163	53,992
Calhoun	305,140	1,547	--	--	1,522	69,475	3,129	55,811	3,680	169,976
Cass	236,371	--	--	--	--	49,622	6,470	73,364	--	106,915
Clinton	50,482	--	--	--	--	16,550	1,133	14,242	1,611	16,946
Eaton	109,286	--	--	--	--	15,065	13,264	22,617	2,601	55,739
Genesee	131,120	--	--	--	--	43,238	23,107	34,137	--	30,638
Gratiot	103,047	2,707	--	--	--	38,753	4,106	33,015	4,938	19,528
Hillsdale	70,940	--	--	--	--	11,837	26,994	3,665	--	28,444
Huron	86,377	--	--	--	--	--	--	1,893	20,950	63,534
Ingham	149,933	660	--	--	--	36,616	16,107	15,669	13,493	67,388
Ionia	90,927	--	--	--	--	35,127	3,557	11,983	3,894	36,366
Jackson	339,305	--	--	--	--	199,038	--	28,562	11,238	100,467
Kalamazoo	149,446	22,306	--	--	12,243	37,892	--	27,789	7,605	41,611
Kent	312,539	6,011	--	--	1,070	165,445	35,213	49,936	--	54,864
Lapeer	175,221	950	708	--	--	74,567	20,877	37,123	1,403	39,593
Lenawee	158,283	--	--	--	--	42,055	28,687	11,064	6,305	70,172
Livingston	266,465	10,032	--	--	8,070	172,238	--	32,138	4,227	39,760
Macomb	97,340	--	--	--	3,799	2,828	16,422	39,432	--	34,859
Monroe	167,546	--	--	--	--	82,093	12,271	22,239	--	50,943
Montcalm	392,071	55,673	--	212	5,166	167,569	1,595	58,336	29,508	74,012
Muskegon	476,093	132,499	--	26	19,116	212,241	4	71,006	21,253	19,948
Oakland	251,416	2,605	--	--	--	148,702	3,061	28,203	--	68,845
Ottawa	321,864	32,461	--	--	30,273	79,066	13,198	70,418	--	96,448
Saginaw	148,425	6,564	--	--	--	78,557	13,258	17,463	6,654	25,929
St. Clair	313,859	41,363	--	--	2,914	101,224	14,148	27,726	1,351	125,133
St. Joseph	283,981	1,730	--	--	--	94,407	--	42,052	24,724	121,068
Sanilac	41,492	--	--	--	--	1,244	--	6,703	14,555	18,990
Shiawassee	250,082	--	--	--	--	92,834	7,722	45,559	10,594	93,373
Tuscola	178,462	6,152	--	4,461	--	20,276	17,186	49,535	32,672	48,180
Van Buren	293,169	13,485	--	--	--	86,559	24,205	43,387	2,022	123,511
Washtenaw	341,725	--	--	--	2,988	220,826	3,723	18,544	1,762	93,882
Wayne	166,096	--	--	--	--	101,604	1,663	9,602	957	52,270
Total	7,945,535	417,709	1,246	4,699	95,203	3,037,048	433,065	1,247,401	244,704	2,464,460
State Total	47,669,136	5,797,977	2,847,012	2,648,562	2,651,968	6,625,625	6,997,862	4,813,225	5,303,404	9,983,501

[1] Species groups: other softwoods - primarily hemlock and tamarack; hard maple - sugar maple and black maple; soft maple - red maple and silver maple; other hardwoods - primarily hickory, yellow birch, beech, ash, balsam poplar, cottonwood, basswood, black walnut, black cherry, butternut, elm, and paper birch.

[2] International 1/4-inch rule.

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FOREST AREA IN EASTERN SOUTH DAKOTA, 1980[1]

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ABSTRACT.—In 1980 eastern South Dakota's forest resources covered 266,300 acres of land, a slight decline from the 296,600 acres reported in 1965. The area of commercial forest land also dropped from 165,400 acres to 113,600 acres. The elm-ash-locust forest type covers 40 percent of the commercial forest area.

KEY WORDS: Commercial forest land, productive-reserved, unproductive, wooded strips, shelterbelts, nonforest with trees, forest type, land use.

One out of every 157 acres in South Dakota east of the 103rd meridian is forested—a total of 266,300 acres.[2] Most of the forest area is along the Grand, Missouri, Belle Fourche, Big Sioux, Cheyenne, and Big White Rivers. An area of 113,600 acres, 43 percent of the total forest area, is suitable for producing timber crops and is classified as commercial forest land.[3] The elm-ash forest type is most prevalent, growing on 40 percent (45,400 acres) of the commercial forest area. The ponderosa pine forest type covers an additional 16 percent or 17,800 acres:

Forest type	Area 1965	Area 1980
	(Acres)	
Ponderosa pine	24,100	17,800
Oak	7,400	4,500
Elm-ash	62,100	45,400
Cottonwood	42,000	18,500
Plains hardwoods	22,000	13,000
Nonstocked	7,800	14,400
Total	165,400	113,600

The most heavily forested county in eastern South Dakota is Shannon County, which has 20,100 acres of commercial forest—1.5 percent of the land area (Table 1).

Forest land declined in eastern South Dakota by 24,300 acres or 8 percent between 1965 and 1980. Commercial forest land decreased 31 percent during the same period.

Land use	1965	1980	Change since 1965
	(Thousand acres)		(Percent)
Forest			
Commercial	165.4	113.6	−31
Noncommercial			
Unproductive	125.2	147.4	+18
Productive-reserved	—	5.3	—
Total forest	290.6	266.3	− 8
Nonforest	41,712.5	41,441.9	− 1
Total land	42,003.1	41,708.2	− 1

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[1] *This report covers the area east of the 103rd meridian. Western South Dakota will be inventoried by the Intermountain Forest and Range Experiment Station.*

[2] *The sampling error for eastern South Dakota's commercial forest area was ± 12.8 percent per million acres of commercial forest land, or ± 38 percent for the entire Unit area of 113,600 acres.*

[3] Commercial Forest Land.—*Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation.*

Published 1965 areas have been adjusted to align the estimates more closely with definitions of land classification and procedures used in the 1980 survey.

Noncommercial forest land totaled 152,700 acres in 1980. The productive-reserved[4] area increased from none in 1965 to 5,300 acres in 1980. This land is located in the Badlands National Monument in Pennington and Shannon Counties. The remaining area of noncommercial forest land is unproductive forest land, too poor to grow timber crops. The unproductive forest land is concentrated in the Badlands area.

Not included in the forest land area, but an important resource in eastern South Dakota are the 287,800 acres of natural and planted wooded strips and shelterbelts. This area includes windbreaks around farm buildings and other structures.

This information on forest land wooded strips, and shelberbelts is part of the results of the third eastern South Dakota forest, made by the North Central Forest Experiment Station during 1979-1980. Other publications giving further details will be available soon.

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[4] *Land sufficiently productive to qualify as commercial forest land but withdrawn from timber utilization through statute or administrative designation, or through exclusive use for Christmas tree production as indicated by annual shearing.*

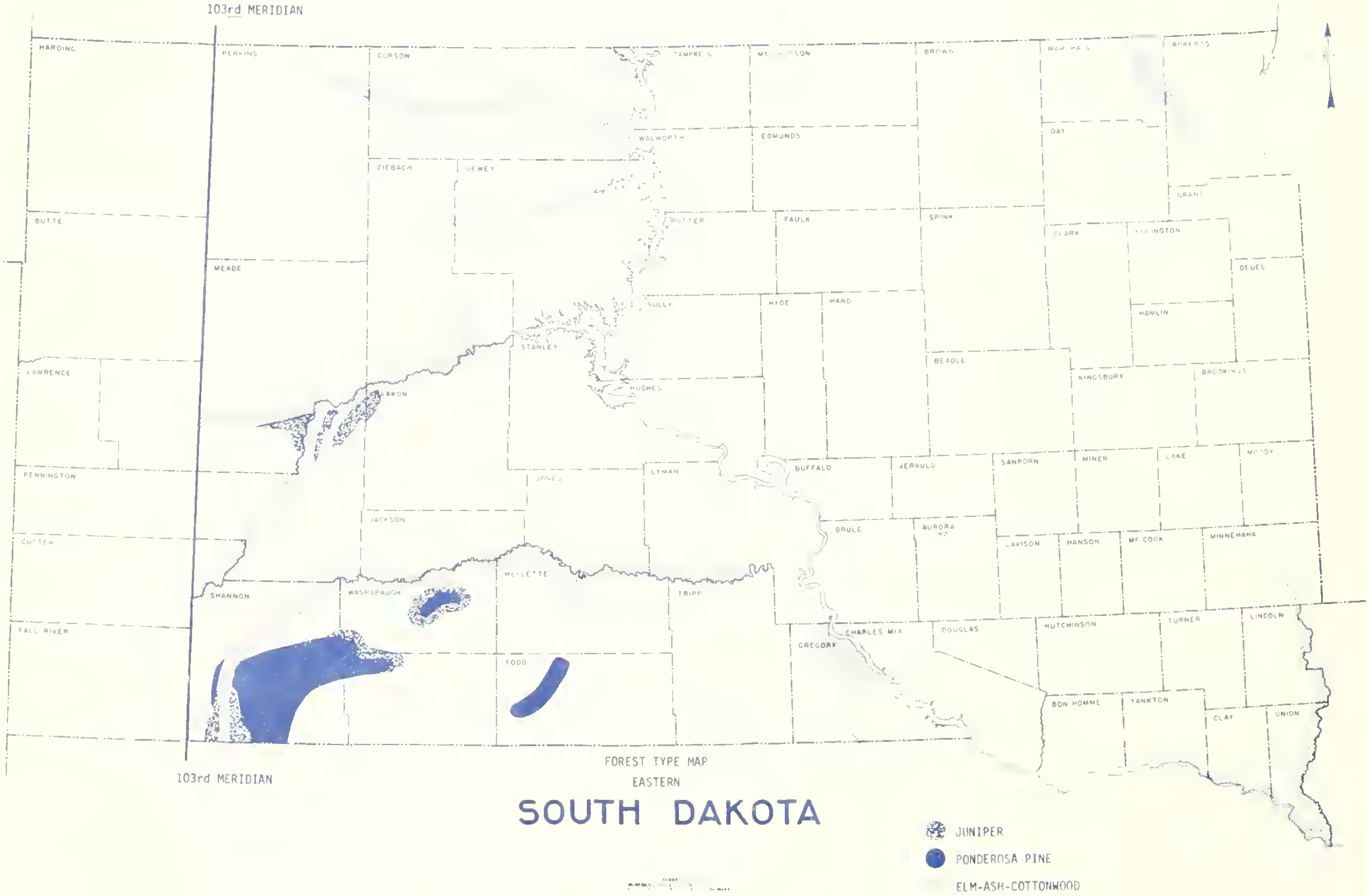

Figure 1. —*Forest area in eastern South Dakota.*

Table 1.--Area of land, forest land, and nonforest land with trees, by county, eastern South Dakota, 1980

County	All[1] land	Forest land[2]				Nonforest land with trees[6]		
		All forest	Productive reserved[3]	Unproductive[4]	Commercial[5]	All nonforest with trees	Wooded strips[7] and shelterbelts[8]	Other nonforest with trees[9]
	----------Thousand acres----------					----------Thousand acres----------		
Aurora	452.3	0.8	--	0.5	0.3	9.6	4.9	4.7
Beadle	805.5	2.5	--	1.4	1.1	6.8	4.7	2.1
Bennet	756.3	5.9	--	3.7	2.2	19.4	6.4	13.0
Bon Homme	353.3	6.4	--	2.9	3.5	10.3	5.4	4.9
Brookings	509.0	2.6	--	1.2	1.4	6.8	3.9	2.9
Brown	1,102.1	4.9	--	2.3	2.6	15.0	8.6	6.4
Brule	521.4	1.4	--	0.8	0.6	13.5	6.3	7.2
Buffalo	304.3	1.1	--	0.6	0.5	3.6	1.8	1.8
Campbell	468.2	0.3	--	0.2	0.1	3.9	3.8	0.1
Charles Mix	697.5	7.4	--	3.5	3.9	22.5	11.5	11.0
Clark	609.7	0.9	--	0.5	0.4	4.6	2.5	2.1
Clay	261.5	1.2	--	0.5	0.7	3.0	1.7	1.3
Codington	444.5	1.9	--	0.8	1.1	1.4	0.9	0.5
Corson	1,578.7	7.9	--	3.4	4.5	16.8	8.9	7.9
Custer[10]	113.3	0.9	--	0.4	0.5	1.3	0.8	0.5
Davison	278.9	1.1	--	0.5	0.6	4.3	2.5	1.8
Day	654.0	2.8	--	1.2	1.6	1.7	1.0	0.7
Deuel	403.8	1.1	--	0.5	0.6	1.6	1.0	0.6
Dewey	1,478.2	3.9	--	1.9	2.0	10.6	5.5	5.1
Douglas	277.6	0.1	--	0.1	--	1.8	0.9	0.9
Edmunds	735.6	--	--	--	--	--	--	--
Faulk	642.3	--	--	--	--	--	--	--
Grant	436.1	3.8	--	1.6	2.2	14.2	7.4	6.8
Gregory	648.6	20.5	--	13.5	7.0	40.8	20.9	19.9
Haakon	1,166.4	4.3	--	2.2	2.1	21.6	8.1	13.5
Hamlin	327.9	1.3	--	0.6	0.7	3.3	1.9	1.4
Hand	919.4	0.3	--	0.2	0.1	7.1	3.7	3.4
Hanson	277.4	0.6	--	0.3	0.3	2.5	1.3	1.2
Hughes	484.2	1.2	--	0.6	0.6	6.8	3.7	3.1
Hutchinson	522.1	1.4	--	0.7	0.7	8.6	4.6	4.0
Hyde	550.5	--	--	--	--	--	--	--
Jackson	519.2	1.2	--	0.7	0.5	4.0	1.9	2.1
Jerauld	339.3	0.6	--	0.3	0.3	2.2	1.2	1.0
Jones	621.5	2.1	--	1.2	0.9	9.1	4.4	4.7
Kingsbury	527.2	1.5	--	0.8	0.7	8.6	4.6	4.0
Lake	358.3	1.1	--	0.6	0.5	6.4	2.8	3.6
Lincoln	369.8	2.6	--	1.2	1.4	5.7	3.0	2.7
Lyman	1,074.5	3.8	--	1.9	1.9	10.6	5.1	5.5
Marshall	542.6	4.3	--	1.9	2.4	20.6	10.8	9.8
McCook	368.4	1.8	--	0.9	0.9	7.0	3.6	3.4
McPherson	734.8	0.1	--	0.1	--	3.4	1.8	1.6

County	All[1] land	Forest land[2]				Nonforest land with trees[6]		
		All forest	Productive reserved[3]	Unproductive[4]	Commercial[5]	All nonforest with trees	Wooded strips[7] and shelterbelts[8]	Other nonforest with trees[9]
Meade[10]	1,668.0	16.8	--	12.8	4.0	15.8	6.6	9.2
Mellette	838.9	10.4	--	5.7	4.7	24.3	11.6	12.7
Miner	364.7	--	--	--	--	--	.0	.0
Minnehaha	518.1	1.6	--	0.6	1.0	1.4	.9	.5
Moody	333.0	2.2	--	1.0	1.2	3.4	1.8	1.6
Pennington[10]	1,104.4	4.1	2.4	0.8	0.9	13.0	6.6	6.4
Perkins	1,846.0	2.9	--	1.6	1.3	18.1	9.4	8.7
Potter	556.1	0.1	--	--	0.1	--	.0	.0
Roberts	705.5	10.2	--	4.7	5.5	8.3	4.7	3.6
Sanborn	364.0	0.8	--	0.4	0.4	4.2	2.2	2.0
Shannon	1,340.0	59.6	2.9	36.6	20.1	47.7	12.7	35.0
Spink	963.4	2.1	--	0.9	1.2	10.3	6.2	4.1
Stanley	916.1	1.4	--	0.6	0.8	5.5	1.9	3.6
Sully	621.9	--	--	--	--	0.1	.0	.1
Todd	888.3	22.5	--	13.9	8.6	28.4	8.7	19.7
Tripp	1,035.6	3.9	--	2.0	1.9	11.5	5.3	6.2
Turner	394.8	1.6	--	0.7	0.9	3.8	1.7	2.1
Union	290.1	4.5	--	2.2	2.3	13.8	6.8	7.0
Walworth	452.3	--	--	--	--	--	.0	.0
Washabaugh	679.0	5.5	--	3.0	2.5	19.5	9.9	9.6
Yankton	331.4	6.0	--	2.5	3.5	13.1	7.5	5.6
Ziebach	1,260.4	2.5	--	1.2	1.3	17.9	9.5	8.4
All counties	41,708.2	266.3	5.3	147.4	113.6	601.1	287.8	313.3

[1] 1980 Bureau of Census estimates. Includes: Forest, nonforest with trees, and nonforest without trees.

[2] Land at least 16.7 percent stocked by forest trees of any size, or formerly having such tree cover, excludes land currently developed for nonforest use such as urban or heavily settled residential or resort areas, city parks, orchards, improved roads or improved pasture land. The minimum forest area classified was 1 acre. Classified as forest were roadside, streamside, and shelterbelt strips of timber with a crown width of at least 120 feet. Unimproved roads and trails, streams and clearings in forest areas were classed as forest if less than 120 feet wide.

3/Land sufficiently productive to qualify as commercial forest land but withdrawn from timber utilization through statute or administrative designation, or exclusive use for Christmas tree production as indicated by annual shearing.

[4] Forest land incapable of producing 20 cubic feet per acre per year of industrial wood under natural conditions, because of adverse site conditions, i.e., sterile soils, dry climate, poor drainage, high elevation, steepness, and rockiness.

[5] Forest land producing crops of industrial wood and not withdrawn from timber utilization by statute or regulation.

[6] Areas of land with trees but with less than 16.7 percent stocking and/or are less than 120 feet wide i.e., cropland with scattered trees, improved pasture with scattered trees, wooded strips, windbreaks, and idle farmland with scattered trees.

[7] An acre or more of continuous forest land that meets the definition of commercial forest land except that it is less than 120 feet wide.

[8] A group of trees less than 120 feet wide and used for the protection of soil and cropfields.

[9] An acre or more containing at least one tree 5.0 inches in diameter, but having less than 16.7 percent stocking.

[10] That portion of the county east of the 103rd meridian.

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DIAMETER GROWTH, SURVIVAL, AND VOLUME ESTIMATES FOR MISSOURI TREES

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ABSTRACT.—Measurements of more than 20,000 Missouri trees were summarized by species and diameter class into tables of mean annual diameter growth, annual probability of survival, net cubic foot volume, and net board foot volume. In the absence of better forecasting techniques, this information can be utilized to project short-term changes for Missouri trees, inventory plots, stands, or forests.

KEY WORDS: Cubic foot volume, board foot volume, crown class, mortality.

North Central Forest Experiment Station researchers are assembling the data necessary to develop a system of growth and mortality simulation models for the Central States similar to those used for the Lake States species in the Stand and Tree Evaluation and Modeling System (STEMS).[1] Much of the data for this research has come from Missouri. In fact, nearly 3,000 forest inventory plots were measured when Missouri's forests were surveyed in the early 1970's (Spencer and Essex 1976). Two thirds of those plots were remeasurements of plots established in 1959.[2] These plots include data for more than 20,000 trees in Missouri.

The large quantity and wide distribution of the Missouri data make them of special interest as a source of individual-tree growth, mortality, and volume information. Summarized here is information concerning mean annual diameter growth, mean annual survival rate, and mean cubic-foot and board-foot volume by species group and diameter class. In the absence of more sophisticated techniques, these summaries are useful guides for estimating growth, mortality, and volume for Missouri trees and stands.

The summary of diameter growth by species group and diameter class (table 1) shows that mean annual diameter growth rates ranged from well below 0.1 inch (0.3 cm) per year for hickory to more than 0.3 inch (0.8 cm) per year for cottonwood. The mean annual diameter growth for all trees was 0.115 inch (0.292 cm). Averaged across all species, diameter growth increased with increasing diameter, but this trend was not consistent for each species group individually. Some of the variation in the diameter growth rates both among and within species groups is due to the different number of observations and different sampling error associated with each of the mean values reported. Summaries of diameter growth by crown class, diameter class, and species group clearly show the faster growth associated with trees from dominant and codominant crown classes (table 2).

The mean annual survival rate for the sampled trees was 98.4 percent (table 3). Mean annual sur-

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[1] *Belcher, D. M.; Holdaway, M. R.; Brand, G. J. A description of STEMS, the Stand and Tree Evaluation and Modeling System (in prep.).*

[2] *Includes 226 plots from the Mark Twain National Forest that were established in 1971 and remeasured in 1977.*

vival rates were generally lower for trees less than 5 inches in diameter or greater than 15 inches in diameter than they were for trees 6 to 14 inches in diameter.

Net cubic-foot and board-foot volumes by species group and diameter class were averaged from more than 13,000 individual tree observations (tables 4 and 5). Gross tree volumes were calculated using Stone's equation[3], which is a function of observed breast height diameter, merchantable height, and top diameter outside bark. Gross volume estimates were corrected for differences in bark thickness among species; field estimates of cull volume were applied to these gross volume estimates to arrive at net tree volume.

Minimum acceptable top diameters outside bark were 4.0 and 9.0 inches for poletimber and sawtimber, respectively. However, poor form often lowered merchantable height below where the minimum top diameter occurred, so top diameters at merchantable height generally increased as diameter increased.[4]

Tables 1–5 can be used to estimate average tree-by-tree growth and survival for Missouri inventory plots. Such projections require a tree list that itemizes species, diameter, and perhaps crown class for a representative sample of trees from the stand or stands being considered. Alternatively, total stand growth can be estimated using the stand table projection techniques described by Husch *et al.* (1972). Stand table projections require a summary of the number of trees by species and diameter class.

Although simple inventory projections can be implemented using only a pencil, some paper, and a hand calculator, they are also readily computerized. For example, Moser (1980), Mawson and Mack (1980), Harrison and Rauch (1979), Pelz (1978), and Ek *et al.* (1973) all describe computerized forest data processing programs that summarize current and projected stand and stock tables from forest inventory data. Growth estimates in those programs are usually derived from increment cores taken during the inventory or from user-supplied growth-rate tables. A similar system could be adapted for use in Missouri with the data in tables 1–3 providing the basis for estimating growth and mortality. Increment core measurements could be used to adjust the growth rate tables to reflect local conditions.

For any of the above projection techniques, tree and stand volume can be estimated from tables of mean tree volume (tables 4 and 5). Or, if all the necessary information were available, local volume equations, such as those prepared for Missouri by Hahn (1975) could be used.

When using the information in tables 1–5, remember that all reported values are averages that are subject to variablity and that some average values are based on very few observations. Furthermore, these values do not account for the effects of site quality, stand density, or stand manipulation on growth. Projections for a period much longer than the 11-year span encompassed by the basic data would be of questionable reliability. We anticipate that when the data from Missouri are merged with similar information from other Central States, it will be possible to formulate and calibrate a system of STEMS-type growth and mortality models applicable both in Missouri and in surrounding States. Such models would account for site quality, stand density, and inter-tree competition to provide more accurate and more biologically realistic projections of tree and stand growth than are possible from the information reported here.

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[3] *A description of this function can be found in the appendix of: Raile, Gerhard K.; Smith, W. Brad.; Weist, Carol A. A Net volume equation for Michigan's Upper and Lower Peninsulas. Gen. Tech. Rep. NC-80. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1982. 12 p.*

[4] *Tables of associated gross merchantable volumes, merchantable heights, and merchantable top diameters are available from the authors.*

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Table 1.--Mean annual diameter growth by species group and diameter class, Missouri[1]

(In inches)

Species group	Number of observations	Diameter class (inches at breast height)															Average all classes
		1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+	
Shortleaf pine	912	.108	.118	.121	.131	.118	.125	.142	.129	.113	.110	--	--	--	--	--	.123
Baldcypress	17	--	--	--	--	.117	--	--	.192	.250	.237	.154	--	.273	.291	.138	.194
Eastern redcedar	247	.077	.103	.082	.100	.095	.077	.121	--	--	--	--	--	--	--	--	.090
Select white oak	4,207	.058	.087	.102	.117	.124	.124	.130	.125	.124	.111	.119	.125	.126	.143	.138	.111
White oak	3,691	.058	.089	.104	.120	.128	.125	.130	.125	.123	.110	.113	.116	.122	.103	.127	.112
Swamp white oak	111	.087	.114	.092	.111	.138	.165	.194	.141	.131	.139	.223	.153	.149	.268	.246	.140
Chinkapin oak	335	.066	.061	.080	.086	.071	.080	.090	.095	.129	.100	.115	.147	-	.093	.094	.082
Other white oak	2,868	.053	.070	.080	.093	.088	.088	.082	.083	.080	.065	.070	.085	.064	.071	.287	.080
Post oak	2,855	.051	.070	.080	.093	.087	.087	.080	.083	.076	.063	.070	.085	.064	.071	.175	.079
Select red oak	839	.090	.138	.140	.168	.158	.180	.179	.167	.161	.177	.175	.186	.194	.205	.245	.164
N. red oak	805	.090	.135	.139	.167	.158	.178	.177	.163	.164	.170	.175	.189	.194	.205	.245	.163
Other red oak	5,134	.086	.127	.146	.156	.159	.159	.155	.160	.157	.171	.157	.158	.177	.179	.173	.148
Scarlet oak	782	.084	.134	.158	.184	.189	.194	.198	.196	.165	.191	.149	.213	.212	--	.185	.168
Shingle oak	128	.255	.170	.164	.171	.209	.208	.215	.159	.217	.104	--	.105	.254	--	--	.182
Blackjack oak	690	.062	.092	.082	.095	.104	.111	.099	.089	.095	.164	.112	.150	--	--	--	.093
Black oak	3,409	.087	.132	.152	.158	.160	.157	.155	.159	.155	.162	.157	.151	.159	.179	.161	.150
Select hickory	1,848	.048	.070	.081	.091	.085	.101	.097	.093	.089	.114	.106	.147	.141	.293	.373	.078
Bitternut hickory	107	.083	.112	.117	.102	.071	.130	.205	--	.100	--	--	--	--	--	--	.106
Pignut hickory	590	.040	.059	.076	.081	.078	.091	.085	.078	.087	.090	.100	--	--	--	.373	.069
Shellbark hickory	120	.063	.076	.065	.102	.096	.103	.119	.090	.101	.157	.128	--	--	.150	--	.086
Shagbark hickory	356	.042	.064	.073	.090	.087	.118	.097	.114	.085	.092	--	.121	141	--	--	.079
Mockernut hickory	649	.048	.072	.083	.093	.085	.093	.079	.100	.075	.114	.070	.227	--	--	--	.077
Other hickory	618	.036	.056	.066	.071	.072	.081	.060	.116	.112	.082	--	.173	.091	--	--	.059
Black hickory	618	.036	.056	.066	.071	.072	.081	.060	.116	.112	.082	--	.173	.091	--	--	.059
Basswood	27	.143	.033	.073	.093	.146	.088	.023	.062	.231	.141	.114	--	.045	--	--	.105
Beech	12	--	.073	--	.154	.264	.250	--	--	.082	--	.064	.036	-	--	.345	.147
Hard maple	228	.049	.061	.072	.098	.133	.122	.112	.102	.193	.081	.038	.175	.254	.140	--	.092
Soft maple	181	.036	.161	.260	.197	.283	.228	.371	.459	.367	.291	.251	.204	.808	.227	.132	.214
Silver maple	116	.134	.233	.332	.210	.313	.216	.387	.459	.400	.291	.295	.431	.808	.227	.132	.303
Elm	585	.057	.086	.083	.110	.112	.111	.179	.119	.111	.157	.190	.149	.128	--	.246	.097
American elm	330	.069	.108	.093	.124	.109	.132	.221	.099	.114	.196	.217	.173	.093	--	.246	.113
Red elm	136	.045	.059	.089	.080	.128	.073	.096	.203	.082	.080	.149	.054	.250	--	--	.088
Black ash	5	--	--	.035	.130	--	--	--	.120	--	--	--	.040	-	--	--	.072
White & green ash	403	.067	.105	.138	.142	.151	.115	.126	.181	.131	.080	.133	.124	.231	.263	--	.124
White ash	193	.059	.098	.123	.117	.129	.101	.118	.166	.115	.031	.090	.210	--	--	--	.106
Green ash	210	.080	.113	.149	.169	.166	.122	.143	.191	.144	.097	.151	.081	.231	.263	--	.140
Sycamore	134	.182	.211	.234	.215	.211	.197	.143	.213	.300	.234	.268	.187	.108	.210	.186	.209
Cottonwood	26	.260	--	-	.588	--	.308	.850	.070	.577	--	.544	.366	.100	.070	.244	.341
Willow	38	.136	--	.387	.359	.276	.242	.238	.160	--	.133	.233	--	.110	--	.200	.232
Hackberry	136	.049	.161	.155	.143	.116	.172	.128	.246	.200	.092	.122	.195	--	.244	.069	.147
River birch	34	.069	.175	.354	.218	.220	.281	-	.236	.158	.248	.107	.157	--	--	.286	.217
Sweetgum	32	-	.103	.046	.168	.168	.173	.077	.086	.146	.043	.046	--	.118	--	--	.118
Black cherry	39	.231	.120	.167	.105	.147	.164	.066	.100	--	--	--	.160	--	--	--	.141
Black walnut	330	.122	.114	.115	.112	.123	.099	.115	.095	.084	.249	.131	.062	--	--	--	.112
Butternut	2	--	--	--	--	.131	--	.173	--	--	--	--	--	--	--	--	.152
Yellow-poplar	3	--	--	--	.336	--	.291	--	--	.182	--	--	--	--	--	--	.270
Other hardwoods	855	.050	.081	.103	.148	.147	.140	.124	.120	.098	.098	.084	.117	.156	.042	.250	.084
Sassafras	107	.052	.067	.067	.058	.110	--	--	--	--	.100	--	--	--	--	--	.058
Noncommercial species	138	.048	.082	.062	.186	.111	--	--	--	--	--	--	--	--	--	--	.060
All softwoods	1,176	.094	.111	.110	.127	.116	.121	.141	.137	.122	.183	.154	--	.273	.291	.138	.117
All hardwoods	18,722	.059	.093	.110	.126	.131	.131	.131	.136	.134	.136	.139	.148	.147	.169	.188	.115
All species	19,898	.061	.094	.110	.126	.130	.131	.132	.136	.134	.137	.139	.148	.148	.171	.185	.115

[1] Growth rates were calculated using as many observations as were available; some rates are based upon one observation. Growth rates for each diameter class larger than 20 inches were usually computed using fewer than 2 percent of the total number of observations for a given species group.

[2] Indented entries designate individual species within a group that have 100 or more observations. Entries for the total species group are not indented and they include data for all species in that group regardless of whether information for one or more of the individual species in the group is reported separately.

Table 2.--Mean annual diameter growth by species group, crown class, and diameter class, Missouri[1]

(In inches)

Species group	Crown class	Number of observations	Diameter class (inches at breast height)															Average all classes
			1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+	
Shortleaf pine	Dominant	92	.213	.200	.202	.195	.155	.143	.146	.114	.110	.110	--	--	--	--	--	.154
	Codominant	536	.270	.189	.140	.130	.106	.117	.127	.156	.143	--	--	--	--	--	--	.129
	Intermediate	105	.140	.109	.069	.063	.021	--	--	--	--	--	--	--	--	--	--	.092
	Overtopped	79	.057	.036	.035	.035	--	--	--	--	--	--	--	--	--	--	--	.046
Eastern redcedar	Dominant	27	.183	.388	.113	.114	.085	--	.121	--	--	--	--	--	--	--	--	.133
	Codominant	105	.120	.125	.080	.109	.108	.099	--	--	--	--	--	--	--	--	--	.101
	Intermediate	63	.078	.093	.060	.067	--	.045	--	--	--	--	--	--	--	--	--	.080
	Overtopped	52	.053	.061	.071	.072	.018	.008	--	--	--	--	--	--	--	--	--	.057
Select white oak	Dominant	995	--	.179	.170	.154	.160	.143	.150	.137	.132	.122	.138	.128	.133	.162	.150	.145
	Codominant	2,113	.152	.138	.124	.123	.121	.119	.120	.113	.115	.096	.097	.114	.102	.065	.041	.121
	Intermediate	609	.083	.082	.082	.077	.083	.066	.064	.073	--	.069	--	.138	--	--	--	.080
	Overtopped	489	.036	.043	.042	.053	.065	.037	.036	--	.023	--	--	--	--	--	--	.041
Other white oak	Dominant	704	.092	.166	.119	.122	.102	.095	.090	.093	.083	.067	.082	.096	.077	.087	.287	.097
	Codominant	1,400	.105	.098	.095	.097	.088	.086	.077	.073	.071	.061	.051	.040	.005	.038	--	.089
	Intermediate	457	.066	.054	.057	.057	.045	.058	.046	.052	.096	--	--	--	--	--	--	.057
	Overtopped	307	.031	.033	.034	.044	.082	.008	.020	--	--	--	--	--	--	--	--	.033
Select red oak	Dominant	315	.138	--	.198	.175	.180	.178	.185	.162	.177	.178	.194	.208	.197	.242	.271	.184
	Codominant	415	.146	.176	.150	.183	.152	.184	.179	.183	.146	.152	.134	.109	.179	.206	.140	.167
	Intermediate	73	.106	.111	.096	.120	.103	.142	.091	--	--	--	.040	--	--	--	--	.107
	Overtopped	32	.046	.079	.080	.025	.025	--	--	--	--	--	--	--	--	--	--	.054
Other red oak	Dominant	1,370	.208	.210	.240	.214	.195	.179	.173	.184	.167	.181	.164	.162	.188	.165	.170	.186
	Codominant	2,823	.153	.166	.157	.153	.153	.149	.142	.130	.139	.152	.138	.142	.130	.250	.184	.152
	Intermediate	635	.087	.091	.081	.091	.094	.086	.072	.065	.090	.079	--	--	--	--	--	.088
	Overtopped	300	.048	.066	.069	.072	.066	.040	.019	--	--	--	.136	--	--	--	--	.057
Hickory (All)	Dominant	418	.169	.142	.092	.113	.091	.115	.099	.100	.089	.123	.086	.134	.141	.150	.373	.105
	Codominant	932	.116	.115	.097	.092	.085	.084	.080	.089	.103	.081	.113	.227	.091	.436	--	.095
	Intermediate	509	.064	.060	.063	.052	.043	.040	.027	--	--	--	--	--	--	--	--	.060
	Overtopped	605	.026	.036	.040	.047	.021	.021	--	--	--	--	--	--	--	--	--	.031
Other commercial hardwoods (All)	Dominant	553	.265	.184	.201	.193	.176	.156	.171	.190	.184	.160	.195	.182	.183	.175	.203	.181
	Codominant	1,101	.109	.149	.160	.161	.152	.151	.142	.139	.148	.153	.147	.133	.044	.250	.125	.151
	Intermediate	584	.094	.105	.080	.094	.112	.092	.066	.103	.072	.269	.102	--	.140	--	.211	.096
	Overtopped	828	.043	.052	.059	.039	.102	.082	.103	.091	--	.106	--	--	--	--	--	.048

[1] Except for Eastern redcedar, includes only species groups with 800 or more observations.

Table 3.--Mean annual probability of survival by species group and diameter class, Missouri[1]

		Diameter class (inches at breast height)															
Species group	Number of observations	1.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+	Average all classes
Shortleaf pine	979	.971	.977	.991	.999	.999	.998	.995	1.000	1.000	--	--	--	--	--	--	.992
Baldcypress	22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.978
Eastern redcedar	262	.985	.997	.998	.997	.995	.991	--	--	--	--	--	--	--	--	--	.994
Select white oak	4,572	.980	.984	.992	.995	.997	.997	.996	.993	.992	.989	.994	.991	.983	.996	.988	.992
Other white oak	3,264	.967	.984	.991	.993	.995	.992	.993	.990	.991	.986	.980	.992	.992	-	-	.988
Select red oak	932	.975	.990	.987	.996	.993	.993	.989	.992	.993	.997	.995	.977	.974	.973	.992	.990
Other red oak	6,098	.954	.983	.987	.991	.991	.990	.986	.985	.981	.981	.975	.975	.978	.970	.973	.984
Select hickory	2,053	.981	.991	.994	.996	.994	.989	.991	.988	.989	.984	--	--	--	--	--	.990
Other hickory	723	.978	.983	.988	.993	.992	.988	.985	.981	--	--	--	--	--	--	--	.985
Basswood	31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.989
Beech	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.000
Hard maple	249	.989	.991	.996	.997	.994	.988	.996	1.000	--	--	--	--	--	--	--	.992
Soft maple	224	.981	--	.985	.987	.990	.985	.972	.974	.981	--	--	--	--	--	.934	.979
Elm	1,315	.973	.964	.953	.935	.938	.911	.909	.878	.878	.864	.889	.861	.932	--	.842	.935
White & green ash	496	.965	.976	.976	.988	.994	.991	1.000	.993	.991	--	--	--	--	--	--	.982
Sycamore	158	.978	--	.982	.986	.981	.988	--	1.000	--	.988	--	--	--	--	--	.986
Cottonwood	37	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.971
Willow	95	.902	--	--	--	.929	.979	.871	.866	--	--	--	--	--	--	--	.924
Hackberry	142	.991	.986	.994	.996	.996	.995	.983	--	--	--	--	--	--	--	--	.994
River birch	48	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.974
Sweetgum	39	--	--	--	.990	--	--	--	--	--	--	--	--	--	--	--	.983
Black cherry	49	--	--	.984	--	--	--	--	--	--	--	--	--	--	--	--	.981
Black walnut	391	.965	.979	.979	.985	.991	.994	.983	1.000	.993	--	--	--	--	--	--	.986
Other hardwoods	1,107	.973	.976	.954	.983	.992	.980	.976	.991	.980	.981	--	--	--	--	--	.975
Noncommercial species	278	.940	.955	.931	--	--	--	--	--	--	--	--	--	--	--	--	.941
All softwoods	1,263	.977	.985	.993	.998	.998	.996	.995	.995	1.000	--	--	--	--	--	--	.992
All hardwoods	22,325	.970	.982	.986	.990	.991	.990	.987	.984	.981	.981	.977	.976	.974	.967	.953	.984
All species	23,588	.970	.982	.987	.991	.992	.990	.987	.984	.981	.981	.977	.976	.975	.967	.954	.984

[1] All values based upon at least 10 observations.

Table 4.--Average net merchantable volume per tree by species group and diameter class, Missouri

(In cubic feet)

Species group	Number of observations	Diameter class (inches at breast height)												
		5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+
Shortleaf pine	889	2.36	5.12	9.58	14.70	20.22	29.81	38.42	52.21	--	--	--	--	--
Baldcypress	17	--	3.91	--	--	23.89	23.44	35.69	48.15	69.62	98.71	--	119.57	150.30
Eastern redcedar	192	2.00	4.50	8.19	11.58	17.46	20.28	--	--	--	--	--	--	--
Select white oak	3,291	2.42	5.12	9.29	14.69	19.99	27.22	35.67	41.89	51.96	65.25	68.26	66.34	117.61
Other white oak	1,545	2.34	4.75	7.95	12.08	16.87	22.39	27.69	38.69	46.75	50.63	60.88	0	223.62
Select red oak	501	2.72	5.13	9.16	14.72	21.21	29.05	35.69	47.43	71.88	73.50	102.69	129.61	134.26
Other red oak	3,704	2.38	5.22	8.99	14.01	19.91	27.32	36.17	44.52	52.11	66.42	89.05	95.51	128.01
Select hickory	568	2.23	5.01	9.04	15.20	22.10	31.16	37.70	49.75	75.08	89.70	--	153.04	192.91
Other hickory	614	2.13	4.89	8.76	14.22	20.63	28.05	42.67	57.08	63.10	94.72	44.76	--	--
Basswood	11	--	2.89	7.16	13.35	18.47	30.05	--	--	--	--	--	--	--
Beech	1	--	--	--	--	--	26.28	--	--	--	--	--	--	--
Hard maple	99	2.47	5.28	9.66	15.59	20.76	32.94	31.50	--	--	--	--	--	--
Soft maple	84	2.63	6.58	11.70	16.06	23.67	30.02	35.31	48.02	63.04	89.56	88.14	--	171.66
Elm	269	2.36	5.11	9.21	14.50	18.78	28.60	42.18	43.18	62.93	57.16	83.81	93.74	251.30
Black ash	7	2.59	--	--	8.21	--	--	--	--	45.59	46.60	--	--	--
White & green ash	226	2.45	5.19	9.54	13.48	21.58	27.18	35.68	44.35	46.52	59.69	86.05	--	183.56
Sycamore	222	3.10	7.10	12.41	19.05	28.45	42.63	48.57	60.52	76.82	110.12	126.48	137.22	226.41
Cottonwood	147	2.48	5.66	10.70	17.60	27.40	36.83	50.94	73.12	81.64	106.78	94.93	204.76	306.42
Willow	199	2.47	6.01	11.77	19.16	28.15	41.07	66.12	90.01	--	--	--	--	--
Hackberry	66	2.29	4.15	8.50	13.06	18.26	31.85	50.55	51.15	--	48.96	69.22	--	--
River birch	68	2.46	6.08	9.21	16.67	24.76	27.57	37.00	47.31	58.00	--	--	106.23	206.78
Sweetgum	23	1.28	4.84	10.30	14.04	11.90	31.82	35.97	--	--	--	--	155.90	--
Black cherry	15	2.19	4.77	6.01	13.92	20.63	30.58	31.98	--	--	--	--	--	--
Black walnut	290	2.38	5.04	8.68	13.62	18.94	22.90	34.78	40.75	38.93	61.55	77.35	--	--
Butternut	5	2.51	5.36	--	11.15	--	30.36	--	--	--	--	--	--	--
Yellow-poplar	1	--	--	--	--	--	--	--	--	--	--	--	--	161.46
Other hardwoods	185	1.94	4.89	9.15	12.93	19.05	24.16	33.30	50.32	60.78	83.77	36.45	51.95	135.64
All softwoods	1,098	2.24	4.99	9.39	14.50	20.07	28.78	38.06	51.05	69.62	98.71	--	119.57	150.30
All hardwoods	12,141	2.36	5.10	9.06	14.32	20.24	28.00	37.58	46.45	58.68	75.44	88.65	108.78	193.95
All species	13,239	2.35	5.09	9.09	14.33	20.23	28.02	37.59	46.57	58.82	75.68	88.65	109.32	191.42

Table 5.--Average net merchantable volume per tree by species group and diameter class, Missouri

(In board feet)[1]

Species group	Number of observations	Diameter class (inches at breast height)									
		11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0+
Shortleaf pine	260	81.66	121.27	177.48	230.71	345.00	--	--	--	--	--
Baldcypress	16	--	101.24	121.92	187.58	261.45	318.96	420.34	--	560.80	649.71
Eastern redcedar	17	61.56	103.03	99.69	--	--	--	--	--	--	--
Select white oak	1,607	70.85	96.20	128.73	165.47	203.42	233.85	301.81	357.57	349.69	432.54
Other white oak	510	59.27	84.12	106.41	136.87	180.25	226.24	262.26	271.98	--	956.81
Select red oak	315	68.12	109.12	142.78	192.30	245.13	337.80	354.89	355.68	737.87	687.68
Other red oak	1,672	70.06	100.78	140.89	181.34	224.22	270.15	310.92	358.34	395.92	495.27
Select hickory	201	75.58	102.81	149.34	185.03	285.16	363.38	412.56	--	606.67	805.94
Other hickory	154	71.77	96.01	142.66	193.36	261.54	378.31	510.11	236.45	--	--
Basswood	8	52.63	69.97	118.09	--	--	--	--	--	--	--
Beech	1	--	--	120.87	--	--	--	--	--	--	--
Hard maple	25	57.28	74.43	132.42	100.59	--	--	--	--	--	--
Soft maple	49	83.78	121.46	145.92	140.39	200.23	248.10	463.20	345.08	--	575.79
Elm	84	59.89	78.19	127.72	171.21	174.45	303.08	379.96	320.20	360.49	406.36
Black ash	3	32.85	--	--	--	--	146.56	212.05	--	--	--
White & green ash	92	51.71	89.08	135.79	172.19	176.27	218.65	414.11	616.18	--	1,028.90
Sycamore	165	72.64	122.69	190.64	230.46	293.40	415.32	581.99	521.26	861.20	1,084.95
Cottonwood	124	104.25	147.98	194.50	264.05	378.71	437.22	542.86	578.25	955.59	1,449.77
Willow	116	85.29	129.94	195.32	290.05	392.42	--	--	--	--	--
Hackberry	25	59.93	89.12	149.29	189.64	290.95	--	190.09	458.79	--	--
River birch	36	80.62	110.09	127.59	213.86	369.69	354.89	--	--	378.94	745.62
Sweetgum	13	64.51	100.46	157.35	275.52	--	--	--	--	888.43	--
Black cherry	7	59.08	78.90	135.69	160.24	--	--	--	--	--	--
Black walnut	133	59.22	88.47	115.40	179.65	191.22	180.07	359.08	428.27	--	--
Butternut	2	56.44	--	113.57	--	--	--	--	--	--	--
Yellow-poplar	1	--	--	--	--	--	--	--	--	--	326.50
Other hardwoods	82	60.49	101.70	145.88	175.23	256.51	341.35	313.54	446.73	238.74	819.32
All softwoods	293	80.42	119.68	168.87	224.96	321.13	318.96	420.34	--	560.80	649.71
All hardwoods	5,425	68.92	98.71	137.85	183.87	231.03	290.74	370.51	397.85	538.92	815.53
All species	5,718	69.83	99.66	138.89	185.03	233.46	291.11	371.03	397.85	540.01	805.91

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[1] International 1/4-inch rule.

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AIR DRYING OF CHUNKWOOD AND CHIPS

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ABSTRACT.—A new method of comminuting wood has resulted in a new wood particle form called chunkwood, which is much larger than the common pulp-size chip. Chunkwood appears well suited for use as a fuel but nothing is yet known about its storage, drying, or combustion characteristics. This paper reports on two exploratory drying experiments we conducted to see whether chunks, with their much larger interparticle voids, dry more readily than chips. In one experiment we used natural convective ambient air to dry chunks and chips and found that chunks dried much faster than chips. In another experiment we used forced ambient air to dry chunks and chips and found that chips dried faster than chunks. However, the chunks offered much less resistance to forced air flow and thus required less fan energy. We recommend that larger, more controlled studies be undertaken to further document the ambient drying characteristics of chunkwood as compared to chips.

KEY WORDS: Energy wood, fuel, moisture content, biomass for energy, fuel enhancement, fuel characteristics.

Today wood is increasingly used for generating industrial energy—mainly process steam and heat. The principle source of energy wood has been mill residues. But recently, whole-tree chips have been gaining in use mainly because they are readily available in large quantities due to the commercial introduction and widespread use of whole-tree portable chipping machines. Although conventional whole-tree chips can be sucessfully combusted in solid fuel boilers, they are not necessarily the most desirable form for wood as a solid industrial fuel. For example, they tend to have high solid particulate emissions because of the high flue gas velocities when burned in industrial scale combustors. Additionally, chips tend to layer and thereby restrict the flow of underfire combustion air. Pulp-size chips also cause bridging problems, require considerable energy to produce, have a low bulk density, and layer closely when stored in piles and thus restrict the movement of air necessary for natural drying. This lack of venting in chip piles also contributes to heat build-up and fire danger.

In conjunction with harvesting operations, we have explored ways to comminute small diameter trees and logging residue into particles suitable for ring flaking for flakeboard production or for use as a solid fuel. As a result of this research, two different types of machine have been developed that produce "chunks" of wood that appear well suited for either use (Arola *et al.* 1982, Arola *et al.* in prep., Barwise *et al.* 1977, Barwise *et al.* 1982). The resulting chunks are much larger, require less energy to produce, and have somewhat greater bulk density than conventional pulp chips. They also exhibit entirely different bulking characteristics because of their chunky and irregular shape.

In a pile or thick layer of this material, large void spaces exist between particles. It was our belief that these chunks, with large interparticle voids, would dry faster and generate less solid particulate emissions when burned than conventional wood chips. However, because these chunks are a new particle form, information is not available on their storage, drying, or combustion characteristics. Our work in chunkwood production and drying is the beginning foundation.

For use as a solid fuel, any amount of drying prior to combustion is advantageous. Therefore, the purpose of our study was to determine drying rate differences between chunked wood and conventional pulp-size chips under ambient air test conditions.

METHODS

We established two simple drying experiments using ambient room air (drawn from within our seasonally heated machine shop building) to compare these new potential fuelwood chunks and conventional pulp-size chips. The first experiment used natural convective air drying while the second experiment used forced air convective drying. In these experiments we used wood from both aspen and red maple. The chips were made using a Morbark "Chip-Pac"[1] Model 3-48 chipper set to produce 3/4-inch long standard pulp chips. The chunks were made on our experimental chunking machine. From independent tests with the machine, we found that chunks ranged from 2 to 5 inches, and averaged 3.5 inches long. Particle cross sections ranged from about 1/2 inch up to the full diameter of the bolts being chunked (Arola *et al.* 1982).

In the natural convective air drying experiment, equal volumes of green chunks and chips were placed in separate 3.6 ft^3 (one-half of a 55-gallon barrel) cylindrical containers, set out in an open room, and allowed to freely dry (fig. 1). Initial tare and sample weights were determined. The green wood weights initially ranged between 60 and 85 pounds. To monitor moisture loss, both containers were periodically weighed. Because of time and space limitations and the preliminary nature of our study, the test was repeated only once, by species. Therefore, our results are not based on replications.

Figure 1.—*Test setup for natural convective drying of chips (left) and chunks (right).*

In the second experiment using forced air convective drying, we devised a test apparatus so that a known quantity of green chips or chunks could be dried by forcing ambient air through the particles. To begin, a 7.3 ft^3 cylindrical container (standard 55-gallon barrel) with a screened bottom insert was filled with chips, weighed, and set on a 7.5 hp variable volume blower system. The blower's inlet restrictor was adjusted to give a nominal 340 cfm of air flow through the filled barrel (fig. 2). The 340 cfm level was chosen because it was the lowest practical level at which this particular blower system would operate and not because it was optimum for drying. As the particle drying progressed, the following data were periodically noted: chip weight; elapsed time; air flow rate; pressure drop through the chips; ambient air temperature and relative humidity; and atmospheric pressure. We also determined beginning and ending moisture content. After the barrelful of chips was dried, an equal weight of chunks was dried following the same procedure. For this series of tests, five repetitions were made for each species using uncontrolled ambient room air. In all cases, we terminated the drying tests when the weight loss stopped or the drying rate was so slow that it was judged impractical to continue.

The aspen tests were run from the end of March until the end of May; the ambient air temperature averaged 73° F, and the relative humidity averaged 32 percent. The red maple tests were run between early June and early August. The ambient air temperature averaged 75° F, and the relative humidity averaged 60 percent.

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[1] *The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others that may be suitable.*

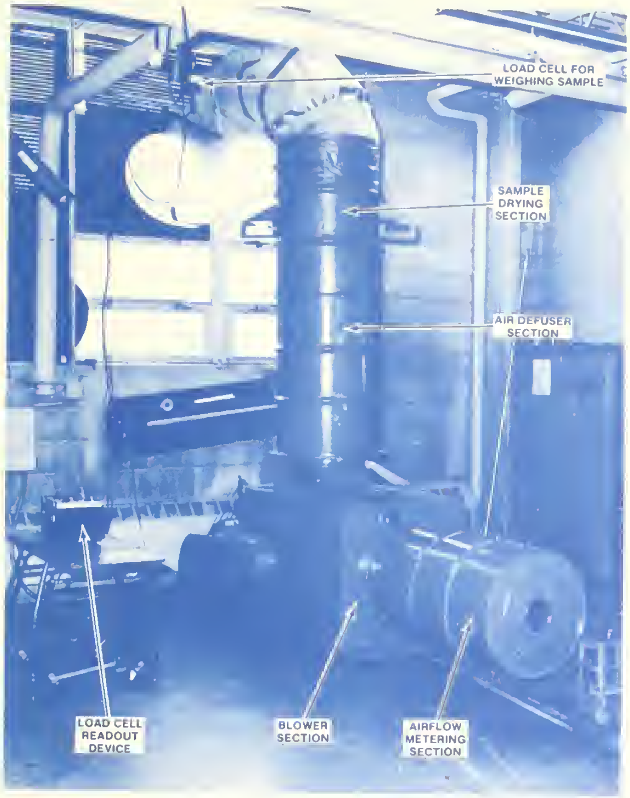

Figure 2.—*Test setup for forced air convective drying.*

For both experiments, we determined and plotted average moisture contents (wet weight basis).

In our second test series we calculated the energy used (power x time) based on the air horsepower dissipated within the wood bed. We calculated air horsepower from the equation (McDonald *et al.* 1967):

$$\text{Air hp} = 0.0001575\,pQ$$

where p = pressure drop across the wood bed in inches of water and Q = air flow rate in ft³/min.

EXPLORATORY RESULTS

In our natural convective air drying tests, we observed that the chunks dried much faster and to a lower moisture content than the chips for both species (fig. 3). This finding supports our belief that chunks dry faster than chips under natural convective air drying. (Conclusive data should be developed under conditions of controlled temperature and humidity.) Though unsubstantiated, we attribute the marked difference between drying rates of chunkwood and chips to the bulky character of the chunkwood, which gives larger air spaces (voids) and allows for easy air flow, as opposed to the flat character of chips, which layer closely and restrict air movement and trap moisture. We observed that at the end of our natural convective air drying tests, when the chips and chunks were emptied from the containers, the chunk container was completely dry while the chip container was rusty and wet. For the red maple (run during the more humid summer months), we actually found standing water at the bottom of the chip barrel.

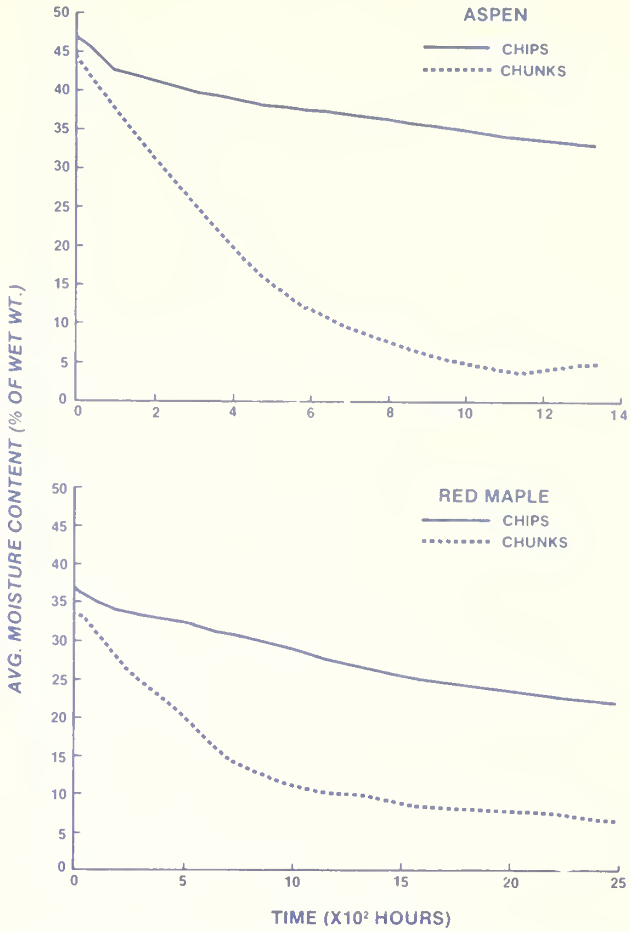

Figure 3.—*Time required for natural convective drying of aspen and red maple chunks and chips.*

In our forced air experiments, we found that the chunks dried slower than the chips (fig. 4); however, the pressure required to force the air through the chunks was much less than for the chips—consequently, the energy required was much less (fig. 5). These differences again are attributed to the chunks' larger interparticle void spaces, which offer much less resistance to air movement. In commercial practice, this energy advantage could possibly offset the added cost of the larger drying bin that would be required to give the same production rate (pounds of dry wood per hour) as for chips.

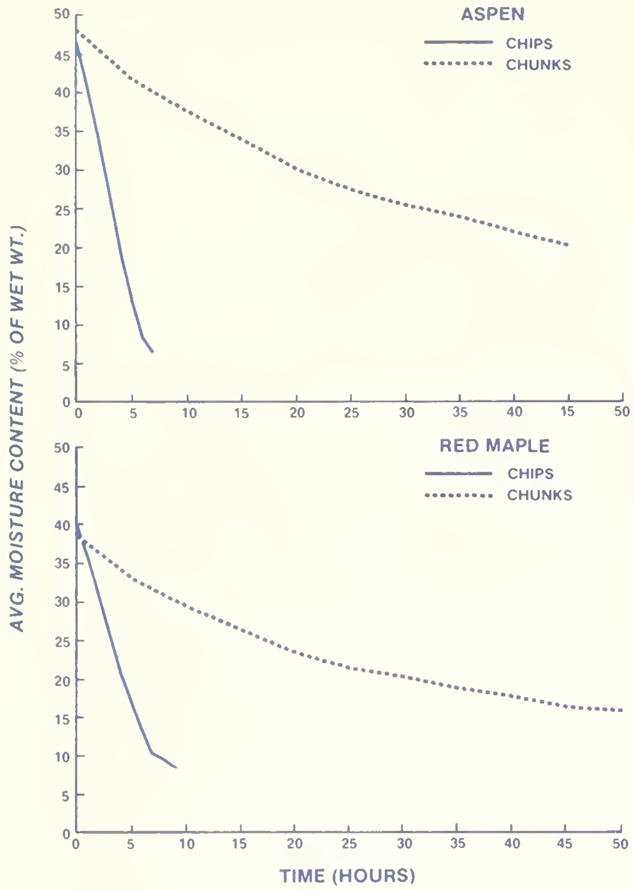

Figure 4.—*Time required for forced air convective drying of aspen and red maple chunks and chips. The curves represent the average of five repetitions.*

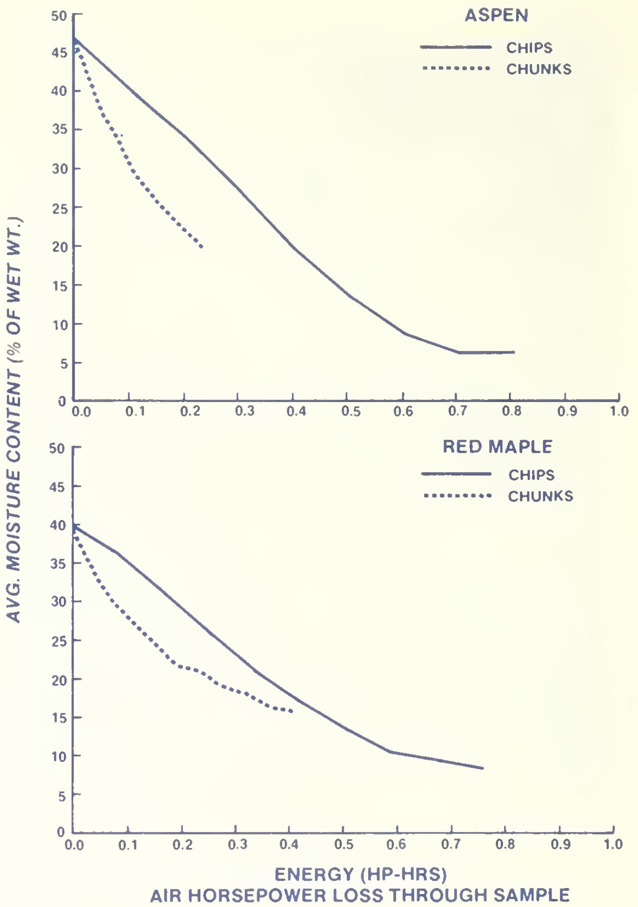

Figure 5.—*Energy required for forced air convective drying of aspen and red maple chunks and chips. The curves represent the average of five repetitions.*

We recognize the statistical limitations of our observations—particularly due to our inability to precisely control temperature and relative humidity. Nonetheless, we feel that this exploratory investigation has indicated that chunks have better drying characteristics than pulp-size chips. Based on our preliminary results, we recommend that more controlled investigations be conducted on a larger scale using ambient air drying of chunks in free-standing piles and in a silo with low velocity forced air.

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NORTH CENTRAL FOREST EXPERIMENT STATION 1992 FOLWELL AVE. ST. PAUL, MN 55108 FOREST SERVICE-U.S.D.A.

Research Note NC-294

1983

A BUDGET TREE IMPROVEMENT PROGRAM

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ABSTRACT.—In an Upper Peninsula Michigan test of simple design, white spruce of a Beachburg, Ontario provenance grew 17.5 percent taller than white spruce from the Ottawa N.F. The paper describes how to convert such tests to low-cost, low-risk, highly flexible improvement programs. The approach is applicable to other species of low priority.

KEY WORDS: White spruce, Lake States region, genetic gains, seed production areas, multigeneration breeding.

We will describe a low-cost alternative to tree improvement in a defined area such as a seed collection zone or a breeding zone. We will use a simple white spruce test as an example.

White spruce from SE Ontario performs well over a large region in north-central and north-eastern United States and adjacent Canada. Five Ontario sources of seed have been particularly mentioned: Douglas (King and Rudolf 1969), Peterborough (Teich 1970), Beachburg (Nienstaedt 1969, Genys and Nienstaedt 1979, Wright *et al.* 1977), Maple Leaf (Stellrecht *et al.* 1974), and Cobourg (Fowler and Coles 1977).

In most seed-source tests in the Lake States, the SE Ontario seedlings have been among the best performers and have been superior to seedlings of the local seed source. In a Minnesota test (Stellrecht *et al.* 1974), the Maple Leaf seedlings grew 17.5 percent higher 15 years after plantation establishment than the best of three control populations; this translated into a 41.5 percent advantage in tree volume. The Ontario-source trees were 76 and 169 percent taller than those in the other two control populations.[1]

Fowler and Coles (1977) have described a program to develop a source of Ottawa River Valley seeds in the Maritimes. Their plan is based on progeny testing with early roguing in the nursery and field test. We suggest a simple and cheaper approach; we believe the method can and should be used for other species as well.

MATERIALS AND METHODS

Beachburg, Ontario seedlings were raised with Ottawa N.F. stock at the Watersmeet, Michigan nursery. Standard nursery procedures were used and 2-2 stock was planted in May 1968 in an open field near Trout Lake, Michigan, approximately 24 miles NNW of St. Ignace. At the time of planting the sod cover was heavy so a sod scalper was used to prepare the ground. Trees from the two populations were planted in alternate rows at an approximate 6 x 8 foot (1.8 x 2.4 m) spacing. There was a total of 94 NS rows with about 140 trees per row. In September 1970 the survival was 97 percent.

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[1] *The controls involve standard nursery stock—two populations from State nurseries and one from an industrial nursery. The sources of seed are unknown but are presumably from Minnesota.*

In October 1981, when the trees were 18 years old, total heights were measured. The sampling was as follows: Pairs of trees—one tree from Beachburg and one from Ottawa in adjacent rows—were measured. We began with the first 4 pairs in row #2 (Beachburg) and #3 (Ottawa) in the SE corner of the planting. Pairs 5-8 were in rows #4 and #5, pairs 9-12 in rows #6 and #7 and so forth on a diagonal from the SE corner of the planting towards the north. When the north edge of the planting was reached, we moved across the rows to the east and again began one row in from the edge of the planting and then proceeded diagonally across the planting towards the southwest. The sampling involved the eastern third of the planting. A total of 232 pairs of trees was measured.

RESULTS

The Beachburg, Ontario trees were the best with a mean height of 3.52 m (11.5 feet) ± 1.02 m (3.3 feet) (st. dev.); the Ottawa N.F. trees averaged 2.99 m (9.8 feet) ± 0.96 m (3.1 feet) (st. dev.). Statistically, the difference is highly significant (t=5.705). The degree of superiority is almost identical to the 17.5 percent difference found by Stellrecht, Mohn, and Cromell (1974). As in their study, this superiority in height growth will translate into large differences in volume per tree.

DISCUSSION

To many tree breeders tree improvement is synonymous with seed orchard establishment either as grafted orchards of phenotypically selected trees or as progeny-test seedling seed orchards. Both are costly and both involve compromises between the amount of genetic gain and efficient seed production. In the grafted orchard, the effectiveness of phenotypic selection will determine the amount of gain. It is most effective on uniform sites in species that occur in pure, even-aged stands. For many species, phenotypic selection in natural stands in not very effective. In addition, roguing genetically inferior clones will reduce seed productivity in grafted orchards.

For maximum improvement, the progeny-test seedling seed orchard will require heavy roguing with resulting inefficient utilization of the site for seed production.

In intensive multigeneration breeding programs of economically valuable species, the key is to keep separate breeding populations and production populations (Kang 1980). Modified seed orchard designs are also available but they are costly, and they are probably not justifiable with low priority species.

Plantings such as the one we have described may be developed into an effective improvement alternative at low cost. For high priority species, such as the white spruce in our example, such plantings can be an interim source of improved seed. With several such plantings providing parent material, more intensive breeding could be started at some point in the future.

The plantation in our example can be converted to a seed-production area by removing all the trees of the Ottawa N.F. seed source first and then thinning the remaining Beachburg, Ontario trees selectively, leaving approximately 1/4 of the trees. Doing the initial thinning in two separate steps will increase the cost somewhat, but it will facilitate the selective thinning of the trees of the superior seed source. The remaining trees would be at an approximate spacing of 14 x 14 feet (4.2 x 4.2 m), a good spacing for seed production in early years. One later selective thinning, removing 2/3 of the remaining trees, would leave about 70 trees per acre (172/ha) at an average spacing of 24.5 x 24.5 feet (7.5 x 7.5 m). In the selective thinning, the first consideration should be vigor, quality, and absence of pests; the second, spacing of the remaining trees.

In order to assure even spacing of selected trees and to minimize the influence of microsite variation of the selection, a grid could be superimposed on the area, and a predetermined number of individuals selected within each cell of the grid—site quality within a grid cell would tend to be more uniform and selection therefore more effective.

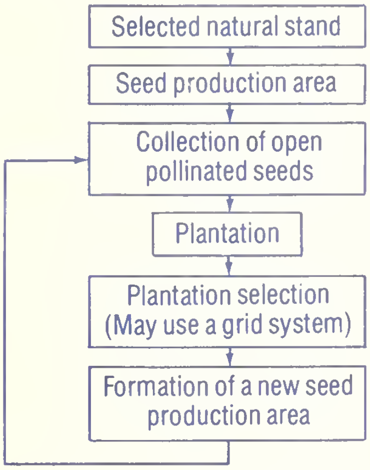
The approach can be used in a multigeneration breeding program. All that will be required is to establish a sequence of plantations always using seed from the previous selectively thinned plantation for each new planting. The approach is low in cost and risk.

Special care should be taken in the nursery in raising the seedlings. Some minor increases in the nursery costs would result. Plantation establishment and maintenance costs would also be higher than usual because special care would be needed in selecting the plantation site and because the best maintenance procedures should be used during establishment. Uniformity of site and maintenance would assure more effective selection. To the degree possible, a site should be selected where the source of outside pollen would be at a minimum to reduce contamination with pollen of low genetical quality.

Negative inbreeding effects with advancing generations could negate the gains achieved early in the program. Large seed collections representing many (100-150) original parent trees would essentially circumvent the problem. If such an original collection were established in a few somewhat different environments and advanced independently from generation to generation, the risk of undesirable inbreeding effects would be further reduced. This is because much of the original genetic diversity could be re-established by mixing the population at some later generation.

Other risks would be small. There will be no major financial loss if the program is abandoned before the selective thinning starts, or at some other stage in its development. The plantings would simply revert to standard uses.

The planting we have described was established with a known superior, broadly adapted source of seed. This is of course an advantage, but it is not essential. Another approach would be to select a high-quality natural stand, develop it into a SPA, and then use the SPA seed for the establishment of the first plantation. This strategy diagrams as follows:



With a network of such plantations over a region, conversion to more intensive breeding programs is possible at any stage. It should be stressed that such a program—and the low-cost program we have described—is environmentally limited to sites similar to sites on which the SPA is established. Future SPA seed established on divergent sites will risk failure. The more the sites diverge from the SPA site, the greater the risk. This, of course, makes the selection of the SPA site particularly important; it must be uniform and representative of the potential planting sites.

The Ottawa trees in the white spruce planting we have described are equivalent to a control. The control permits comparison with currently used planting stock.[2] It is not essential for the breeding, but including such a standard indicates the progress being made.

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[2] *In this particular test a more local Michigan provenance would have been a better standard.*

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Research Note NC-295

1983

DETERMINING LIGHT TRANSMITTANCE CHARACTERISTICS OF WOOD AND BARK CHIPS

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Robert C. Radcliffe, *Mechanical Engineering Technician,*
and **John A. Sturos,** *Research Mechanical Engineer,*
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ABSTRACT.—Describes computer-assisted testing for measuring light transmittance of wood and bark chips. Electronic interface permitted the computer to collect physical data accurately and efficiently and to analyze and present the data in several tabular and graphical formats.

KEY WORDS: Photosorting, mini computers, computer interfacing, computer graphics, bark-chip segregation.

The bark content of wood chips in the pulping process is a critical factor in determining paper quality. With the advent of whole-tree chippers, the percentage of bark has increased, thus degrading the end product. Reducing the bark content would greatly enhance paper quality.

There are various systems for segregating whole-tree chips; one method being investigated is based on the light transmittance characteristics of wood and bark. Light transmittance is the relative amount of light that penetrates the wood or bark chip, usually measured as a percentage of the incident light.

EXPERIMENTAL APPARATUS

Obtaining statistically valid data on the average light transmittance of bark and wood chips requires the measurement of a large quantity of individual chips. To facilitate accurate and efficient measurements of light transmittance, we developed an experimental setup that used a mini-computer (fig. 1). In addition to the usual data analysis and storage functions, the computer program also performed a self-calibration of the test fixture (lamp, optical detector, and amplifier) at the beginning of each data set and prompted the operator to insert each new chip at the proper time.

The experimental setup comprised an incandescent light source (a quartz-halogen projector lamp), a photometer, an interface amplifier, an analog-to-digital (A/D) converter, and the computer. The lamp, operated from a regulated DC power supply, furnished a constant light level with no 60 hertz ripple. The photometer was a United Detector Technology[1] model 40X. It will respond either linearly or logarithmically to produce a corresponding electrical output of 0 to 50 millivolts. A fixed aperture was placed over the detector to make the sampled area independent of chip size. The logarithmic mode was used here to permit measurements over a wide dynamic range without changing scales. The interface

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[1] *The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.*

Figure 1.—*Setup for measuring light transmittance.*

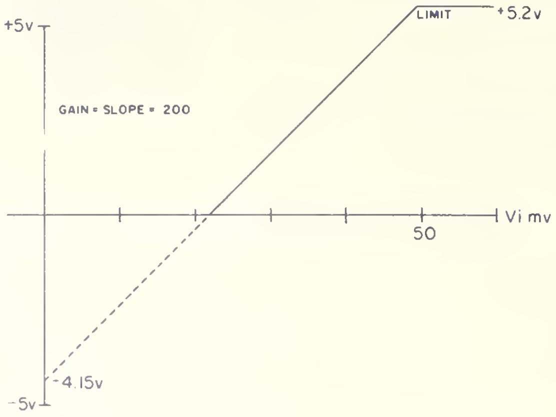

Figure 2.—*Transfer characteristic of photometer interface amplifier.*

amplifier converts the signal produced by the photometer to that required by the A/D converter. The A/D converter in turn feeds the digital signal into a Hewlett Packard 9825A desk-top computer for data manipulation.

The interface amplifier and the 8-bit A/D converter were designed and assembled by using standard electronic components. The A/D converter has 16 input channels permitting the simultaneous acquisition of a wide variety of electrical signals, although for this application only one channel was used. The photometer output voltage range of interest was 20 to 50 mV. The interface amplifier converts this range to the 0 to 5.2 V input range of the A/D converter as shown in the transfer characteristic (fig. 2). Thus, the input signal was amplified by a factor of 200, then shifted down by about 4.15 V to permit increased A/D resolution in the range of interest. Because the input to the A/D converter must not go below -0.3 V or above +5.4 V under any conditions, the amplifier circuit was also designed to limit at zero and +5.2 V, respectively.

PROCEDURE

Samples of 5/8-inch wood and bark chips of six Lake States species were tested. Included were quaking aspen (*Populus tremuloides),* balsam fir (*Abies balsamea),* jack pine (*Pinus banksiana),* white spruce (*Picea glauca),* sugar maple (*Acer saccharum),* and red pine (*Pinus resinosa).* All species were tested under both green and ovendry conditions. A randomly selected group of 50 bark and 50 wood chips of the desired species was sequentially numbered. All successive measurements were then done in sequence to permit correlation of the various data for each chip. The self-calibration sequence was run once for each group of chips by using a pair of known optical attenuators. The following experimental procedure was then used to create the desired data base:

1. Measure wood or bark chip thickness (to 0.001-inch) and key into computer.
2. Place chip in test fixture and initiate automatic light transmittance measurement (by tapping a switch).
3. Manipulate data and store record (done automatically by computer).
4. Dry chips in oven.
5. Remeasure chip thickness and key into computer.
6. Remeasure light transmittance of dry chip.
7. Manipulate dry data and store record (done automatically).

Once the data are in computer memory, they can be presented in graphs (fig. 3) or tables (table 1).

RESULTS AND CONCLUSIONS

The probability density and distribution functions of the light transmittance (optical density)[2] for two species of green chips is shown in figure 3. The graphs demonstrate the possibility of distinguishing wood from bark in some species by using light transmittance techniques. Aspen demonstrated these qualities best; the other five species showed the same qualities but to a lesser degree (table 1). Jack pine had the least separation of the species measured as also shown in figure 3.

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[2] *Optical density (O.D.) is defined as the common logarithm of the inverse of light transmittance (T).* $(O.D. = \log_{10}\frac{1}{T})$.

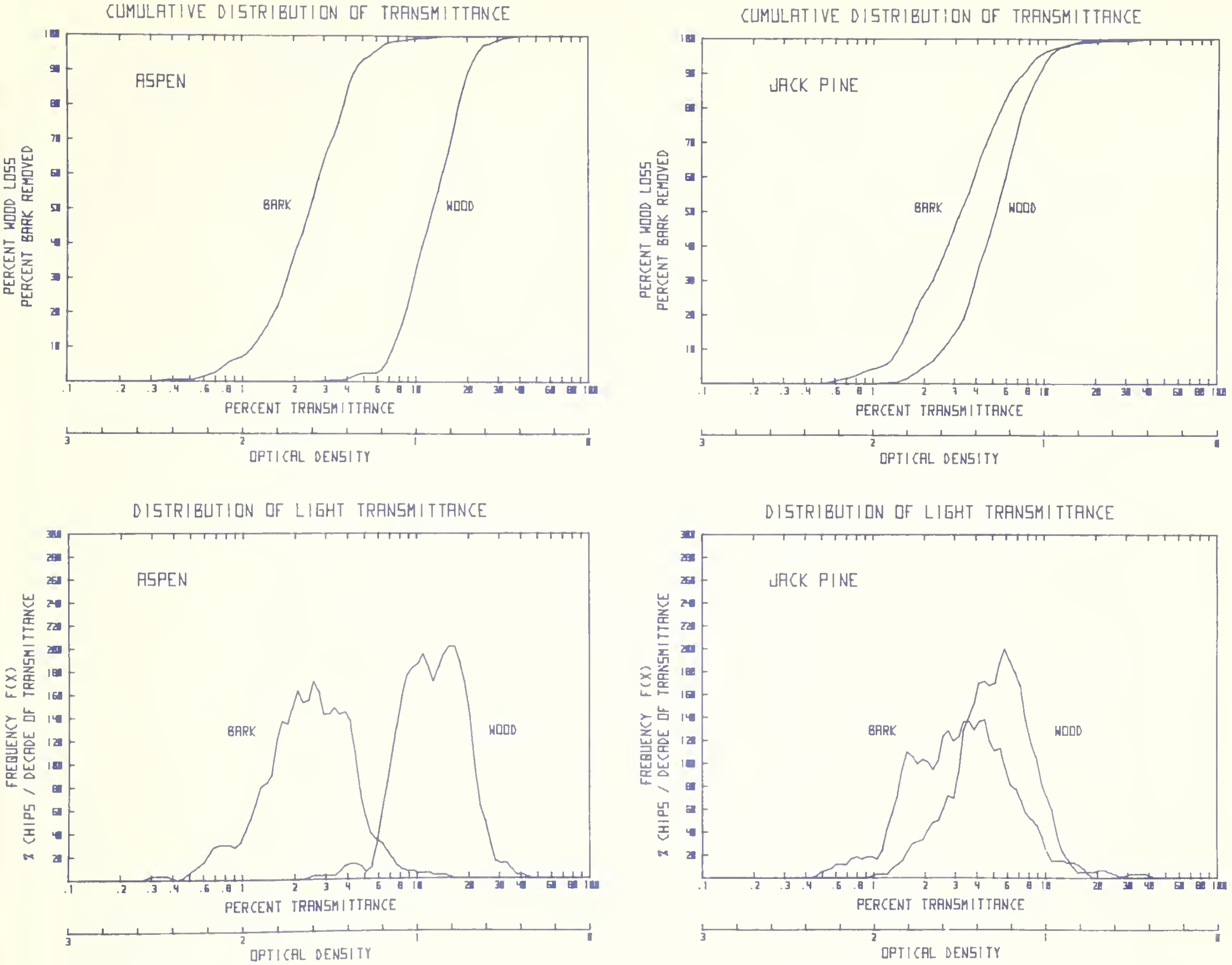

Figure 3.—*Computer graphs of light transmittance of aspen and jack pine.*

For those species with nearly disjoint transmittance distributions, electronic differentiation of a low or high light level passing through each chip can be used to actuate a mechanism to segregate bark and wood (Sturos and Brumm 1978), with the optimum sorting threshold being selected for each species.

Using the computer in this project helped us create an accurate data base. Because of the large quantity of chips required, manually keying the data into the computer would probably have introduced some errors and would have required a more highly trained operator than we used. It also would have required more time to collect the desired data. The present system can readily be modified for making other automatic measurements by simply altering the amplifier circuit.

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Table 1.—*Computer tables of six Lake States species tested*

		THICKNESS (IN)		% TRANSMITTANCE	
		GREEN	DRY	GREEN	DRY
ASPEN					
WOOD	MEAN	.132	.123	13.48	4.55
	ST.DEV.	.032	.030	5.40	1.74
BARK	MEAN	.184	.141	2.79	1.64
	ST.DEV.	.063	.052	1.65	0.78
BALSAM FIR					
WOOD	MEAN	.124	.118	12.46	5.98
	ST.DEV.	.032	.031	7.75	2.31
BARK	MEAN	.203	.171	3.97	3.31
	ST.DEV.	.076	.071	1.71	1.40
MAPLE					
WOOD	MEAN	.139	.130	4.04	2.39
	ST.DEV.	.038	.038	1.82	0.95
BARK	MEAN	.123	.104	2.47	3.27
	ST.DEV.	.028	.026	1.27	1.19
JACK PINE					
WOOD	MEAN	.149	.143	5.72	3.92
	ST.DEV.	.048	.047	2.95	1.81
BARK	MEAN	.112	.080	4.05	3.38
	ST.DEV.	.040	.038	3.41	2.87
RED PINE					
WOOD	MEAN	.141	.137	13.52	4.03
	ST.DEV.	.042	.037	7.64	1.96
BARK	MEAN	.084	.064	7.71	5.29
	ST.DEV.	.041	.037	4.79	4.55
WHITE SPRUCE					
WOOD	MEAN	.120	.119	4.79	3.67
	ST.DEV.	.034	.035	2.07	1.43
BARK	MEAN	.167	.092	2.18	2.45
	ST.DEV.	.028	.025	1.08	1.14

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1983

SHEARING RESTORES FULL PRODUCTIVITY TO SPARSE ASPEN STANDS

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ABSTRACT.—Four mature but grossly understocked (15 to 23 percent of normal) aspen stands were regenerated by suckering following shearing. Eight years later, aspen standing crop varied with site quality from 3.4 to 8.0 tons per acre—nearly the potential for these sites at this age. Shearing is as effective as complete clearcutting for regenerating aspen.

KEY WORDS: *Populus tremuloides*, *Populus grandidentata*, root suckers, regeneration, site preparation.

Mature but sparsely stocked quaking and bigtooth aspen (*Populus tremuloides* Michx., *P. grandidentata* Michx.) stands are difficult to regenerate. Most are economically inoperable because of their low volumes, others because of their remoteness or inaccessibility. Even mechanized timber harvesting, the best known way to regenerate aspen, may not be feasible under some circumstances (Perala 1977). So some other means of eliminating the parent stand and reducing competing trees or tall shrubs is needed to stimulate the initiation and development of root sprouts (suckers) to form a new fully stocked stand (Perala 1977, Schier 1981).

Chainsaw felling, prescribed burning, and poisoning are all useful regeneration tools and each has its advantages and disadvantages. Another possibility is shearing—cutting, and felling trees with a sharp blade mounted on a crawler tractor. Shearing should not be confused with "bulldozing" where trees are merely broken down or uprooted with little or no stimulation of suckering (Forbes and Harvey 1952, Gysel 1957).

Although shearing has been practiced in aspen stands for some time, the minimum stocking required of the parent stand, the soils on which the practice is applicable, and the subsequent development of the sucker stand for timber production have not been documented. To obtain more information on the potential of shearing to regenerate aspen stands, we began a study in 1973 in Sawyer County, Wisconsin. This note summarizes 8 years of aspen development following shearing of understocked aspen stands on soils differing mainly in their drainage characteristics.

METHODS

In April 1973, about a month before the initiation of shoot growth, four aspen stands in Sawyer County, Wisconsin, were sheared using a sharpened Rome[1] K G blade mounted on a D6 Caterpillar tractor. Although the winter snowpack had melted and the ground was not frozen, soil and root disturbance was minimal. Trees were severed and felled in place without windrowing. Much of the shrub layer was crushed by the equipment, but there was no deliberate attempt to uproot or otherwise destroy it.

Because of the small areas treated, time studies were not kept. Current operational shearing rates are about 2 acres per hour.

The stands were all about 50 years old and ranged in site quality from good to poor (Table 1). The soils were silt loams, varying primarily in soil moisture characteristics (Table 2). Moisture is a prime determinant in the productivity of aspen (Perala 1977).

Within each stand, a 2-acre square study area was established and inventoried from four 0.1 acre circular sample plots prior to shearing. In November 1973, after the first year's production of suckers, 25 1-milacre circular plots were used to systematically sample each stand. Numbers and dominant heights of all woody stems were recorded by species. After 8 years' growth, each stand was again inventoried using the method of nonoverlapping triangles (Loetsch *et al*. 1973) on a 4 x 5 (=20) sample point grid. Dominant and codominant aspens measured for total height and d.b.h. defined the corners of the triangles. Intermediate and suppressed aspens and other hardwoods were counted within each triangle. The data were summarized and expanded to an area basis according to Loetsch *et al*. (1973). An index of biomass, BH (basal area x mean height), was computed for the dominant trees. Total aspen BH was estimated from a cumulative BH over cumulative stem number function.[2] Total aspen biomass was estimated from Perala (1973).

RESULTS AND DISCUSSION

The first- and especially the eighth-year inventories showed dramatic responses to shearing and to site quality (Table 3). The number of suckers regenerated and surviving was inversely related to site quality. Indeed, the number of suckers regenerated on the best site was sufficient to give only 68 percent initial stocking. However, by age 8 all stands were fully stocked with 650 to 810 potential crop trees (dominants and codominants) per acre.

Table 1.—*Aspen parent stand characteristics*

Stand	Basal area	Trees per acre	Mean d.b.h.	Total volume[1]	Site index[2]
	Ft²/acre	*Number*	*In.*	*Ft³/acre*	*Ft*
1	21	55	8.3	570 (15)	(70)[3]
2	29	195	5.3	760 (23)	(65)
3	18	145	4.8	460 (15)	63
4	23	183	4.8	470 (22)	52

[1] Numbers in parentheses are percent of "normal" stocking (Perala 1977).

[2] At age 50.

[3] Values in parentheses are estimates based on soil characteristics (Perala 1977); others are measured.

Table 2.—*Soil moisture characteristics (USDA, SCS 1975, 1976)*

Stand	Soil series	Depth to water table	Permeability	Zone of prominent mottles
		Feet		*Inches*
1	ANTIGO	>5	moderate to rapid	none
2	AUBURNDALE	1-3	moderate	6 to 43
3	FREER	1-3	moderately slow	7 to 32
4	FREER	1-3	moderately slow	7 to 32

Height growth and biomass production were directly related to site quality (Table 3). The sucker stand on the Antigo soil was particularly productive and compared favorably with some highly productive stands of the same age reported elsewhere in the U.S. and Canada (Bella and DeFranceschi 1980; Perala 1973, 1979). Even the least productive stands (Freer soil) were growing at full site potential, judging from comparison with aspen biomass yield tables published by Bella and DeFranceschi (1980).

Hardwood stocking was also directly related to the productivity of these soils (Table 3). Hazel (*Corylus cornuta* Marsh.) and willow (*Salix* spp.) were common in all regenerated stands as was alder (*Alnus rugosa* (Du Roi) Spreng.) on the Antigo soil. The shrubs and hardwoods were developing as an understory beneath the aspens.

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[1] *Mention of trade names is for the convenience of the reader and does not constitute endorsement by the USDA Forest Service over other products equally suitable.*

[2] *On file, Forestry Sciences Laboratory, Grand Rapids, MN.*

Table 3.—*Regeneration and sucker development*

Stand	Age 1 stocking	Dominant height		Total aspen stem density		Hardwood[2] stem density	Aspen biomass, age 8			
		Age 1	Age 8	Age 1	Age 8	Age 8	D&C[3]	I&S[4]	Total	Total annual productivity
	Percent[1]	----*Feet*----		-----*Number/acre*-----			---------*Dry tons/acre*---------			
1	68	3.9	30	5,700	1,500	3,200	6.2	1.8	8.0	1.0
2	100	4.6	25	9,800	2,300	850	3.5	2.3	5.8	0.7
3	100	4.3	20	11,900	3,400	740	2.3	1.9	4.2	0.5
4	96	4.6	18	20,500	3,500	560	1.5	1.9	3.4	0.4

[1] Milacre basis.

[2] Northern red oak (*Quercus rubra* L.), paper birch (*Betula papyrifera* Marsh.), red maple (*Acer rubrum* L.).

[3] Dominants and codominants.

[4] Intermediates and suppressed.

This study did not define the lower limit of parent aspen stocking needed for successful regeneration of aspen stands, but it is in the neighborhood of 55 aspens or 18 ft^2 of basal area per acre. Another study (Perala 1981) showed that stocking density of quaking aspen suckers is not diminished up to 17 ft away from mature parent trees. This means that about 50 aspens per acre are needed to provide fully productive stands. That study also showed that sucker stocking was still about 325 stems per acre at 30 ft away. Therefore, about 15 trees per acre will regenerate an irregularly stocked stand that may be acceptably productive, and most likely fully productive after another regeneration cut. For bigtooth aspen, higher parent stand stocking is needed (Perala 1981). Obviously, regular spacing of parent trees is just as important as density to assure full, uniform sucker stocking.

CONCLUSIONS

Shearing is highly effective in restoring full productivity to severely understocked aspen stands. Based on the relatively high productivity of these sucker stands, there is no reason to believe that shearing is any less effective than complete clearcutting for regenerating aspen. The success of shearing can be attributed mostly to the same reasons that make clearcutting so effective—*i.e.*, the elimination of the aspen overstory which encourages suckering by relieving the apical dominance effect and by allowing warming of the soil with the reduction in shade (Perala 1977, Schier 1981). Reduction of competition by shrubs may have secondary importance.

This study showed that frozen ground is not essential for shearing, if care is taken to avoid excessive scarification and disturbance to aspen roots. However, research is needed to determine if resistance to uprooting and soil compaction differs significantly among soil textures and moisture regimes.

This study was not designed to determine if shearing effectiveness varies between dormant and growing season. Laboratory and greenhouse studies (Schier 1981) suggest that the period of most active shoot growth (when aspen root carbohydrate levels and, therefore, sucker growth potential are lowest) may be the most sensitive. Field studies by Stoeckeler (1947) and Zehngraff (1946) found reduced sucker numbers and height growth following summer cutting of aspen. Thus, shearing anytime during the dormant period from leaf coloration to bud burst would seem to be most prudent.

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ADJUSTING THE STEMS REGIONAL FOREST GROWTH MODEL TO IMPROVE LOCAL PREDICTIONS

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ABSTRACT.—A simple procedure using double sampling is described for adjusting growth in the STEMS regional forest growth model to compensate for subregional variations. Predictive accuracy of the STEMS model (a distance-independent, individual tree growth model for Lake States forests) was improved by using this procedure.

KEY WORDS: Growth model, double sampling, ratio estimators.

In recent years much effort has been expended to create mathematical models capable of accurately predicting the dynamic processes of forest growth (Fries 1974). Several of these models have been fitted to data from wide geographic areas and broad ranges of site and stand conditions (Arney 1974, Ek and Monserud 1974, Stage 1973, USDA Forest Service 1979).

Frequently, it is desirable to "extend" a model slightly beyond the geographic area for which it was calibrated or to use it intensively within a small portion of the stated range. However, the model may perform poorly for these applications.

When a regional growth model is calibrated using permanent growth plot remeasurement data, the resulting coefficients generally reflect the average of the natural forces operating in that geographic area during the period between remeasurements. Thus, predictions may deviate when the growth model is applied intensively to a subregion within or slightly beyond the geographic range of the model, hence making the regional coefficients inappropriate.

To compensate for such variations, it is seldom practical to recalibrate the entire model. Indeed, all that may be needed is to "fine tune" or "self-calibrate" the existing regional model to improve performance in the subregion or extended area (Stage 1973). This paper describes a simple way to adjust the STEMS regional growth model to compensate for subregional variation.

STEMS is a distance-independent, individual tree growth model currently calibrated for two major geographic areas: the Pacific Northwest and the Lake States (Belcher *et al.* 1981, Shifley 1981, USDA Forest Service 1979, Ek *et al.* 1980, Hahn *et al.* 1979, Smith and Raile 1979, Lundgren and Essex 1979). The Lake States model was calibrated with remeasurement data from approximately 1,500 permanent plots containing 93,000 trees in Minnesota, Wisconsin, and Michigan (Christensen *et al.* 1979). Subsequent validation tests revealed that as one progresses south and east in the Lake States, the predictive power of the Lake States STEMS model diminishes (Leary *et al.* 1979). At the time the model was developed, calibration data were not available from the Upper Peninsula of Michigan and only conifer plantation data were available from the Lower Peninsula. Thus, in effect, applications in Michigan are "extensions" of the current STEMS model.

During the course of a recent field survey in the Upper Peninsula of Michigan, 415 permanent inventory plots that had been previously measured in 1965 were remeasured in 1979. The 8,000 trees on these plots provided the data to calculate growth adjustment factors to improve the predictions of STEMS in this subregion.

METHODS TO ESTIMATE ADJUSTMENTS

Measurements made in 1965 on the 415 permanent plots formed the basis for a 14-year projection by the STEMS model. The projected tree data were then compared with the data from the 1979 remeasurement to produce a file of initial and final observed d.b.h. and final predicted d.b.h. The file of predicted and observed values was then divided into diameter classes by species group. A correction factor was derived for each species group and diameter class where the data indicated measurable deviation from the growth of the model. This method is an application of double sampling with ratio of means estimators (Cochran 1977).

The diameter increment adjustment, applied to the annual predicted diameter increment, was derived from the following function:

$$GR_{ij} = \frac{\bar{y}_{ij}}{\bar{x}_{ij}}$$

where: GR = annual adjustment factor for diameter increment,
i = *ith* species group,
j = *jth* d.b.h. class,
$\bar{y}$ = mean difference of initial and final observed diameters, and
$\bar{x}$ = mean difference of initial observed and final predicted diameters.

Following the derivation of the adjustment factors for growth, a totally independent data set of 9,000 trees from 419 permanent remeasurement plots in the Upper Peninsula of Michigan was used to test the "tuned" STEMS model. The plots were initially measured in 1964 and 1965 and remeasured in 1975.

Validation tests of the adjusted and unadjusted STEMS model were made by comparing prediction errors of the two models for stand basal area and numbers of trees by forest type, and diameter increment by species. Mean annual prediction error and standard deviation were used as measures of bias and precision of the estimates, respectively.

RESULTS AND DISCUSSION

The annual adjustment rates for diameter increment reflect the magnitude of the subregional deviation from the regionally calibrated model by species group and diameter class (table 1). For all forest types, annual basal area prediction error after adjustments decreased nearly five-fold, from an overprediction of 0.60 square feet per acre per year to an overprediction of 0.13 square feet per acre per year (table 2). All forest types except northern white-cedar, oak, and lowland hardwoods improved in precision or bias, and 8 of the 14 types simultaneously reduced bias and increased precision.

Overall, d.b.h. prediction error for the adjusted STEMS model improved 94 percent, from an annual error of 0.033 inches to (-)0.002 inches (table 3). Adjustments by species produced a simultaneous decrease in bias and increase in precision for 16 of the 23 species included in the validation data. Thus, the adjustments to the model reduced bias and increased precision of basal area and d.b.h. predictions, while only modestly changing predictions for number of trees. An overall change in bias was expected, because the adjustments were essentially linear. However, we assumed that the changes in precision were primarily the effect of modified species interactions resulting from the adjustments or the separate ratios by d.b.h. class.

Table 1.—*STEMS annual growth increment adjustment factors for the Upper Midwest Peninsula of Michigan.*

		Annual diameter increment adjustment factor		
		DBH class		
Species group	**Trees**	**1.0-4.9**	**5.0-14.9**	**15.0-24.9**[1]
	Number			
Jack pine	116	0.8926	0.8107	1.0000
Red pine	62	1.1430	.8954	.6489
White pine	88	1.0000	1.5620	1.6745
White spruce	97	.7386	.6905	1.0000
Balsam fir	429	.8313	.8314	1.0000
Black spruce	159	.7082	.7307	1.0000
Tamarack	51	1.2785	1.8116	1.0000
N. white-cedar	608	.7167	.6372	.5917
Hemlock	243	1.1327	1.1702	.8357
Black ash	260	1.7230	1.3585	1.0000
Red maple	749	.8486	.7797	.7772
Elm	97	.9675	.6521	.4938
Yellow birch	321	1.5898	.9637	.9617
Basswood	134	.5418	.6648	.4966
Sugar maple	1,537	.6622	.6975	.8297
Red oak	38	1.0000	.8188	.8100
Bigtooth aspen	81	1.0000	.7760	1.0000
Quaking aspen	440	1.9135	.7408	.6747
Paper birch	245	1.3005	.7190	1.4168
Other hardwoods	184	.9632	.5771	1.0000
Noncommercial	65	.4646	.2228	1.0000

[1] Data insufficient to compute adjustments for trees greater than 25 inches DBH.

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Table 3.—*Average annual prediction errors for growth increment by species for the STEMS model (unadjusted and adjusted) in the Upper Peninsula of Michigan*

		Growth increment annual prediction error			
		Unadjusted		Adjusted	
Species	**Observations**	**Mean**	**s**	**Mean**	**s**
	Number	*Inches*			
Jack pine	205	0.036	0.060	0.009	0.060
Red pine	157	−.018	.070	−.044	.066
White pine	149	.105	.103	−.001	.094
White spruce	247	.131	.109	.042	.097
Balsam fir	631	.010	.065	−.012	.063
Black spruce	462	.010	.047	−.009	.045
Tamarack	44	−.008	.051	.071	.066
N. white-cedar	555	.028	.046	−.011	.045
Hemlock	188	.019	.066	.028	.064
Black ash	44	.035	.056	.080	.079
Red maple	568	.025	.064	−.003	.059
Elm	61	.029	.105	−.041	.093
Yellow birch	247	.008	.064	.007	.062
Basswood	108	−.001	.075	−.042	.070
Sugar maple	438	.020	.066	−.023	.062
White ash	6	−.006	.089	.006	.091
Red oak	98	.001	.067	−.032	.085
Bigtooth aspen	137	.039	.071	−.004	.063
Quaking aspen	1,019	.058	.074	.003	.069
Paper birch	555	.033	.050	−.001	.049
Other hardwoods	129	.034	.075	.037	.073
Noncommercial	24	.082	.032	−.020	.023
All species	6,012	.033	.074	−.002	.067

were available to calculate factors in the method presented, 32 percent (37 of 132) of the correction factor cells had insufficient data to determine an adjustment (cells containing an adjustment factor of 1.0000 in table 1). This does not include the d.b.h. classes for trees more than 25 inches in diameter that had no cells with sufficient data to calculate a correction factor. An alternative solution would be to derive a single adjustment factor for each species rather than for each species and diameter class. This would reduce the amount of calibration data needed.

It is important to realize that information not available during the original calibration may be added during the adjustment process. Valuable time need not be spent recalibrating the entire model. The calibration data, however, should be representative of the size and vigor of the species to which the adjustment will be applied.

The predictive ability of the STEMS growth model in the Upper Peninsula of Michigan was significantly improved using simple correction factors derived from a recent set of remeasurement data. These adjustment factors transformed the STEMS regional growth model into a more powerful local growth model.

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Table 2.—*Average annual prediction errors for basal area and number of trees by forest type for the STEMS model (unadjusted and adjusted) in the Upper Peninsula of Michigan*

		Annual basal area prediction error				Annual number of trees prediction error			
		Unadjusted		Adjusted		Unadjusted		Adjusted	
Forest Type	**Plots**	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**
	Number	*Feet ^{2}/acre/year*				*Number of trees/acre/year*			
Jack pine	25	0.74	1.13	0.48	0.96	4.75	9.72	4.47	9.31
Red pine	16	.44	1.09	– .71	.91	–1.51	6.88	– .80	4.93
White pine	9	.96	.82	.13	.68	.18	.48	.18	.72
Hemlock	8	.18	1.03	– .12	1.09	–1.41	3.73	1.18	3.82
Balsam fir	22	1.18	1.97	.67	1.84	4.15	8.26	4.16	8.24
Black spruce	27	.49	.61	.22	.55	1.43	4.57	1.66	4.43
Tamarack	30	.76	1.06	.20	.92	– .70	11.77	–1.26	6.68
N. white – cedar	4	– .07	.26	– .25	.33	– .35	.42	– .14	.16
White spruce	6	.97	1.24	– .07	1.08	– .18	1.45	– .59	1.47
Oak	5	.12	.64	– .23	.56	1.67	5.47	1.70	5.43
Lowland hardwoods	5	.10	.60	– .37	.80	– .07	.78	–2.40	4.53
Northern hardwoods	85	.50	1.00	.01	.98	1.00	5.54	.97	5.92
Aspen	162	.65	.79	.15	.77	.36	2.19	.36	2.14
Birch	15	1.16	.67	.53	.77	– .39	2.64	.34	4.55
All species	419	0.60	1.02	0.13	0.95	0.80	5.69	0.82	5.09

Residual analysis regressing periodic d.b.h. prediction errors of the adjusted and unadjusted STEMS models with initial basal area (X_1), initial average stand diameter (X_2), initial site index (X_3), initial tree crown ratio (X_4), and initial tree d.b.h.(X_5) was performed using the following test model:

residuals=

$$B_0 + B_1 X_1 + B_2 X_2 + B_3 + B_4 X_4 + B_5 X_5 + e. \quad (1)$$

Most of the variables and their cross products were significant for both the adjusted and unadjusted STEMS models, but the variability explained in each case was minimal (0.04 vs. 0.08 percent according to R^2 values for the adjusted and unadjusted models, respectively). This seems to indicate that a variable or relation not currently considered in the STEMS model may play a significant role in describing the growth process.

Further residual analysis at the tree level indicated that for 10-year periodic diameter increments of 1.5 inches or less, the adjusted model was 81 percent more accurate in explaining prediction error variability (R^2 values of 0.31 and 0.56 for the unadjusted and adjusted models, respectively) and also had a smaller prediction error.

Although STEMS was designed as an individual-tree projection system, predictions of plot characteristics such as basal area and number of trees are also important. Predicted changes in number of trees were 22 percent more accurate with the adjusted model than the unadjusted model (R^2 values of 0.46 vs 0.56 for the unadjusted and adjusted models respectively). And predicted basal area was 4 percent more accurate with the adjusted model (R^2 values of 0.57 and 0.59, respectively).

Overall, the analysis indicates that the adjusted STEMS model is a better prediction tool for Michigan.

CONCLUSION

The value of the adjustment process lies in adjusting species when evidence is sufficient to do so. Species for which subregional data are insufficient to determine measurable deviation or for which no significant deviation exists would rely on the regional model calibration to fill in the gaps, thus providing the user with a more powerful "local" model. This process should be of particular interest to STEMS users who own or manage large forest holdings in concentrated areas and have some basic remeasurement information available.

The success of model adjustment ultimately hinges on availability of sufficient quantities of recent remeasurement data for calibrating and validating the selected procedure. Note that even though 8,000 trees

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FOREST AREA IN KANSAS, 1981

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ABSTRACT.—The 1981 forest inventory of Kansas showed that 2.6 percent of the total land area is forested. Commercial forest land accounted for 89 percent or 1,207,900 acres of the forest land and oak-hickory is the major forest type. An important Kansas resource are the 150,000 acres of natural wooded strips.

KEY WORDS: Commercial forest land, noncommercial forest land, wooded strips, land use, forest type.

The forest land of Kansas occupies 1.4 million acres, about 2.6 percent of the total land area (table 1). Forest land can be broken down into two elements: commercial and noncommercial forest land. Commercial forest land—that suitable for producing industrial timber—accounts for 1,207,900 acres (89 percent) of the forest land in Kansas. This is an increase of 16,400 acres (1.4 percent) since the last inventory.

LAND USE	1965[1]	1981
	(Thousand acres)	
Forest		
Commercial	1,191.5	1,207.9
Noncommercial		
Unproductive	157.4	128.4
Productive-reserved	0.9	22.4
Total forest	1,349.8	1,358.7
Nonforest	51,160.9	50,979.3
Total land	[2]52,510.7	[3]52,338.0

Noncommercial forest land in Kansas amounted to 150,800 acres in 1981. Of this amount, 22,400 acres were productive but reserved for uses other than timber production such as parks and natural areas. The remaining 128,400 acres are unproductive forest land too poor to grow timber for industrial use.

Most of the commercial forest land occurs in the eastern part of the State along the Missouri River and several other rivers (fig. 1). Linn County, located in the Southeastern Unit of the State, contains 48,700 acres of commercial forest land—more than any other county in the State (table 1). And Leavenworth County in the Northeastern Unit has the largest percentage of commercial forest with 14.6 percent.

Oak-hickory makes up 26.2 percent of the commercial forest area and is the largest forest type, elm-ash-cottonwood accounts for 24.0 percent of the commercial forest area and is the second largest forest type, willow makes up 0.3 percent of the commercial forest area and is the smallest forest type:

Forest type	Area of commercial forest land (Thousand acres)
Oak-hickory	316.6
Elm-ash-cottonwood[4]	289.6
Lowland plains hardwoods	265.9
Elm-ash-locust	110.3
Cottonwood[5]	68.1
Upland plains hardwoods	49.4
Post-blackjack oak	30.9
Eastern redcedar-hardwoods	27.5
Willow	4.2
Nonstocked	45.4
Total	1,207.9

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[1] *1965 data have been adjusted to be compatible with 1981 data due to changes in definitions between surveys.*

[2] *From U.S. Bureau of Census. 1960.*

[3] *From U.S. Bureau of Census. 1980.*

[4] *Elm-ash-cottonwood type is a lowland forest in which elm, ash, cottonwood, and willow, singly or in combination, comprise a plurality of the stocking.*

[5] *Cottonwood type is forest in which cottonwood comprises a majority of the stocking.*

Table 1.–*Area of land, forest land, and nonforest land with trees by county, Kansas, 1981*

NORTHEASTERN UNIT

		Forest land[2]				Nonforest land with trees[5]			
County	Land area[1]	All forest	Non-commercial[3]	Commercial[4]		All	Wooded strips[6]	Other	
	Thousand acres				*Percent*	*Thousand acres*			*Percent*
Atchison	275.7	24.8	1.0	23.8	8.6	8.3	1.8	6.5	3.0
Brown	365.8	19.7	1.0	18.7	5.1	9.5	1.3	8.2	2.6
Clay	404.2	16.0	0.7	15.3	3.8	5.0	0.9	4.1	1.2
Dickinson	545.4	14.0	0.5	13.5	2.5	7.0	1.2	5.8	1.3
Doniphan	248.0	29.9	1.2	28.7	11.6	12.9	1.9	11.0	5.2
Douglas	294.9	30.0	1.9	28.1	9.5	20.5	2.5	18.0	7.0
Franklin	369.4	27.3	1.6	25.7	7.0	14.6	2.5	12.1	4.0
Geary	241.2	21.1	2.5	18.6	7.7	9.5	1.5	8.0	3.9
Jackson	420.9	33.5	1.1	32.4	7.7	24.2	6.4	17.8	5.7
Jefferson	342.6	43.5	2.5	41.0	12.0	22.6	3.0	19.6	6.6
Johnson	305.9	27.4	1.4	26.0	8.5	13.7	2.1	11.6	4.5
Leavenworth	296.0	45.8	2.5	43.3	14.6	23.2	5.9	17.3	7.8
Marshall	561.7	31.5	1.8	29.7	5.3	30.4	4.0	26.4	5.4
Miami	377.5	47.9	1.6	46.3	12.3	23.0	5.2	17.8	6.1
Nemaha	459.9	16.9	0.6	16.3	3.5	7.3	1.8	5.5	1.6
Osage	444.7	34.4	3.2	31.2	7.0	21.1	3.4	17.7	4.7
Pottawatomie	529.8	44.4	3.5	40.9	7.7	20.4	3.7	16.7	3.9
Riley	379.6	35.0	2.8	32.2	8.5	20.1	2.2	17.9	5.3
Shawnee	351.2	26.9	1.3	25.6	7.3	14.8	2.2	12.6	4.2
Wabaunsee	510.1	31.8	2.5	29.3	5.7	15.7	3.2	12.5	3.1
Washington	575.0	14.8	0.5	14.3	2.5	18.4	5.4	13.0	3.2
Wyandotte	95.4	7.6	0.4	7.2	7.5	1.8	0.5	1.3	1.9
All counties	8,394.9	624.2	36.1	588.1	7.0	344.0	62.6	281.4	4.1
SOUTHEASTERN UNIT									
Allen	323.3	11.4	1.4	10.0	3.1	17.3	2.2	15.1	5.4
Anderson	373.5	19.5	3.9	15.6	4.2	18.9	2.1	16.8	5.1
Bourbon	408.4	43.4	8.3	35.1	8.6	48.1	2.0	46.1	11.8
Butler	923.7	24.1	2.9	21.2	2.3	36.4	6.5	29.9	3.9
Chase	497.2	10.5	0.6	9.9	2.0	14.4	2.1	12.3	2.9
Chautauqua	412.0	67.8	19.3	48.5	11.8	29.3	3.0	26.3	7.1
Cherokee	377.9	27.0	5.0	22.0	5.8	27.1	2.8	24.3	7.2
Coffey	393.6	12.5	2.5	10.0	2.5	13.8	0.9	12.9	3.5
Cowley	721.7	28.1	2.8	25.3	3.5	14.4	2.9	11.5	2.0
Crawford	380.7	24.2	2.4	21.8	5.7	27.2	3.3	23.9	7.1
Elk	416.0	37.4	9.7	27.7	6.7	16.7	1.5	15.2	4.0
Greenwood	726.2	29.0	3.8	25.2	3.5	34.5	5.1	29.4	4.8
Labette	417.8	20.2	4.2	16.0	3.8	18.2	1.0	17.2	4.4
Linn	384.5	56.6	7.9	48.7	12.7	24.9	3.2	21.7	6.5
Lyon	540.5	12.4	1.2	11.2	2.1	11.5	2.4	9.1	2.1
Marion	604.2	9.3	1.9	7.4	1.2	6.6	0.8	5.8	1.1
Montgomery	413.3	29.4	6.5	22.9	5.5	19.7	2.2	17.5	4.8
Morris	443.3	7.8	0.9	6.9	1.6	6.8	1.4	5.4	1.5
Neosho	368.7	17.1	3.3	13.8	3.7	16.2	1.1	15.1	4.4
Wilson	368.0	32.8	7.6	25.2	6.8	40.8	2.3	38.5	11.1
Woodson	318.8	15.8	3.2	12.6	4.0	15.2	1.5	13.7	4.8
All counties	9,813.3	536.3	99.3	437.0	4.5	458.0	50.3	407.7	4.7
WESTERN UNIT									
Barber	727.2	6.9	0.3	6.6	0.9	17.5	2.2	15.3	2.4
Barton	573.1	1.1	—	1.1	0.2	0.5	0.1	0.4	0.1
Cheyenne	653.4	2.7	—	2.7	0.4	6.2	1.7	4.5	0.9
Clark	624.0	5.1	0.4	4.7	0.8	8.3	0.6	7.7	1.3
Cloud	459.3	8.7	0.1	8.6	1.9	5.5	0.1	5.4	1.2
Comanche	504.8	1.2	0.2	1.0	0.2	5.8	0.4	5.4	1.1
Decatur	572.0	2.3	—	2.3	0.4	2.1	0.8	1.3	0.4
Edwards	396.5	1.7	—	1.7	0.4	1.3	0.2	1.1	0.3
Ellis	576.3	2.7	—	2.7	0.5	4.0	0.3	3.7	0.7
Ellsworth	458.9	3.1	—	3.1	0.7	3.0	0.6	2.4	0.7
Finney	833.3	0.4	—	0.4	—	0.4	0.1	0.3	—
Ford	703.2	0.9	0.2	0.7	0.1	5.7	0.4	5.3	0.8
Gove	686.0	0.1	—	0.1	—	1.8	—	1.8	0.3
Graham	575.0	4.9	0.2	4.7	0.8	7.4	1.0	6.4	1.3
Grant	368.1	0.3	0.2	0.1	—	2.9	0.1	2.8	0.8

(table 1 continued on next page)

(table 1 continued)

WESTERN UNIT

County	Land area[1]	Forest land[2]				Nonforest land with trees[5]			
		All forest	Non-commercial[3]	Commercial[4]		All	Wooded strips[6]	Other	
	Thousand acres				*Percent*	*Thousand acres*			*Percent*
Gray	555.2	2.3	—	2.3	0.4	0.5	0.1	0.4	0.1
Greeley	498.2	0.1	—	0.1	—	0.3	—	0.3	0.1
Hamilton	638.4	3.5	0.2	3.3	0.5	3.0	0.4	2.6	0.5
Harper	513.3	5.1	0.4	4.7	0.9	17.7	1.4	16.3	3.4
Harvey	345.9	1.9	0.2	1.7	0.5	6.8	0.7	6.1	2.0
Haskell	369.7	—	—	—	—	—	—	—	—
Hodgeman	550.7	—	—	—	—	0.1	—	0.1	—
Jewell	582.2	11.1	1.3	9.8	1.7	12.1	1.5	10.6	2.1
Kearny	555.3	0.7	0.2	0.5	0.1	0.3	—	0.3	0.1
Kingman	553.9	8.0	1.0	7.0	1.3	21.6	1.6	20.0	3.9
Kiowa	462.6	0.7	0.1	0.6	0.1	2.5	1.2	1.3	0.5
Lane	459.1	0.1	—	0.1	—	—	—	—	—
Lincoln	460.6	3.3	0.2	3.1	0.7	8.1	0.9	7.2	1.8
Logan	686.9	1.0	—	1.0	0.1	0.4	0.1	0.3	0.1
McPherson	576.1	4.0	0.2	3.8	0.7	6.0	0.7	5.3	1.0
Meade	626.3	2.1	0.2	1.9	0.3	1.6	0.1	1.5	0.3
Mitchell	459.1	8.4	1.4	7.0	1.5	24.8	1.5	23.3	5.4
Morton	467.9	2.6	0.2	2.4	0.5	1.6	0.4	1.2	0.3
Ness	687.7	0.4	—	0.4	0.1	0.1	—	0.1	—
Norton	558.6	3.3	0.3	3.0	0.5	5.7	0.7	5.0	1.0
Osborne	564.4	6.5	0.2	6.3	1.1	6.1	0.7	5.4	1.1
Ottawa	461.3	7.3	0.6	6.7	1.5	9.0	0.3	8.7	2.0
Pawnee	483.1	2.3	0.4	1.9	0.4	8.5	1.6	6.9	1.8
Phillips	567.5	7.4	1.4	6.0	1.1	22.4	1.7	20.7	3.9
Pratt	470.5	1.6	—	1.6	0.3	0.6	0.1	0.5	0.1
Rawlins	684.4	2.2	0.2	2.0	0.3	1.8	0.4	1.4	0.3
Reno	805.6	7.3	1.0	6.3	0.8	23.9	0.9	23.0	3.0
Republic	459.9	8.7	0.5	8.2	1.8	10.8	0.9	9.9	2.3
Rice	465.9	1.8	0.2	1.6	0.3	3.4	0.2	3.2	0.7
Rooks	568.7	6.9	0.5	6.4	1.1	16.3	1.4	14.9	2.9
Rush	459.5	0.1	—	0.1	—	0.2	0.1	0.1	—
Russell	556.4	4.6	0.1	4.5	0.8	1.5	0.2	1.3	0.3
Saline	461.6	3.4	0.3	3.1	0.7	9.0	0.4	8.6	1.9
Scott	459.2	0.1	—	0.1	—	—	—	—	—
Sedgewick	644.7	8.0	1.2	6.8	1.1	19.1	0.7	18.4	3.0
Seward	409.7	2.1	0.1	2.0	0.5	3.1	0.6	2.5	0.8
Sheridan	573.5	1.2	—	1.2	0.2	0.6	0.1	0.5	0.1
Sherman	676.4	—	—	—	—	—	—	—	—
Smith	574.0	3.6	—	3.6	0.6	5.7	3.9	1.8	1.0
Stafford	504.0	3.7	0.2	3.5	0.7	10.1	0.4	9.7	2.0
Stanton	435.6	—	—	—	—	0.9	—	0.9	0.2
Stevens	465.6	0.6	—	0.6	0.1	0.4	0.1	0.3	0.1
Sumner	757.4	15.7	0.5	15.2	2.0	39.6	2.1	37.5	5.2
Thomas	687.7	0.3	—	0.3	—	0.2	—	0.2	—
Trego	569.8	1.8	0.3	1.5	0.3	5.9	0.3	5.6	1.0
Wallace	584.7	0.3	0.2	0.1	—	2.6	0.1	2.5	0.4
Wichita	459.9	—	—	—	—	—	—	—	—
All counties	34,129.8	198.2	15.4	182.8	0.5	387.3	37.1	350.2	1.1
All units	52,338.0	1,358.7	150.8	1,207.9	2.3	1,189.3	150.0	1,039.3	2.3

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[1] U.S. Bureau of Census. 1980.

[2] Land at least 16.7 percent stocked by forest trees of any size or land formerly having such tree cover, excludes land currently developed for nonforest use such as urban or heavily settled residential or resort area, city parks, orchards, improved roads, or improved pasture. The minimum forest area classified was 1 acre. Roadside, streamside, and shelterbelt strips of timber with a crown at least 120 feet wide and unimproved roads and trails, streams, and clearings in forested areas if less than 120 feet wide were classified as forest.

[3] Unproductive forest land incapable of yielding crops of industrial wood because of adverse site conditions, and productive public forest land withdrawn from commercial timber production through statute or administrative regulation.

[4] Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation.

[5] Area of land with trees but less than 16.7 percent stocked, and/or area less than 120 feet wide, i.e., cropland with scattered trees, improved pasture with scattered trees, wooded strips, windbreaks, and idle farmland with scattered trees.

[6] An acre or more of continuous forest land that would otherwise meet the standards for commercial forest land except that it is less than 120 feet wide.

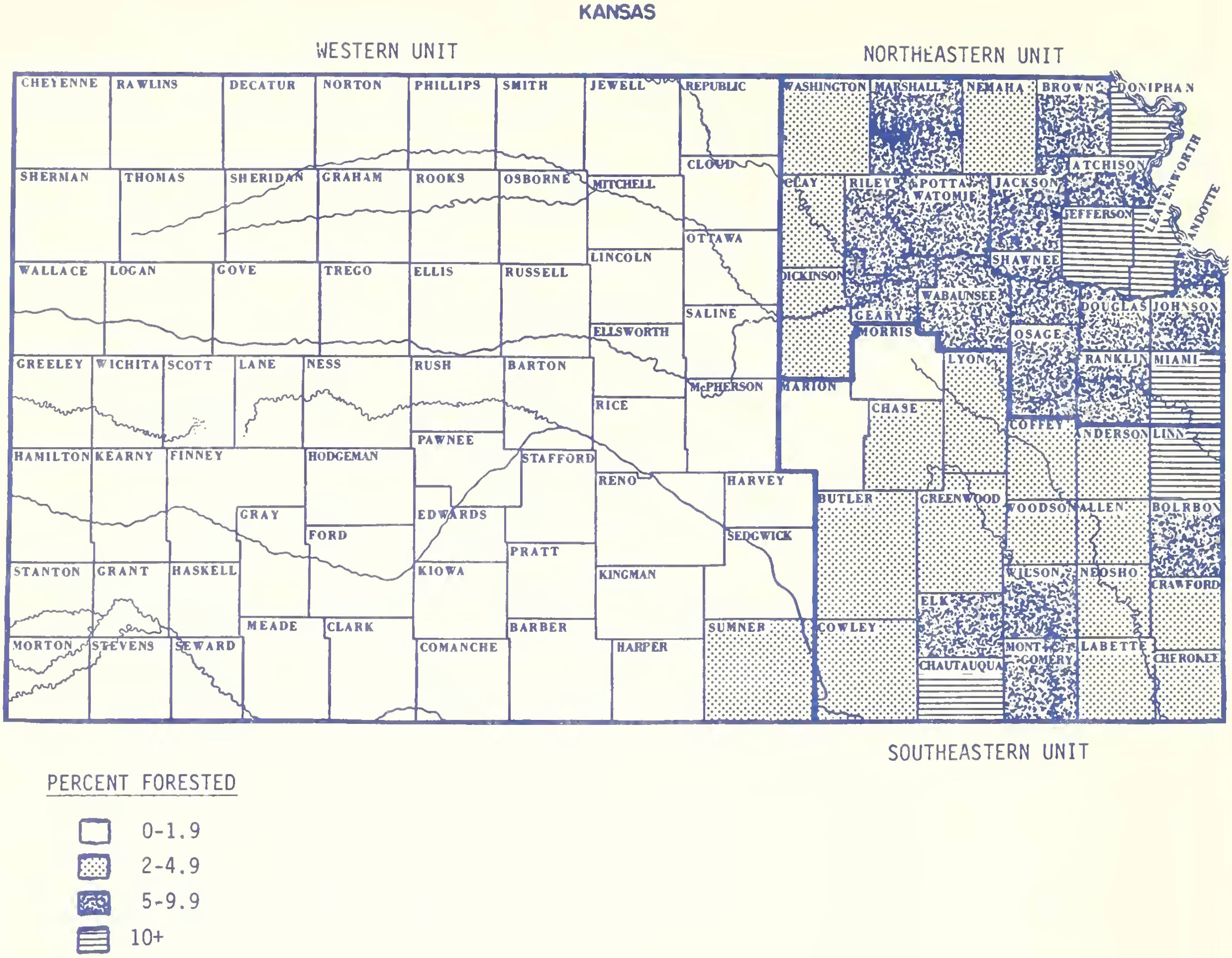

Figure 1.–*Percent of commercial forest land by county, Kansas, 1981.*

An important Kansas resource not included in the forest land area is the nonforest with trees category, and particularly the 150,000 acres of natural wooded strips. These areas meet all the requirements for commercial forest land except they are less than 120 feet wide:

Nonforest with trees land class	**Area of nonforest with trees** (Thousand acres)
Improved pasture or rangeland with scattered trees[6]	533.6
Wooded pasture[7]	209.8
Windbreaks[8]	186.3
Natural wooded strips	150.0
Cropland with scattered trees	63.0
Idle farmland with scattered trees	23.9
Marshland with scattered trees	22.7
Total	1,189.3

The information in this note comes from the third Kansas forest inventory made during 1980 and 1981 by the North Central Forest Experiment Station and the Kansas State and Extension Forester's office.

Sampling error for this survey was 2.45 percent for the area of commercial forest land.

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[6] *Improved pasture or rangeland with trees—land currently improved for grazing by cultivating, seeding, irrigating, or clearing of trees or brush, that is less than 16.7 percent stocked with all trees.*

[7] *Wooded pasture—pasture land with more than 16.7 percent stocking in all trees, but less than 25 percent stocking in growing-stock trees, and would qualify as pastured commercial forest land except that the primary land use is grazing. Evidence of grazing is severely compacted soil and heavily browsed herbaceous and woody understory.*

[8] *Windbreaks—a group of trees less than 120 feet wide primarily used for protecting buildings, soil, and cropland.*

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ALLOMETRIC BIOMASS EQUATIONS FOR 98 SPECIES OF HERBS, SHRUBS, AND SMALL TREES

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ABSTRACT.—Biomass regression coefficients from the literature for the allometric equation form are presented for 98 species of shrubs and herbs in the northern U.S. and Canada. The equation and coeffients provide estimates of grams of biomass (ovendry weight) for foliage, woody stem and total biomass.

KEY WORDS: Regression, metric, dry weight, herbs, shrubs.

Biomass estimates for herbs and shrubs have many uses in determining wildlife habitat and forest fuel conditions. Although many independent variables and equations have been chosen in biomass studies, the simple allometric equation is most frequently used (Stanek and State 1978, Hitchcock and McDonnell 1979). This equation for predicting biomass in grams (Y) from stem diameter or percent cover (X) has two forms:

$$Y = aX^b \quad (1)$$

or

$$\ln Y = a + b\ln X, \quad (2).$$

The purpose of this paper is to compile coefficients for these equations for species in eastern Canada and the northern United States from seven sources (Telfer 1969, Grigal and Ohmann 1977, Ohmann *et al.* 1976, Brown 1976, Roussopoulos and Loomis 1979, Ohmann *et al.* 1981, Connolly 1981).

For convenience, Eq. 2 may be put in the form of Eq. 1 by solving for Y and transforming the coefficients. The new equation becomes:

$$Y = a' X^b \quad (3)$$

where $a' = e^a$ and coefficients a and b are the same as in Eq. 2. The equation coefficients from Ohmann *et al.* (1976), Grigal and Ohmann (1977), Roussopoulos and Loomis (1979), Ohmann *et al.* (1981), and Connolly (1981) are taken directly from the original sources. Telfer (1969) and Brown (1976) reported coefficients for the logarithmic form, which we converted. Telfer's coefficients were additionally adjusted to convert the independent variable from basal diameter in mm to cm. Thus, for Telfer $a' = e^a\ 10^b$ in Eq. 3.

Roussopoulos and Loomis fit their data to Eq. 2 but converted these coefficients after correcting for the bias inherent in the fitting of the logarithmic form (Baskerville 1972, Yandle and Wiant 1981). Brown indicated that the effects of this bias on his biomass estimates ranged from 2 to 9 percent with an average of 5 percent. The coefficients presented by Brown are unadjusted for bias, as are those presented by Telfer. All coefficients presented are for estimating biomass in grams ovendry weight.

One caution is necessary: some of the equations use stem diameter at 15 cm as the independent variable and others use basal diameter. Roussopoulos and Loomis (1979) present a regression technique for estimating basal diameter at 15 cm, thereby facilitating the use of basal diameter equations even though field measurements may have been collected at 15 cm.

Refer to the original publications for details about methods, specific locations of data sources, or any other questions regarding the biomass studies.

Table 1.--Coefficients and related statistics for the allometric relationship, Biomass = aX^b

Species	Biomass[1/] key	Independent[2/] variable (x)	Coefficients		Number of observations	R^2	Range of independent variable	Location[3/]	Source
			a	b					
Tree seedlings and saplings									
Abies balsamea	T	D2	72.715	2.250	25	0.96	0.50-3.30	MN	Roussopoulos and Loomis (1979)
	W	D2	42.904	2.404	25	.97	0.50-3.30	MN	Roussopoulos and Loomis (1979)
	F	D2	29.319	2.011	25	.94	0.50-3.30	MN	Roussopoulos and Loomis (1979)
Acer rubrum	W	D2	21.730	3.654	10	.91	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	60.367	2.342	36	.94	0.30-4.10	MN	Roussopoulos and Loomis (1979)
	W	D2	45.947	2.505	36	.93	0.30-4.10	MN	Roussopoulos and Loomis (1979)
	F	D2	13.082	1.840	36	.91	0.30-4.10	MN	Roussopoulos and Loomis (1979)
Betula papyrifera	W	D2	22.865	3.502	10	.76	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	3.421	1.838	4	.99	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	76.316	2.279	23	.93	1.30-3.60	MN	Roussopoulos and Loomis (1979)
	W	D2	62.830	2.378	23	.93	1.30-3.60	MN	Roussopoulos and Loomis (1979)
	F	D2	14.717	1.529	23	.66	1.30-3.60	MN	Roussopoulos and Loomis (1979)
Fagus grandifolia	T	D1	20.996	2.906	20	.99	0.18-3.55	Canada	Telfer (1969)
	F	D1	4.528	2.354	20	.99	0.18-3.55	Canada	Telfer (1969)
Picea spp.	T	D2	65.757	2.287	25	.97	0.50-3.30	MN	Roussopoulos and Loomis (1979)
	W	D2	28.670	2.566	25	.98	0.50-3.30	MN	Roussopoulos and Loomis (1979)
	F	D2	36.288	2.047	25	.95	0.50-3.30	MN	Roussopoulos and Loomis (1979)
Populus spp.	T	D2	46.574	2.527	27	.96	0.50-3.30	MN	Roussopoulos and Loomis (1979)
	W	D2	35.264	2.657	27	.97	0.50-3.30	MN	Roussopoulos and Loomis (1979)
	F	D2	10.828	2.052	27	.87	0.50-3.30	MN	Roussopoulos and Loomis (1979)
Populus tremuloides	W	D2	34.502	2.874	28	.91	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	2.227	4.258	14	.96	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D1	27.980	2.715	20	.99	0.23-4.06	Canada	Telfer (1969)
	F	D1	9.849	2.156	20	.96	0.23-4.06	Canada	Telfer (1969)
Quercus rubra	T	D1	44.726	2.649	20	.99	0.22-3.99	Canada	Telfer (1969)
	F	D1	11.694	2.198	20	.97	0.22-3.99	Canada	Telfer (1969)
Thuja occidentalis	T	D2	68.423	1.863	38	.94	0.30-5.10	MN	Roussopoulos and Loomis (1979)
	W	D2	30.800	2.244	38	.94	0.30-5.10	MN	Roussopoulos and Loomis (1979)
	F	D2	35.288	1.442	38	.90	0.30-5.10	MN	Roussopoulos and Loomis (1979)

(Table 1 continued on next page)

(Table 1 continued)

Species	Biomass[1] key	Independent[2] variable (x)	Coefficients a	Coefficients b	Number of observations	R2	Range of independent variable	Location[3]	Source
Tall shrubs									
Acer glabrum	T	D1	37.864	2.752	31	0.98	0.40-3.70	MT, ID	Brown (1976)
	F	D1	6.475	2.038	31	.89	0.40-3.70	MT, ID	Brown (1976)
Acer pensylvanicum	T	D1	22.395	2.878	20	.99	0.92-4.31	Canada	Telfer (1969)
	F	D1	5.916	2.220	20	.98	0.92-4.31	Canada	Telfer (1969)
Acer spicatum	W	D2	43.660	2.630	27	.78	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	2.869	3.669	11	.61	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	52.090	2.724	45	.92	0.70-3.20	MN	Ohmann et al. (1976)
	W	D2	40.940	2.781	90	.93	0.60-3.20	MN	Ohmann *et al.* (1976)
	F	D2	11.130	2.123	45	.80	0.70-3.20	MN	Ohmann *et al.* (1976)
	T	D2	73.182	2.259	25	.95	0.30-4.30	MN	Roussopoulos and Loomis (1979)
	W	D2	54.779	2.407	25	.95	0.30-4.30	MN	Roussopoulos and Loomis (1979)
	F	D2	17.305	1.696	25	.89	0.30-4.30	MN	Roussopoulos and Loomis (1979)
Alnus crispa	W	D2	39.684	2.696	26	.86	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	5.650	2.222	25	.75	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	55.450	2.409	45	.94	0.70-2.10	MN	Ohmann et al. (1976)
	W	D2	43.940	2.214	90	.87	0.60-2.10	MN	Ohmann *et al.* (1976)
	F	D2	13.970	1.682	45	.63	0.70-2.10	MN	Ohmann *et al.* (1976)
Alnus rugosa	W	D2	31.328	3.050	15	.99	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	3.123	3.071	12	.72	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	33.722	2.712	29	.96	0.25-3.00	MN	Connolly (1981)
	W	D2	23.138	3.018	29	.96	0.25-3.00	MN	Connolly (1981)
	F	D2	13.540	0.845	29	.65	0.25-3.00	MN	Connolly (1981)
Alnus sinuata	T	D1	33.886	2.466	30	.95	0.70-6.30	MT, ID	Brown (1976)
	F	D1	7.885	1.588	30	.82	0.70-6.30	MT, ID	Brown (1976)
Alnus spp.	T	D2	63.280	2.380	28	.93	0.80-4.10	MN	Roussopoulos and Loomis (1979)
	W	D2	48.762	2.509	28	.90	0.80-4.10	MN	Roussopoulos and Loomis (1979)
	F	D2	14.725	1.828	28	.90	0.80-4.10	MN	Roussopoulos and Loomis (1979)
Amelanchier alnifolia	T	D1	36.855	2.887	39	.99	0.40-4.50	MT, ID	Brown (1976)
	F	D1	5.425	2.111	39	.83	0.40-4.50	MT, ID	Brown (1976)
Amelanchier spp.	W	D2	37.909	2.963	27	.92	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	5.432	2.008	14	.88	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	64.180	2.322	45	.83	0.50-1.90	MN	Ohmann et al. (1976)
	W	D2	50.630	2.547	90	.90	0.50-1.90	MN	Ohmann *et al.* (1976)
	F	D2	13.340	1.547	45	.47	0.50-1.90	MN	Ohmann *et al.* (1976)
	T	D2	71.534	2.391	27	.93	0.50-4.10	MN	Roussopoulos and Loomis (1979)
	W	D2	60.997	2.445	27	.94	0.50-4.10	MN	Roussopoulos and Loomis (1979)
	F	D2	10.478	1.988	27	.83	0.50-4.10	MN	Roussopoulos and Loomis (1979)
Artemisia tridentata	T	D1	23.594	2.242	22	.92	0.80-6.90	MT, ID	Brown (1976)
	F	D1	4.968	1.888	22	.75	0.80-6.90	MT, ID	Brown (1976)
Betula pumila	T	D2	59.777	2.579	36	.96	0.25-2.25	MN	Connolly (1981)
	W	D2	53.283	2.689	36	.96	0.25-2.25	MN	Connolly (1981)
	F	D2	6.265	1.106	36	.52	0.25-2.25	MN	Connolly (1981)
Ceanothus velutinus	T	D1	39.252	2.847	30	.92	0.60-2.50	MT, ID	Brown (1976)
	F	D1	14.688	2.415	30	.67	0.60-2.50	MT, ID	Brown (1976)

(Table 1 continued on next page)

(Table 1 continued)

Species	Biomass[1/] key	Independent[2/] variable (x)	Coefficients a	Coefficients b	Number of observations	R2	Range of independent variable	Location[3/]	Source
Cornus rugosa	W	D2	32.421	3.152	9	0.96	0.50-1.50	MN	Grigal and Ohmann (1977)
	F	D2	8.616	2.541	9	.94	0.50-1.50	MN	Grigal and Ohmann (1977)
	T	D2	74.114	2.457	27	.96	0.30-3.60	MN	Roussopoulos and Loomis (1979)
	W	D2	55.886	2.591	27	.96	0.30-3.60	MN	Roussopoulos and Loomis (1979)
	F	D2	17.131	2.093	27	.93	0.30-3.60	MN	Roussopoulos and Loomis (1979
Cornus stolonifera	T	D1	39.646	2.575	31	.93	0.60-3.40	MT, ID	Brown (1976)
	F	D1	9.450	1.762	31	.58	0.60-3.40	MT, ID	Brown (1976)
	T	D2	32.791	3.806	33	.89	0.25-1.75	MN	Connolly (1981)
	W	D2	25.515	4.039	33	.89	0.25-1.75	MN	Connolly (1981)
	F	D2	7.992	2.440	33	.73	0.25-1.75	MN	Connolly (1981)
Corylus cornuta	W	D2	38.031	3.267	43	.85	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	4.808	3.571	9	.99	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	54.100	1.229	45	.13	0.60-2.30	MN	Ohmann *et al.* (1976)
	W	D2	38.570	1.582	90	.20	0.60-2.30	MN	Ohmann *et al.* (1976)
	T	D2	62.819	2.420	36	.89	0.30-2.50	MN	Roussopoulos and Loomis (1979)
	W	D2	50.154	2.523	36	.90	0.30-2.50	MN	Roussopoulos and Loomis (1979)
	F	D2	12.115	2.010	36	.81	0.30-2.50	MN	Roussopoulos and Loomis (1979)
Gaylussacia baccata	T	D1	44.942	2.156	22	.86	0.46-2.57	Canada	Telfer (1969)
	F	D1	13.950	1.502	22	.65	0.46-2.57	Canada	Telfer (1969)
Hamamelis virginiania	T	D1	38.111	2.900	21	.99	0.18-4.31	Canada	Telfer (1969)
	F	D1	9.480	2.162	20	.96	0.18-4.31	Canada	Telfer (1969)
Holodiscus discolor	T	D1	43.337	3.033	31	.93	0.70-2.70	MT, ID	Brown (1976)
	F	D1	8.706	2.605	31	.86	0.70-2.70	MT, ID	Brown (1976)
Ilex verticillata	T	D1	53.497	3.340	20	.94	0.19-0.90	Canada	Telfer (1969)
	F	D1	10.747	2.851	20	.93	0.19-0.90	Canada	Telfer (1969)
Juniperus communis	T	D1	59.205	2.202	23	.92	0.80-2.90	MT, ID	Brown (1976)
	F	D1	30.387	1.650	23	.80	0.80-2.90	MT, ID	Brown (1976)
Lonicera utahensis	T	D1	43.293	2.957	32	.92	0.30-1.70	MT, ID	Brown (1976)
	F	D1	7.404	2.158	32	.67	0.30-1.70	MT, ID	Brown (1976)
Menziesia ferruginea	T	D1	21.607	3.150	37	.98	0.40-2.10	MT, ID	Brown (1976)
	F	D1	1.937	2.263	37	.83	0.40-2.10	MT, ID	Brown (1976)
Nemopanthus mucronatus	T	D1	31.532	2.819	20	.97	0.16-2.85	Canada	Telfer (1969)
	F	D1	4.246	2.231	20	.97	0.16-2.85	Canada	Telfer (1969)
Philadelphus lewisii	T	D1	40.772	2.999	28	.90	0.50-2.90	MT, ID	Brown (1976)
	F	D1	6.828	2.778	28	.71	0.50-2.90	MT, ID	Brown (1976)
Physocarpus malvaceus	T	D1	41.679	2.576	38	.94	0.40-3.80	MT, ID	Brown (1976)
	F	D1	9.728	2.036	38	.89	0.40-3.80	MT, ID	Brown (1976)
Prunus pensylvanica	W	D2	49.916	2.547	9	.95	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	4.947	2.836	3	.00	0.50-1.75	MN	Grigal and Ohmann (1977)
Prunus spp.	T	D2	68.041	2.237	25	.90	0.80-3.80	MN	Roussopoulos and Loomis (1979)
	W	D2	55.076	2.306	25	.87	0.80-3.80	MN	Roussopoulos and Loomis (1979)
	F	D2	12.382	2.024	25	.77	0.80-3.80	MN	Roussopoulos and Loomis (1979)

(Table 1 continued on next page)

(Table 1 continued)

Species	Biomass[1/] key	Independent[2/] variable (x)	Coefficients a	Coefficients b	Number of observations	R^2	Range of independent variable	Location[3/]	Source
Prunus virginiana	T	01	9.934	2.920	31	0.98	0.60-2.90	MT, ID	Brown (1976)
	F	01	8.846	1.902	31	.74	0.60-2.90	MT, IO	Brown (1976)
	W	D2	35.575	2.704	9	.86	0.25-1.25	MN	Grigal and Ohmann (1977)
	F	02	7.953	1.954	4	.90	0.25-1.25	MN	Grigal and Ohmann (1977)
Salix spp.	T	01	27.194	2.762	31	.97	0.70-3.70	MT, IO	Brown (1976)
	F	01	6.411	2.066	31	.68	0.70-3.70	MT, ID	Brown (1976)
	W	[illegible]	17.815	4.919	9	.92	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	[illegible]	4.514	3.692	9	.89	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	87.790	1.981	36	.87	0.80-3.80	MN	Ohmann *et al.* (1976)
	W	02	56.090	2.208	90	.92	0.60-3.80	MN	Ohmann *et al.* (1976)
	F	D2	21.590	1.686	36	.54	0.70-3.80	MN	Ohmann *et al.* (1976)
	T	D2	55.925	2.594	25	.96	0.5-3.00	MN	Roussopoulos and Loomis (1979)
	W	D2	43.316	2.726	25	.95	0.50-3.00	MN	Roussopoulos and Loomis (1979)
	F	D2	12.280	2.120	25	.94	0.50-3.00	MN	Roussopoulos and Loomis (1979)
	T	D1	46.271	2.325	20	.97	0.45-3.41	Canada	Telfer (1969)
	F	D1	14.256	1.729	20	.82	0.45-3.41	Canada	Telfer (1969)
	T	02	60.153	2.202	72	.83	0.25-3.00	MN	Connolly (1981)
	W	02	41.287	2.565	72	.87	0.25-3.00	MN	Connolly (1981)
	F	02	13.194	1.224	72	.64	0.25-3.00	MN	Connolly (1981)
Shepherdia canadensis	T	01	33.016	2.407	30	.89	0.70-2.90	MT, ID	Brown (1976)
	F	D1	7.463	2.034	30	.80	0.70-2.90	MT, ID	Brown (1976)
Sorbus americana	W	02	13.982	4.900	9	.92	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	02	2.885	3.454	3	.00	0.50-1.75	MN	Grigal and Ohmann (1977)
	T	D2	44.394	3.253	24	.95	0.50-3.80	MN	Roussopoulos and Loomis (1979)
	W	D2	35.960	3.427	24	.95	0.50-3.80	MN	Roussopoulos and Loomis (1979)
	F	D2	8.083	2.601	24	.93	0.50-3.80	MN	Roussopoulos and Loomis (1979)
Sorbus scopulina	T	01	26.390	2.881	29	.95	1.00-4.20	MT, ID	Brown (1976)
	F	01	4.468	2.581	29	.84	1.00-4.20	MT, ID	Brown (1976)
Viburnum lantanoides	T	01	29.615	3.243	19	.95	0.28-1.59	Canada	Telfer (1969)
	F	D1	6.182	2.679	19	.92	0.28-1.59	Canada	Telfer (1969)
	T	01	43.570	2.774	20	.98	0.29-3.10	Canada	Telfer (1969)
	F	D1	7.143	2.205	20	.95	0.29-3.10	Canada	Telfer (1969)
Viburnum rafinesquianum	W	02	39.921	4.132	9	.98	0.50-1.50	MN	Grigal and Ohmann (1977)
	F	D2	8.526	3.007	8	.95	0.50-1.50	MN	Grigal and Ohmann (1977)
Medium and low shrubs									
Berberis repens	T	01	19.609	2.092	36	.70	0.30-0.90	MT,ID	Brown (1976)
	F	01	8.174	1.586	36	.48	0.30-0.90	MT,IO	Brown (1976)
Chamaedaphne calyculata	T	01	41.330	2.626	20	.94	0.14-0.82	Canada	Telfer (1969)
	F	D1	10.556	2.220	20	.89	0.14-0.82	Canada	Telfer (1969)
Comptonia peregrina	T	D1	44.691	3.314	20	.97	0.21-1.48	Canada	Telfer (1969)
	F	D1	13.585	3.014	20	.97	0.21-1.48	Canada	Telfer (1969)
Diervilla lonicera	T	02	14.211	1.217	21	.45	0.30-0.50	MN	Roussopoulos and Loomis (1979)
	W	D2	12.269	1.608	21	.53	0.30-0.50	MN	Roussopoulos and Loomis (1979)
	F	D2	3.082	0.613	21	.19	0.30-0.50	MN	Roussopoulos and Loomis (1979)

(Table 1 continued on next page)

(Table 1 continued)

Species	Biomass[1/] key	Independent[2/] variable (x)	Coefficients a	Coefficients b	Number of observations	R^2	Range of independent variable	Location[3/]	Source
Ilex glabra	T	D1	55.096	3.011	20	0.91	0.23-1.87	Canada	Telfer (1969)
	F	D1	18.947	2.722	20	.81	0.23-1.87	Canada	Telfer (1969)
Kalmia angustifolia	T	D1	26.692	2.384	20	.95	0.09-0.87	Canada	Telfer (1969)
	F	D1	8.497	2.091	20	.90	0.09-0.87	Canada	Telfer (1969)
Ledum groenlandicum	T	D1	37.597	2.832	22	.96	0.23-0.83	Canada	Telfer (1969)
	F	D1	12.331	2.413	22	.90	0.23-0.83	Canada	Telfer (1969)
Lonicera canadensis	W	D2	28.090	2.166	9	.93	0.25-1.25	MN	Grigal and Ohmann (1977)
	F	D2	6.592	2.681	4	.90	0.25-1.25	MN	Grigal and Ohmann (1977)
	T	D2	33.900	1.793	25	.68	0.30-1.00	MN	Roussopoulos and Loomis (1979)
	W	D2	28.899	1.942	25	.67	0.30-1.00	MN	Roussopoulos and Loomis (1979)
	F	D2	5.319	1.275	25	.39	0.30-1.00	MN	Roussopoulos and Loomis (1979)
	T	D1	51.996	2.770	20	.96	0.12-0.69	Canada	Telfer (1969)
	F	D1	15.610	2.399	20	.86	0.12-0.69	Canada	Telfer (1969)
Lonicera hirsuta	W	D2	46.002	3.402	13	.68	0.25-1.00	MN	Grigal and Ohmann (1977)
	F	D2	3.926	1.163	10	.24	0.25-1.00	MN	Grigal and Ohmann (1977)
Lonicera oblongifolia	W	D2	18.093	3.089	4	.70	0.25-0.50	MN	Grigal and Ohmann (1977)
	F	D2	6.009	3.115	4	.75	0.25-0.50	MN	Grigal and Ohmann (1977)
Myrica pensylvanica	T	D1	60.795	2.867	20	.98	0.19-1.20	Canada	Telfer (1969)
	F	D1	18.361	2.529	20	.93	0.19-1.20	Canada	Telfer (1969)
Rhamnus alnifolia	W	D2	30.971	2.764	6	.87	0.50-1.75	MN	Grigal and Ohmann (1977)
	F	D2	2.009	3.835	6	.88	0.50-1.75	MN	Grigal and Ohmann (1977)
Rhododendron canadense	T	D1	24.079	2.612	20	.92	0.28-1.07	Canada	Telfer (1969)
	F	D1	5.183	2.050	20	.83	0.28-1.07	Canada	Telfer (1969)
Ribes spp.	T	D1	49.001	3.112	37	.90	0.40-1.40	MT, ID	Brown (1976)
	F	D1	8.706	2.538	37	.63	0.40-1.40	MT, ID	Brown (1976)
	W	D2	32.001	5.256	9	.78	0.25-0.75	MN	Grigal and Ohmann (1977)
	F	D2	1.513	3.023	9	.55	0.25-0.75	MN	Grigal and Ohmann (1977)
Rosa acicularis	W	D2	14.527	3.042	8	.88	0.25-0.75	MN	Grigal and Ohmann (1977)
	F	D2	3.286	2.004	8	.88	0.25-0.75	MN	Grigal and Ohmann (1977)
	T	D2	83.240	2.837	23	.83	0.30-1.30	MN	Roussopoulos and Loomis (1979)
	W	D2	63.140	3.224	23	.82	0.30-1.30	MN	Roussopoulos and Loomis (1979)
	F	D2	22.853	2.282	23	.79	0.30-1.30	MN	Roussopoulos and Loomis (1979)
Rosa blanda	W	D2	31.182	4.074	9	.84	0.25-0.75	MN	Grigal and Ohmann (1977)
	F	D2	4.160	2.302	9	.60	0.25-0.75	MN	Grigal and Ohmann (1977)
Rosa spp.	T	D1	37.637	2.779	32	.96	0.20-1.20	MT, ID	Brown (1976)
	F	D1	7.561	2.112	32	.88	0.20-1.20	MT, ID	Brown (1976)
Rubus idaeus	T	D1	43.992	2.860	26	.89	0.30-0.90	MT, ID	Brown (1976)
	F	D1	18.394	2.932	26	.85	0.30-0.90	MT, ID	Brown (1976)
Rubus parviflorus	T	D1	32.105	2.538	27	.88	0.30-1.40	MT, ID	Brown (1976)
	F	D1	12.146	2.024	27	.72	0.30-1.40	MT, ID	Brown (1976)

(Table 1 continued on next page)

(Table 1 continued)

Species	Biomass[1] key	Independent[2] variable (x)	Coefficients		Number of observations	R2	Range of independent variable	Location[3]	Source
			a	b					
Rubus strigosus	W	D2	11.519	4.032	11	0.73	0.25-0.75	MN	Grigal and Ohmann (1977)
	F	D2	7.081	3.871	11	.75	0.25-0.75	MN	Grigal and Ohmann (1977)
Spirea alba	T	D2	40.932	2.658	18	.96	0.25-1.25	MN	Connolly (1981)
	W	D2	32.031	3.092	18	.95	0.25-1.25	MN	Connolly (1981)
	F	D2	8.013	1.444	18	.66	0.25-1.25	MN	Connolly (1981)
Spiraea betulifolia	T	D1	36.745	2.604	31	.84	0.20-0.80	MT, ID	Brown (1976)
	F	D1	11.130	2.281	31	.80	0.20-0.80	MT, ID	Brown (1976)
Spiraea spp.	T	D1	36.648	2.579	20	.91	0.10-1.26	Canada	Telfer (1969)
	F	D1	5.493	1.720	20	.90	0.10-1.26	Canada	Telfer (1969)
Symphoricarpos albus	T	D1	32.786	2.285	31	.88	0.20-1.20	MT, ID	Brown (1976)
	F	D1	6.437	1.721	31	.68	0.20-1.20	MT, ID	Brown (1976)
Vaccinium globulare	T	D1	29.607	3.150	44	.97	0.30-1.70	MT, ID	Brown (1976)
	F	D1	4.393	2.537	44	.84	0.30-1.70	MT, ID	Brown (1976)
Vaccinium scoparium	T	D1	22.488	2.148	31	.62	0.30-0.70	MT, ID	Brown (1976)
	F	D1	1.670	1.567	31	.26	0.30-0.70	MT, ID	Brown (1976)
Vaccinium spp.	T	D1	95.143	3.706	20	.94	0.14-0.56	Canada	Telfer (1969)
	F	D1	13.224	3.034	20	.74	0.14-0.56	Canada	Telfer (1969)

[1] Biomass in grams ovendry weight: T = total aboveground biomass; W = woody aboveground biomass; and F = foliage biomass.

[2] D1 = basal diameter in cm and D2 = diameter at 15 cm aboveground in cm.

[3] Canada = Maritime Provinces, ID = northern Idaho, MN = northern Minnesota, and MT = western Montana.

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Table 2.--Coefficients and related statistics for the allometric relationship, Biomass = aX^b

Species	Biomass[1] key	Independent[2] variable (x)	Coefficients[3]		Number of observations	R^2
			a	b		
Herbaceous vegetation						
Anemone spp.	G18	PC	0.0142	1.8387	56	0.72
Apocynum androsaemifolium	G18	PC	.2524	0.7750	21	.38
Aralia nudicaulis	G18	PC	.1062	1.0205	135	.56
Aster ciliolatus	G18	PC	.1247	0.9985	15	.81
Aster macrophyllus	G18	PC	.1192	1.0226	344	.50
Clintonia borealis	G18	PC	.1551	0.7616	108	.47
Cornus canadensis	G18	PC	.1376	0.9214	155	.63
Epilobium angustifolium	G18	PC	.3423	1.1588	18	.23
Fragaria spp.	G18	PC	.2227	0.7104	81	.42
Galium spp.	G18	PC	.0134	1.8697	30	.92
Gramineae	G18	PC	.9740	0.6750	137	.45
Lathyrus spp.	G18	PC	.4043	0.6873	62	.57
Linnaea borealis	G18	PC	.3650	0.8354	62	.84
Mainthemum canadense	G18	PC	.0650	1.0481	134	.46
Pteridium aquilinum	G18	PC	.4590	0.7669	15	.55
Pyrola spp	G18	PC	.1272	0.4472	46	.95
Streptopus roseus	G18	PC	.0660	0.9272	168	.57
Trientalis borealis	G18	PC	.0072	1.8320	19	.99
Viola spp.	G18	PC	.0588	0.7776	20	.81
Shrubs						
Diervilla lonicera	G18	PC	.3238	0.8601	21	.68
Ledum groenlandicum	G18	PC	.0001	3.3410	6	.62
Lonicera canadensis	G18	PC	.2727	0.9266	25	.93
Rosa spp.	G18	PC	.3964	0.7867	68	.50
Rubus parviflorus	G18	PC	.2508	0.7885	18	.60
Rubus pubescens	G18	PC	.0214	1.6346	168	.78
Rubus strigosus	G18	PC	.1601	1.1089	119	.64
Vaccinium angustifolium	G18	PC	.1496	1.2458	104	.72
Vaccinium myrtilloides	G18	PC	.3747	0.9340	82	.59

[1] G18 = total aboveground biomass per 1,800 cm^2 (ovendry weight).

[2] PC = ground cover in percent.

[3] Source for coefficients is Ohmann *et al*. (1981). Data collected in northern Minnesota.

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DIMENSIONAL CHARACTERISTICS OF HARDWOOD TOP AND LIMB RESIDUE

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ABSTRACT.—Sawtimber harvesting in northern hardwood stands leaves behind a large amount of residue in the form of tops and limbs. This paper presents typical dimensional characteristics of residue for northern hardwood tops including data on lengths, widths, diameters, and complete branch details.

KEY WORDS: Wood energy, delimbing, biomass utilization, harvesting, topwood residue.

The abundant supply of wood in the United States has led to some wasteful practices, especially with respect to sawtimber residue. Developing new technology and markets will help encourage the utilization of these residues and thus reduce the needless waste of a natural resource.

USDA Forest Service scientists have determined that, after northern hardwood sawtimber harvesting, between 40 and 50 percent of a tree's weight above the stump is left as residue (Mattson and Carpenter 1975). For example, the average topwood residue weight from a 21-inch-d.b.h. sugar maple tree is about 2,000 pounds (Steinhilb and Winsauer 1976). If this single top were recovered for energy, it would be equivalent to one 42-gallon barrel of oil. In the Eastern U.S., an estimated 50 million dry tons of hardwood residue in the form of tops and limbs remain each year after harvesting (Carpenter 1980).

What makes topwood residue rather unique is that it becomes "available" for essentially a zero prior investment because current practice in timber harvesting depreciates the whole tree at time of harvest while utilizing only the saw log portion. This practice will eventually change as topwood harvesting becomes commonplace, but it presently provides an economic incentive.

Continuing research studies are investigating methods to recover this topwood residue. A complete recovery system would include schemes for:

1. Removing the residue from the forest to a landing or roadside,
2. transporting it to a location for further processing, or,
3. processing it in the forest or at the landing and then transporting it.

For the key elements—handling, transportation, and processing—certain facts must be known such as volumes per acre, weights, number of pieces per acre, and physical size of the material. Previous research studies have documented the volumes, weights, and densities per acre of residue tops and limbs (Winsauer and Steinhilb 1980, Steinhilb and Dye 1973, Grantham and Howard 1980, Bradley *et al.* 1980).

What has not been documented are the dimensional characteristics of topwood residue. To design both efficient and economical equipment to handle, transport, or process a top, researchers must know the actual diameters of the main stem and branches. Other details such as the number of branches and their angle with the main stem are also necessary, especially to design equipment to remove limbs. The results presented here will help to fill the gap in engineering data by providing the dimensional characteristics of hardwood top and limb residue. No attempt was made to document the density of tops per a given area or estimate weights or board feet, etc.

DESCRIPTION OF SITES

The topwood data presented in this paper came from a sample of 64 tops. To attempt to eliminate any bias due to logging practice or site differences, the tops were selected from three separate sites. All three sites were mixed northern hardwood stands on rolling terrain in the Upper Peninsula of Michigan: one in Houghton County, one in Keweenaw County, and one in Baraga County. The sites in Houghton and Keweenaw Counties, located on land owned by the Copper Range Company, were marked by that company for the sawtimber harvesting that took place approximately 6 months before the topwood measuring. The Baraga County site, owned by Michigan Technological University, was also marked and cut about 6 months earlier. All three sites were logged by different loggers. These sites were managed and marked for a selective sawtimber harvest which precludes the harvesting of trees under a certain minimum d.b.h. (usually 12 inches).

The breakdown of species of tops for each site is:

Baraga County – 13 red maple *(Acer rubrum)*
6 sugar maple
(Acer saccharum)
1 elm *(Ulmus americana)*
Houghton County – 23 sugar maple
(Acer saccharum)
1 yellow birch
(Betula alleghaniensis)
Keweenaw County – 19 sugar maple
(Acer saccharum)
1 yellow birch
(Betula alleghaniensis)

PROCEDURE

At least 20 tops at each site were measured to provide representative data for a "typical" hardwood top. For each top measured, the following data were recorded with all diameters "outside bark" (d.o.b.):

1. Species.
2. Stump diameter.
   All stumps were identified for each top, and diameters were measured at approximately 1 foot above the ground.
3. Stump to top butt distance (merchantable length).
   Measured 1 foot from stump to butt of top along ground.
4. Butt diameter of top.
5. Length of top.
   Length from top butt to top of foliage.
6. Crown width (maximum).
7. Branch data for those greater than 4 inches d.o.b.
   The number of branches, the location of their juncture with the main stem, their angle with the main stem, and their length to 4 inches d.o.b.
8. Number of branches less than 4 inches d.o.b.

DATA ANALYSIS

The first step in the analysis was to establish whether any site or species differences existed. The data were grouped into the following variables by site: Species; stump to top butt distance; stump diameter; top butt diameter; crown width; top length; number of branches in each of six branch classes by diameter in inches, 0-3.9, 4-5.9, 6-7.9, 8-9.9, 10-11.9, 12-15; and branch angle with the main stem of 0-29, 30-59, or 60-90 degrees. From an engineering viewpoint, there are no major site differences as evidenced by means and corresponding standard deviations of the variables. By comparing the results of Houghton and Keweenaw Counties (predominately sugar maple) to those of Baraga County (predominately red maple), there again proved to be no major species differences. Based on these results, all further analysis was done using all 64 residue tops treated as one group.

RESULTS AND CONCLUSIONS

Figure 1 shows a typical northern hardwoods residue top with mean dimensions and their corresponding standard deviations. In addition, the histograms in figures 2 through 6 give a more detailed breakdown of the dimensions.

Topwood is available, but it cannot be just skidded out intact. Because of the average length (36 feet) and width (25 feet) of a top, skidding would seriously damage the residual stand. Reducing the top by manual chain sawing is both costly and unsafe. What looks most promising is a mechanized scheme in which the tops are first reduced and then transported to a landing for further processing.

The details of branch sizes and lengths are shown in table 1 and in figures 7 and 8. Table 1 and figure 7 include only data on the branches themselves, not on the main stems. Figure 8, which presents information on the lengths of roundwood greater than 4 inches d.o.b., includes data on both branches and main stems. The data presented in figure 8 strongly suggest that this material could be utilized for higher value solid wood products rather than simply for chips for fiber and/or fuel.

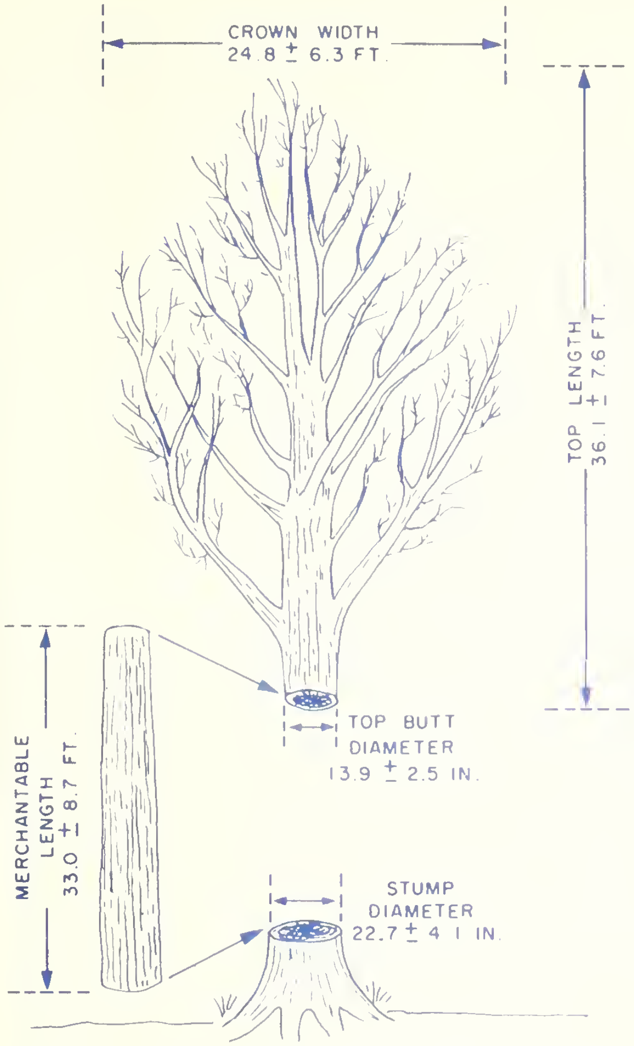

Figure 1.—*Descriptive measures (means and standard deviations) of topwood residue in a mixed northern hardwood stand. Sample size is 64 tops.*

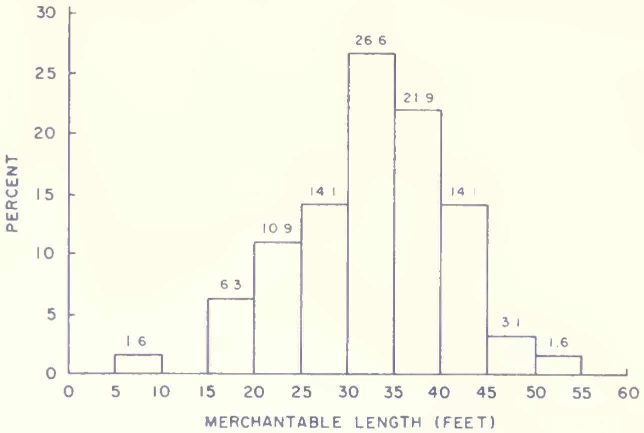

Figure 3.—*Distribution of merchantable lengths for 64 trees (stump to top butt distances).*

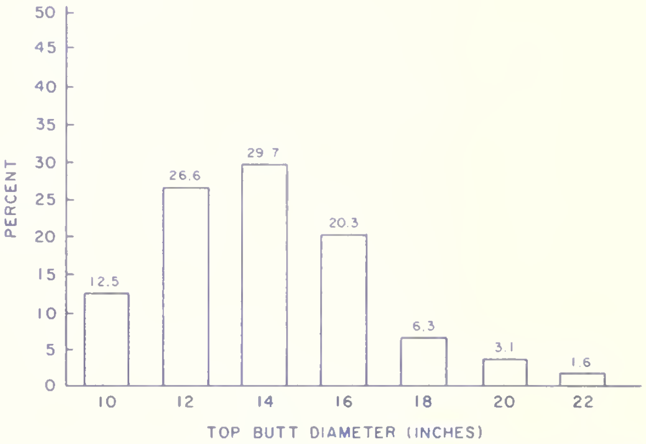

Figure 4.—*Distribution of top butt diameters for 64 tops.*

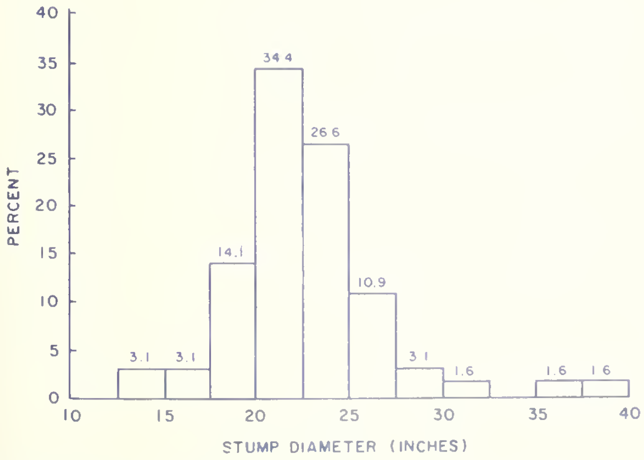

Figure 2.—*Distribution of stump diameters for 64 stumps.*

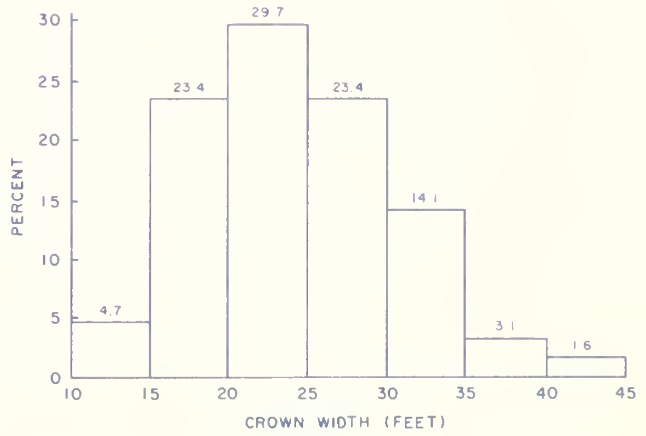

Figure 5.—*Distribution of maximum crown widths for 64 tops.*

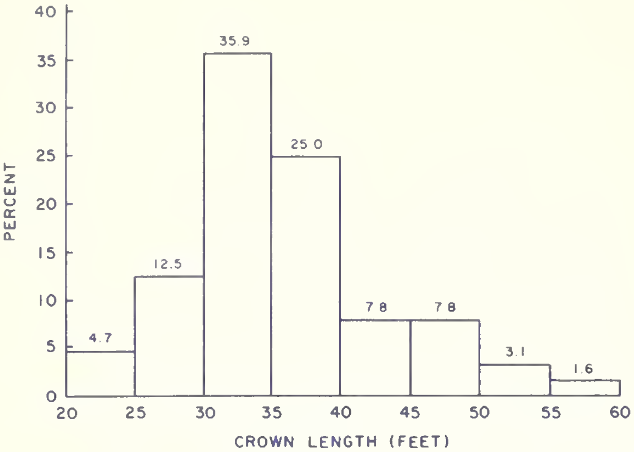

Figure 6.—*Distribution of crown lengths for 64 tops.*

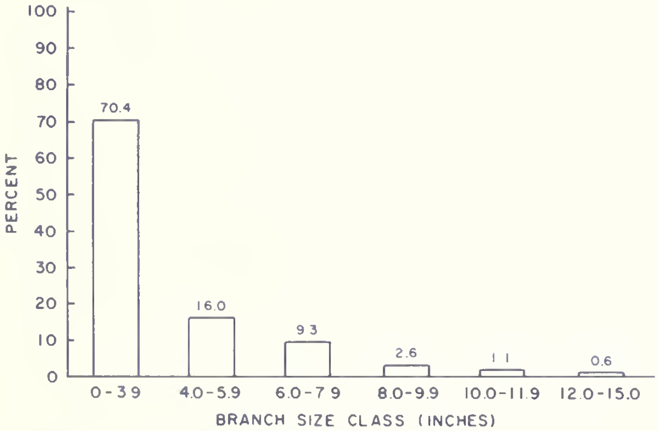

Figure 7.—*Distribution of branch size classes for 64 tops. (Does not include main stem.)*

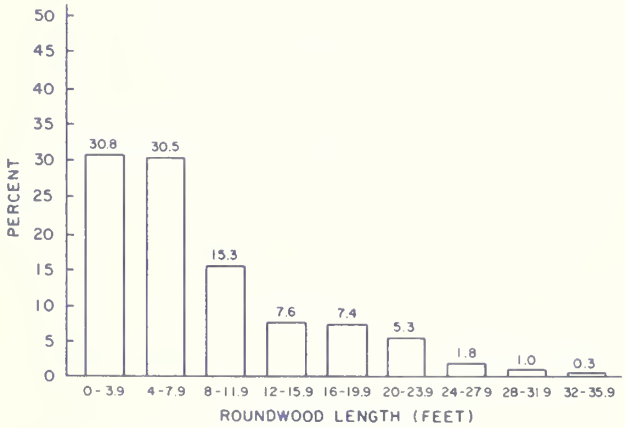

Figure 8.—*Distribution of lengths of roundwood greater than 4 inches d.o.b. for 64 tops. (Includes both main stem and branches.) NOTE: Total number of pieces is 393; mean length is 7.9 feet (std. dev. = 6.7).*

Table 1.—*Branch details*[1]

	Number of branches per top	
Branch size class (inches)	**Range**	**Mean**
0– 3.9	2–34	15.3
4– 5.9	0–7	3.3
6– 7.9	0–7	1.9
8– 9.9	0–2	.5
10–11.9	0–2	.2
12–15	0–2	.1

[1] Does not include main stem.

For branches greater than 4 inches d.o.b., the angle with the main stem is distributed as follows:

0–30 degrees	33 percent
30–60 degrees	44 percent
60–90 degrees	23 percent

A correlation matrix was calculated for all variables. There proved to be no relations that would be useful from an engineering viewpoint. The largest correlation is stump diameter versus top butt diameter with an r value of 0.53. The next largest is branch class six versus top butt diameter with an r of 0.51. All other correlations were negligible.

Further research is needed on various schemes and devices to harvest northern hardwood top and limb residue. The results presented here have established a representative set of engineering data to guide this research.

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