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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Periodic Mowings Suppress Tamarisk Growth, Increase Forage for Browsing

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Tamarisk (Tamarix pentandra Pall.) was clipped (completely defoliated) and mowed at 2-, 4-, 8-, and 24-week intervals throughout the growing season. Plant mortality increased with frequency of clipping. Plants were not killed by the 1 season of mowing, but dry foliage yields were similar to yields produced by clipping treatments. In central Arizona, mowings in May, July, and September are necessary to keep foliage succulent and within reach of browsing cattle. Evapotranspiration decreased approximately 50 percent following mowing treatments.

Tamarisk (Tamarix pentandra Pall.) has been mowed on parts of the Middle Rio Grande flood channel for many years, but the effects of repeated mowing on survival were not determined. In central Arizona, we determined effects of partial and complete defoliation of tamarisk at various weekly intervals throughout the growing season, and possible water savings as a result of such treatments.

The study area was approximately 2 miles upstream from Granite Reef Diversion Dam on the Salt River. Study plots were on a relatively mature flood-plain site containing alluvial soils which varied in texture generally from a silty sand at the surface to a coarse gravel subsurface. The water table during summer months was 0.80 to 2.50 feet below ground surface and between 4 and 5 feet in winter months when river flows were reduced. In low areas adjacent to study plots, ground water rose above the surface during high river flows.

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Methods

Preparation and Treatments

1962 Study Plot.--In January 1962, an 0.87-acre plot containing an almost pure stand of tamarisk ranging in height from 4 to 24 feet was cleared. All plants were cut to within 0.8 foot of the ground and litter removed from the study plots. The area was fenced to exclude livestock. Fifty plants with stem diameters of more than 0.05 foot and less than 0.24 foot at the 0.8-foot height level were selected for each treatment. Discarded plants were either removed or chemically treated periodically to suppress growth.

Plants were clipped (complete defoliation) at 2-, 4-, 8-, and 24-week (control) intervals during the growing season. Plants which survived were re-treated in the same way and at the same intervals in the summer of 1963.

1963 Study Plot.--The study area adjacent to the 1962 plot was cleared and prepared in a similar manner. Treatments consisted of 2-, 4-, 8-, and 24-week clipping, using 30 plants for each treatment, and equal numbers of additional plants for simulated mowing studies at the same weekly intervals throughout the growing season. A portable wooden frame 1 foot high was used as a guide for standardization of mowing within and between treatments. Total available carbohydrate root reserves were analyzed on random plants at the end of each treatment. These analyses reduced the number of samples in clipping and mowing plots as the growing season progressed.

Evapotranspiration Measurements

In a pretreatment run, relative evapotranspiration (ET) losses from six tamarisk plants were measured by the "tent" technique (Decker et al. 1962)[2] under Decker's supervision in June and July 1963. Three of the plants were used as controls and were not disturbed. Each control plant was randomly paired with a plant to be treated. Prior to treatment, ET measurements were taken between 1130 and 1230 hours on 4 cloudless days. A polyvinyl tent was used for each plant. Relative humidity of air entering and leaving the tents was recorded every 5 minutes, and mean ET losses were averaged for four runs. One plant of each pair was then cut to within a foot of the ground to simulate a mowing treatment. After treatment, relative ET losses from the same matched pairs of plants were determined by averaging means of four additional ET runs. All six plants were spaced approximately 20 feet apart with bermudagrass (Cynodon dactylon L.) sod in space intervening.

Carbohydrate Reserves

At the end of each clipping and mowing treatment in 1963, root systems of living plants were removed and analyzed for readily hydrolyzable carbohydrate content.[3] Methods of processing and analyzing are reported by Bartley and Otto (1958). Twenty-four root samples from each 2-, 4-, and 8-week clipping and mowing treatment were collected from March 20 through August 21, and 20 root samples were collected on August 21 from the 24-week (control) plots.

[2] *Names and dates in parentheses refer to Literature Cited, p. 4.*

[3] *Analysis conducted by the U. S. Bureau of Reclamation, Div. of Research, Water Conservation Branch, Weed Control Section, Denver, Colo.*

Results

Yield

Dry matter yield was less as frequency of clippings increased, and in general, as the growing season progressed. These results agree with earlier work of Wagner (1952), and Cook et al. (1958) with forbs and grasses. Woods and Cassady (1961) found that cutting sandhill shrub oaks (Quercus laevis and Q. incana) at 4-week intervals resulted in fewer and shorter sprouts than 8-week cutting intervals. Sprout lengths in our study averaged 0.67, 1.74, 3.57, 9.58 feet for the 2-, 4-, 8-, and 24-week treatments, respectively, while average weights of dried foliage per plant for the first growing season were 4.3, 16.8, 102.8 and 1555.8 grams for same treatment intervals (fig. 1).

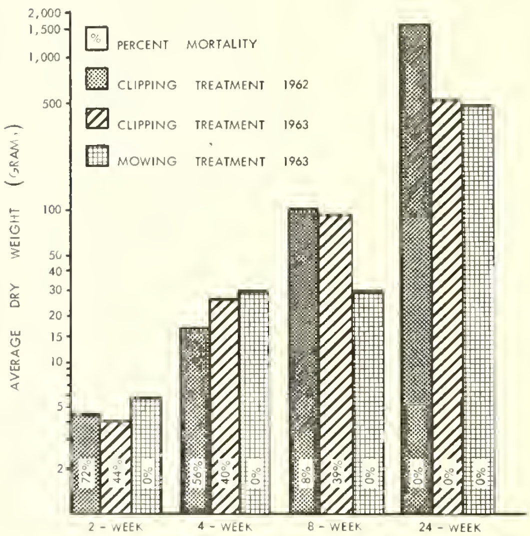

Figure 1.--Logarithmic scale showing average growth (dry weight in grams) and first-season mortality of tamarisk following periodic clipping in 1962 and 1963, and mowing treatments in 1963.

Pronounced inhibition of growth on apical buds on 2- and 4-week mowings created a hedgelike shrub. On 8- and 24-week mowing treatments, however, three to six sprouts on each plant assumed apical dominance and grew rapidly.

Mortality

Mortality was higher as frequency of clippings increased (fig. 1) which agrees with earlier work (Brown 1954, Kust 1960, Jung and Smith 1960). Also, winter survival was less with increased frequency of clipping. Mortality of plants clipped in 1962 increased to 92, 82, 39, and 0 percent on the 2-, 4-, 8-, and 24-week treatment intervals, respectively, before 1963 clipping treatments began. The plants which survived were re-treated in 1963 and had 100, 94, 50, and 0 percent mortality at the end of the second season of clipping. Plants clipped only in 1963 showed a somewhat different mortality pattern compared to 1962 treatments: Those clipped at 2-, 4-, and 8-week intervals in 1963 had almost the same survival rates (39 to 44 percent). All plants in mowing treatments survived 1 season of treatment.

Evapotranspiration Losses

In a pretreatment ET test, three tamarisk plants used as controls (fig. 2) lost an average of 212 grams of water per hour while plants selected for mowing (A, B, C) lost an average of 177 grams per hour. After A, B, and C were mowed, they lost an average of 91 grams per hour per plant versus 218 grams by controls, or approximately 50 percent less water

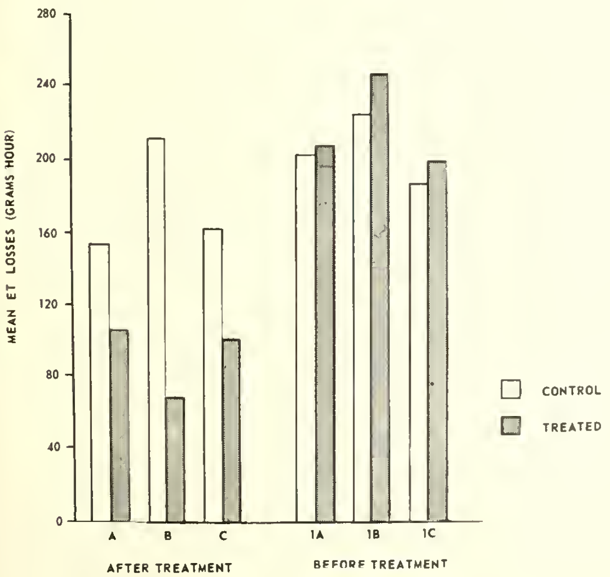

Figure 2--The average evapotranspiration losses from three paired tamarisk plants before and after mowing treatments at Granite Reef, Ariz.

after the mowing treatment. Bermudagrass sod beneath each tamarisk and soil evaporation undoubtedly account for most ET losses after tamarisk is mowed, and probably some ET losses before mowing treatments were the result of the same factors, but to a lesser degree because of the shading and reduced wind caused by the tamarisk overstory.

Average height of control and treated plants used in the ET study was 13.8 and 12.4 feet, respectively. Similarly, crown width at breast height averaged 8.5 feet for controls and 7.8 feet for treated plants. Ovendried weights of photosynthetic tissue from treated plants averaged 1,400 grams with B more than double the weight (2,300 grams) of either A (922 grams) or C (980 grams).

Carbohydrate Reserves

A 5-year average for total available carbohydrate root reserves from undisturbed tamarisk in central Arizona was determined by Bartley and Otto (1963). They showed available carbohydrate percentages to be highest in September (46 ± 8) and lowest in March, April, and May (24 ± 6).

Root reserves of plants clipped or mowed in 1963 were definitely lower than control plants and the 5-year average for untreated plants. For example, plants clipped at 2-week intervals had an average carbohydrate content of 24.2 and 25.0 percent on March 21 and August 23, respectively. Mean average carbohydrates of plants for the growing season were 20.30, 23.03, and 18.99 percent in 2-, 4-, and 8-week clipping plots, respectively. Average available carbohydrates of plants in the 2-, 4-, and 8-week mowing plots were 27.06, 24.66 and 24.43 percent, respectively. Plants in the 24-week clipping and mowing (control) plots averaged 30.49 percent. However, carbohydrate data do not closely follow yield or mortality rates and are not valid in predicting plant responses to treatments conducted.

Discussion

In many areas of the Southwest, complete eradication of tamarisk is probably not economically feasible. Initial treatment with herbicides or mechanical clearing is costly and re-treatment is always necessary. Estimates

Figure 3--Bermudagrass and tamarisk resprouts on a periodically mowed flood plain. Mature tamarisk, willow, and arrowweed (background) yield little forage.

of benefits in water savings following such treatments on a reach or reservoir delta are not always reliable. Tamarisk, however, can be suppressed on flood plains and reservoir deltas by periodic mowing. In central Arizona, mowings in May, July, and September are necessary to keep foliage succulent and within reach of browsing cattle. Numerous observations of tamarisk sites indicate young tamarisk is heavily browsed on flood plains throughout the Southwest, and if tamarisk is mowed at prescribed intervals, it is estimated that bermudagrass and tamarisk resprouts (fig. 3) would produce hundreds of pounds of available forage per acre per year on what would otherwise be relatively low-yield sites.

Tamarisk was killed by frequent foliage removal, although mortality rates varied between treatment years. Mortality increased when tamarisk plants were completely defoliated at frequent intervals. Plants were not killed by 1 season of mowing. Yields of dry foliage from complete defoliation at all treatment intervals were similar to yields produced by mowing treatments. Evapotranspiration was decreased by approximately 50 percent following mowing treatments. Total hydrolyzable carbohydrate root contents decreased with severity of treatments; they were lowest after clipping treatments and highest in untreated control plants. Clipping treatments decreased available carbohydrate root reserves more than mowing treatments, but carbohydrate data did not closely follow yield or mortality curves. Tamarisk flowers throughout the growing season, so flowering does not appear to be a factor in explaining seasonal trends in available carbohydrate root reserves. Neither temperature nor water-table heights appear to account for carbohydrate changes during the 5-year series of Bartley and Otto (1963).

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Cattle Diets on Native and Seeded Ranges in the Ponderosa Pine Zone of Colorado

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Forage maturity at time of consumption was a major factor determining the general nutritive quality of range cattle diets. Cattle grazing seeded ranges in spring and fall had higher quality diets than cattle grazing native range yearlong, because seeded ranges started growth earlier in the spring and became dormant later in the fall.

Seeded ranges incorporated into the grazing management system may offer a practical means of increasing efficiency of livestock production in mountain cow-calf operations (Currie 1966).[2] Effective livestock gains are limited to the period of the year when forage plants are growing rapidly. Under present management practices, this period extends from early June to late September in most areas of the mountainous West. Livestock production is limited by forage low in quality, if not quantity, at other periods of the year. One way to increase this period of effective gain may be to seed species that begin growth earlier in the spring and remain green later in the autumn than do native forage species. These species used in a grazing management system, particularly for early-spring and late-fall grazing, could lengthen the period of availability of high-quality forage.

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[2] *Names and dates in parentheses refer to Literature Cited, p. 11.*

Use of these seeded species in early spring and in late fall would also relieve considerable grazing pressure on native summer range during two particularly critical periods of the year.

Unfortunately, little is known about the nutritive quality of native or seeded forage species in the ponderosa pine zone. Nothing is known of the effects of integrated use of both seeded and native species on animal nutrition. To obtain this information, the actual botanical and nutritive composition of the grazing animal's diet must be known. This report presents information obtained in a preliminary 1-year study of the diets of two 12-cow herds of Hereford cattle grazing ranges of the Manitou Experimental Forest near Colorado Springs, Colorado. One herd grazed native ranges yearlong (native-range herd); the other grazed both seeded and native ranges on an integrated basis (integrated-use herd).

Study Methods

Samples of the forage grazed by ruminal fistulated steers (fig. 1) were collected from March 1965 to February 1966. These animals grazed with the cow herds, and were assumed

Figure 1.--Ruminal fistulated steer with open fistula cannula.

to have diets similar to the cows. Initially, one steer was incorporated into each herd, but one of the steers became unmanageable early in the study and was no longer useful for sample-collection purposes. Consequently, the remaining steer was used for all subsequent sample collections, and was alternated between herds during periods of the year when the herds were grazing separate ranges. The various types of forage grazed by the two herds and the dates of use are presented in the grazing management plan (fig. 2).

Forage samples were collected from fistulated steers at approximately 1-month intervals, with more frequent collections during periods of rapid vegetational change. Usually two samples were obtained during each collection period--one during the late afternoon and another the following morning. On two occasions (August 10 and September 14), however, both morning and afternoon samples were collected during the same day. Grazing samples were obtained from the fistulated steers by the "rumen evacuation" technique outlined by Lesperance et al. (1960a).

Samples were analyzed both chemically and botanically. Chemical analyses for crude protein and phosphorus were performed according to AOAC (1960) procedures. Botanical analysis was performed by first grinding ovendried rumen samples in a Wiley[3] mill equipped with a 1-mm. screen. Small subsamples of the finely ground material were then mounted on standard microscope slides and analyzed under a compound binocular microscope at 125X. The botanical composition of each sample was determined by the relative number of epidermal fragments of each species recognized in 100 microscope fields. Reference slides of known species anticipated in the samples were analyzed prior to the actual sample analyses to learn diagnostic features of the epidermal tissue of each species.

Results and Discussion

Nutritive Composition of the Diet

Dietary evaluations based on chemical analyses without supplementary digestibility information do not reveal the true nutritive value of forage. They do provide valuable comparative information, however, and serve to show which constituents may be deficient or present in excess. The scope of this investigation was also severely limited by the small number of samples obtained. Consequently, inferences from the results should be made with caution.

Dietary crude protein.--Crude protein in the diets of the two cow herds followed seasonal trends largely indicative of the effects of forage maturity (fig. 3). Levels were high in early spring when forage plants were young and growing rapidly, then declined throughout the summer and autumn as the forage matured. The annual mean levels of dietary crude protein of the two herds were similar (9.08 and 9.78 percent for the native-range herd and integrated-use herd, respectively), but the short-term differences induced by the three grazing periods on seeded range were important. The herd grazing seeded ranges in the spring encountered high protein levels approximately 30 days earlier in the year than did

[3] *Mention of a trade name or product is for the convenience of the reader, and does not constitute endorsement or preferential treatment by the U. S. Department of Agriculture.*

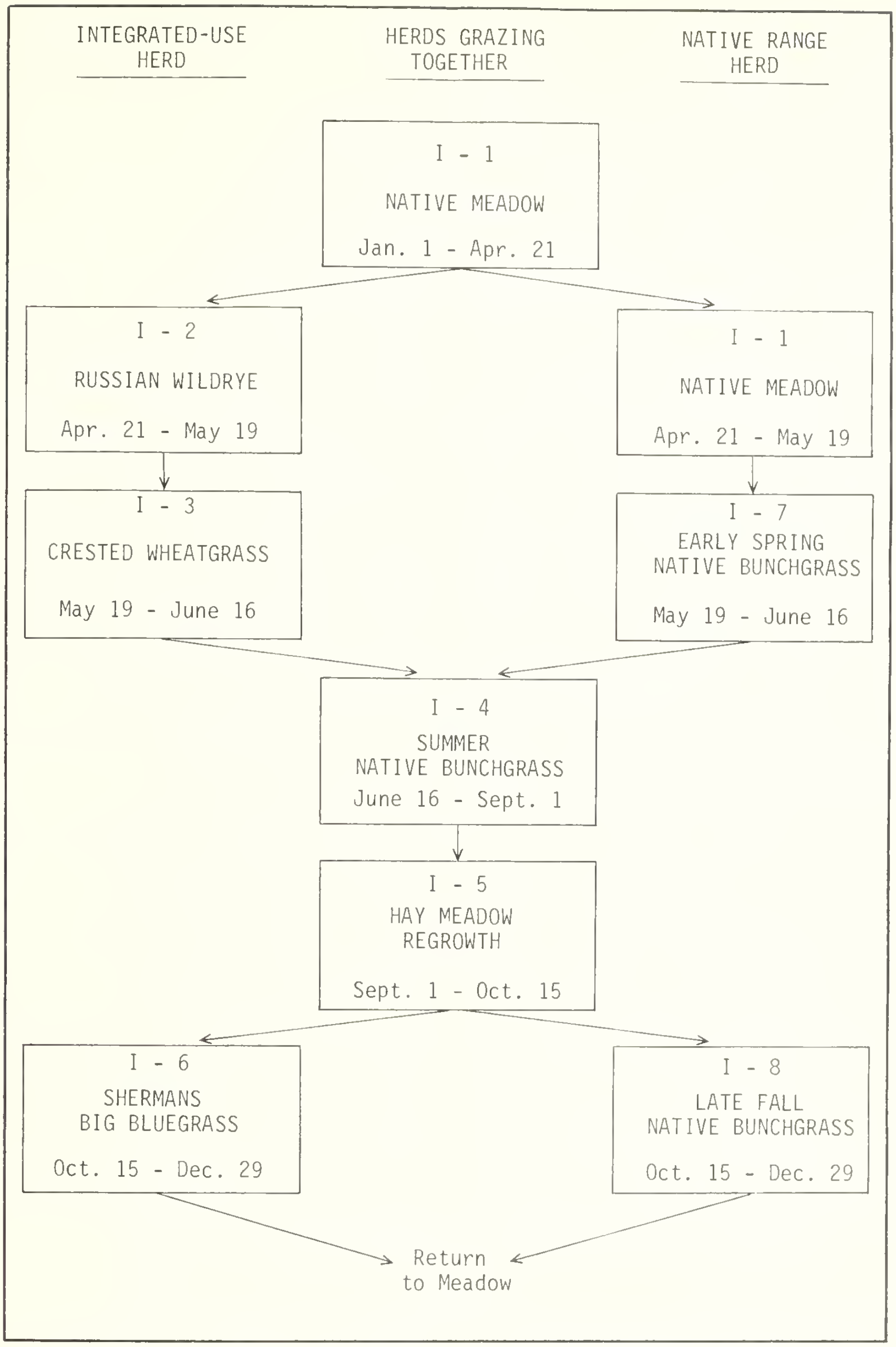

Figure 2.--Grazing management plan used to regulate the integrated use and native-range cow herds and their respective fistulated steers.

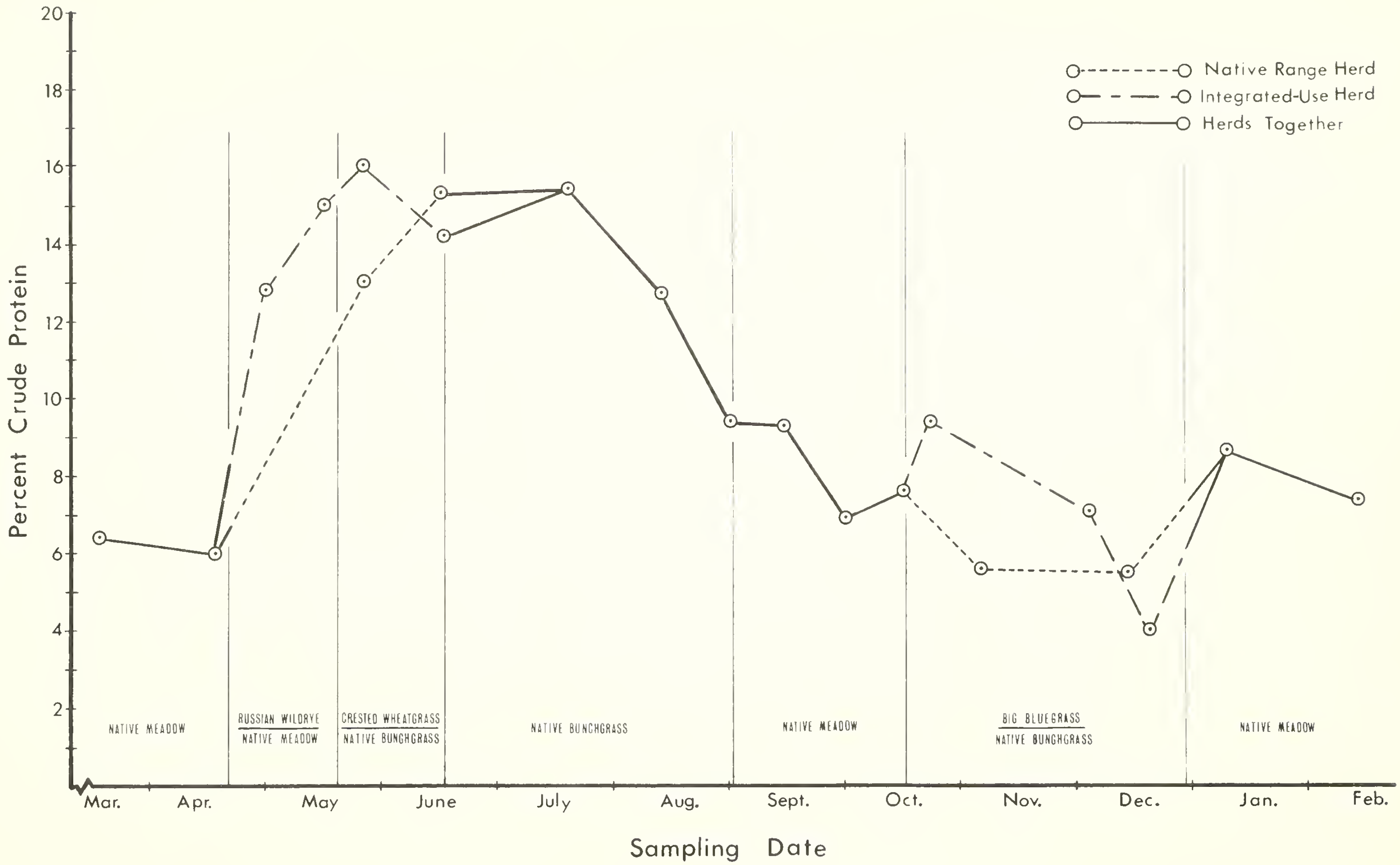

Figure 3.--Annual trends of dietary crude protein in forage samples collected by fistulated steers.

the herd grazing native ranges. This response is largely attributable to the earlier start of growth in the two seeded species, Russian wildrye (Elymus junceus Fisch.) and crested wheatgrass (Agropyron cristatum (L.) Gaertn.).

When the two herds were again separated in late autumn, dietary protein levels of the herd grazing seeded Sherman big bluegrass (Poa ampla Merr.) rose sharply, whereas protein in the diet of the herd grazing native range continued to decline. Again, the state of maturity of the forage probably accounted for a considerable degree of the response. The native bunchgrass forage was completely dormant by late October, whereas big bluegrass still contained large amounts of green tissue.

Dietary protein of both herds rose markedly when they were shifted to native meadow range in early January (fig. 3). This response may also reflect the physiological condition of the forage, as field observations on January 8 showed that the forage species grazed contained green tissue near their bases.

The various fluctuations in dietary protein cannot be attributed completely to changes in forage quality induced by advancing maturity, particularly those fluctuations that occurred over a relatively short period of time. Animal selectivity, as influenced both by species and quantity of forage available, undoubtedly modified the seasonal trends. Several researchers (Weir and Torell 1959, Lesperance et al. 1960b) have illustrated that dietary protein often declines with increasing limitations imposed upon animal selectivity by advancing degrees of range utilization. It is difficult to ascribe a particular fluctuation to any one cause, however, because most causes are interrelated. It is tempting to attribute the 2 percent decline during the grazing period on crested wheatgrass to increasing limitations on animal selectivity. The decline occurred over a relatively short time interval, in a pasture with restricted area (18 acres) and number of species available, at a season of the year when no major phenological changes were occurring. However, chemical analyses of hand-clipped, cage-protected herbage from the pasture indicated a similar decline in plant protein.

The marked decline of dietary protein throughout the autumn grazing period on big bluegrass was possibly the result of a compound effect of advancing forage maturity and limited animal selectivity. The particularly low level in the December 19 sample occurred during a period when there was a 4-inch snow cover. The grazing animals were forced to consume the coarse, fibrous, and probably less nutritious portions of the big bluegrass plants that protruded above the snow.

Dietary phosphorus.--Phosphorus in the diets of the two cow herds followed trends generally similar to those of crude protein (fig. 4). Peak levels in spring were followed by a general decline throughout the summer to minimum levels in autumn. Dietary phosphorus of both herds rose appreciably when they were introduced to native meadow range in January.

Averaged over the entire year of the study, phosphorus in the diets of the two herds was not greatly different (0.34 percent for the native-range herd and 0.35 for the integrated-use herd). Noteworthy differences were observed, however, during the three grazing periods when the herds were separated. In early spring, Russian wildrye provided higher levels of dietary phosphorus than did native forage, but this advantage was short lived. When the integrated-use herd was shifted to crested wheatgrass range, samples from the two herds indicated that native bunchgrass supplied considerably more phosphorus than did the crested wheatgrass. When the two herds were again separated in late autumn, dietary phosphorus of the herd grazing big bluegrass was usually somewhat higher than that of the herd grazing native range.

The overall seasonal trends in dietary phosphorus also indicate the effects of forage maturity upon plant phosphorus. Several researchers (Hart et al. 1932, Cook and Harris 1950) reported that phosphorus in various species of range forage was highest in the spring, but declined throughout the summer and autumn as the forage plants matured. Cook and Harris further observed that certain factors of the site may modify seasonal trends.

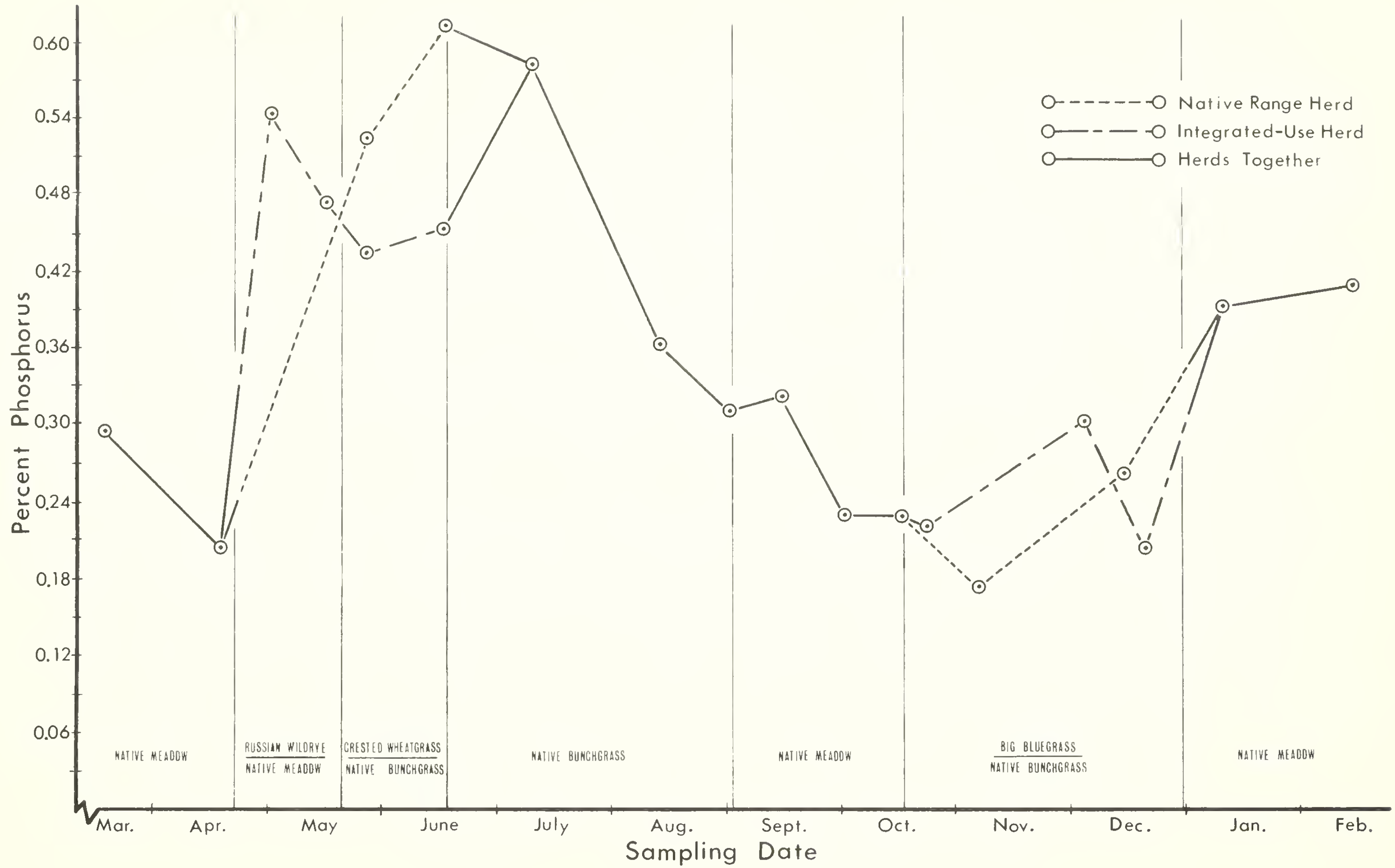

Figure 4.--Annual trends of dietary phosphorus in forage samples collected by fistulated steers.

Several fluctuations in dietary phosphorus cannot be explained completely by changes induced by advancing forage maturity. A good example is the decline during the grazing period on Russian wildrye (fig. 4). This decline occurred during a season when there were no major phenological changes. Since dietary protein increased appreciably during the same period, it is doubtful that the decline was due to limited forage availability or animal selectivity. The relatively low levels of dietary phosphorus throughout the grazing period on crested wheatgrass were also due to some factor or group of factors not discernible in this study. A high percentage of the forb, lambsquarters goosefoot (Chenopodium album L.) in the December 3 sample from the big bluegrass unit may partially account for the slight rise in dietary phosphorus at that time.

The results obtained from this study relative to dietary phosphorus may be useful in depicting general trends, but the accurate determination of dietary phosphorus from forage samples obtained from fistulated animals is questionable. Ruminant saliva is particularly rich in phosphorus, and correction techniques for its added effects were unavailable in this study. Van Dyne and Heady (1965a) maintain that dietary phosphorus determinations without adequate correction procedures (e.g., isotope dilution techniques) are entirely misleading.

Botanical Composition of the Diet

Results obtained in the botanical evaluation of the diets selected by the two cow herds permit only limited conclusions. Only one animal was used to sample the forage grazed by each herd; frequently the same animal was used for both herds. Van Dyne and Heady (1965b) calculated that a minimum of five animals is necessary in most botanical determinations of diet. Furthermore, a maximum of only two samples, and frequently only one, was obtained per collection period. Consequently, the conclusions that can be drawn from this study are severely limited by the low intensity of sampling. However, several interesting, and perhaps important, observations were made.

Botanical composition of samples collected from seeded ranges.--Seeded species comprised the forage available to the integrated-use herd for a total of 18 weeks in the spring and autumn of the study. The botanical composition of the dietary samples collected from each of the seeded ranges is presented in table 1. Generally, samples collected on seeded range were less variable in species composition than were those collected on native range. Obviously, the animals were limited in selectivity to the relatively small number of species available in these units. In all but one case, the seeded species under study contributed 73 percent or more to the composition of the samples. The exception was observed December 3 on the big bluegrass unit, when that species comprised only 20.7 percent of the sample. The remainder of the material was primarily lambsquarters goosefoot. This sample was collected early in the morning when there was a heavy dew on the plants. The added moisture may have softened the dry tissue of the forb, making it more appealing to the collecting steer.

Fringed sagebrush (Artemisia frigida Willd.) in the diet increased from 1.6 to 20.4 percent during the grazing period on crested wheatgrass pasture. Limited forage availability near the end of the grazing period may have forced the animals to alter their selectivity in favor of the fringed sagebrush, or other factors influencing plant palatability may have induced the animals to seek out the fringed sagebrush plants.

Botanical composition of samples collected from native ranges.--Fistulated steers grazing native bunchgrass and native meadow ranges were highly variable in their selectivity (tables 2 and 3). Samples collected during consecutive sampling periods within a particular grazing unit often differed extensively. In addition, samples collected on consecutive days within a period were sometimes quite variable. Consequently, no meaningful trends or preferences for individual species could be established. However, several interesting points were brought to light that may be helpful in designing future studies.

Groupings of all species as either grasses or forbs indicated that forbs were more im-

Table 1. --Percentage botanical composition of grazed forage samples from seeded ranges

Species or group	Grazing units and sample collection dates											
	I-7 Spring Native Bunchgrass		I-4 Summer Native Bunchgrass							I-8 Fall Native Bunchgrass		
	May 25	June 15	July 8*	July 8*	Aug. 10	Aug. 10	Aug. 14	Aug. 31	Sept. 1	Nov. 4	Nov. 5	Dec. 13
Grasses and grass-like species:												
Agropyron smithii	....	< 0.10	49.15	51.31	...	< 0.10	1.72	0.74	22.61	9.45	49.86	5.72
Blepharoneuron tricholepis	....	...	< 0.10	0.56	0.22	...	...	...	...	...	...	...
Bouteloua gracilis	....	...	< 0.10	0.10	...	33.06	5.36	7.15	13.40	4.26	0.54	...
Calamagrostis inexpansia	....	...	...	...	...	...	...	...	...	10.97	...	...
Carex heliophila	< 0.10	0.99	...	...	4.89	1.89	1.03	2.83	1.00	7.92	14.82	13.08
Danthonia parryi	....	...	...	...	1.55	0.67	...	1.49	5.02	...	...	...
Festuca arizonica	4.32	1.49	...	0.56	25.80	7.18	16.55	21.01	20.60	...	...	4.90
Koeleria cristata	3.63	< 0.10	...	...	3.45	2.44	8.45	7.60	5.19	3.66	0.80	3.27
Muhlenbergia montana	1.82	14.64	...	5.26	29.70	25.47	11.03	19.82	12.23	3.96	2.69	35.42
Poa pratensis	2.73	...	...	0.75	...	...	11.72	3.72	2.34	13.11	7.81	0.81
Stipa comata	< 0.10	4.96	...	...	1.00	0.54	4.31	4.32	...	1.52	...	...
Stipa robusta	3.86	3.72	< 0.10	...	0.33	...	...	...	...	8.53	1.61	2.45
Unidentifiable grasses	25.00	23.32	10.82	11.09	25.47	16.53	18.79	6.41	7.54	11.89	7.00	3.27
Total grasses	41.36	49.22	59.97	69.53	92.41	87.88	79.46	75.09	89.93	75.25	85.13	68.95
Forbs:												
Arenaria fendleri	...	...	2.00	...	1.67	0.95	2.76	2.08	0.33	...	...	...
Artemisia frigida	19.77	23.32	...	...	...	2.98	8.96	10.73	7.70	8.53	9.43	15.80
Astragalus striatus	...	...	...	...	...	...	...	...	...	...	...	4.08
Chenopodium album	...	...	< 0.10	...	...	...	...	...	...	...	...	...
Chrysothamnus viscidiflorus	...	...	...	...	...	...	...	...	0.16	...	...	...
Erigeron flagellaris	...	...	...	...	...	...	...	...	...	1.52	...	...
Geranium parryi	...	< 0.10	...	...	...	...	...	...	...	...	...	...
Melilotus officinalis	< 0.10	...	< 0.10	< 0.10	...	...	...	1.19	...	...	...	...
Polygonium aviculare	...	...	8.96	1.88	...	...	...	...	...	...	...	...
Potentilla pennsylvanica	32.39	12.40	...	3.19	...	...	...	...	...	0.61	2.42	1.36
Unidentifiable forbs	5.91	15.13	24.42	23.68	5.89	7.86	10.34	10.73	1.84	14.02	2.96	9.81
Total forbs	57.91	50.75	35.38	30.44	7.56	11.79	22.06	24.73	10.03	24.68	14.81	31.05

* Samples collected by steers A and B, respectively.

Table 2. --Percentage botanical composition of grazed forage samples from native bunchgrass ranges

Species or group	Grazing units and sample collection dates								
	I-2 Russian wildrye		I-3 Crested Wheatgrass		I-6 Big Bluegrass				
	May 1	May 15	May 25	June 16	Oct. 21	Oct. 22	Dec. 2	Dec. 3	Dec. 19
Grasses and grass-like species:									
Agropyron cristatum	...	...	97.30	79.60	...	...	...	...	...
Agropyron smithii	...	...	...	...	0.46	...	0.38	...	...
Carex heliophila	...	...	...	...	...	...	< 0.10	...	...
Elymus junceus	81.50	73.00	...	...	...	...	...	...	...
Juncus balticus	8.00	1.61	...	...	...	...	...	...	...
Muhlenbergia richardsonis	...	...	...	...	...	...	< 0.10	...	0.30
Poa ampla	...	...	...	...	81.55	84.41	75.23	20.86	92.17
Poa pratensis	1.20	3.23	...	...	...	...	...	...	...
Stipa comata	...	...	...	...	4.35	5.69	0.58	...	...
Unidentifiable grasses	...	16.40	...	...	8.23	5.88	...	0.72	0.60
Total grasses	90.70	94.24	97.30	79.60	94.58	95.98	76.19	21.58	93.07
Forbs:									
Artemisia frigida	1.20	...	1.61	20.39	0.46	...	0.58	1.44	0.60
Chenopodium album	...	...	...	...	...	...	21.94	74.10	6.32
Potentilla pennsylvanica	...	0.92	...	...	...	...	...	...	...
Taraxacum officinale	...	...	...	...	...	<0.10	...	...	...
Unidentifiable forbs	8.00	3.00	0.73	...	4.12	3.58	0.38	2.88	...
Total forbs	9.20	3.92	2.34	20.39	4.58	3.58	22.90	78.42	6.92

Table 3.--Percentage botanical composition of grazed forage samples from native meadow ranges

Species or group	Grazing units and sample collection dates										
	I-1 Native Meadow Winter Range					I-5 Hay Meadow Regrowth					
	Jan. 8*	Jan. 9*	Feb. 12*	Mar. 17	Apr. 17	Sept. 14	Sept. 14	Sept. 30	Oct. 1	Oct. 14	Oct. 15
Grasses and grass-like species:											
Agropyron smithii	...	...	...	...	...	1.76	<0.10	1.22	<0.10	...	...
Agropyron trachycaulum	0.86	45.66	17.65	2.64	3.71	...	...	...	...	...	...
Agrostis scabra	...	...	...	...	6.81	...	...	...	...	...	...
Andropogon scoparius	...	...	...	0.90	...	...	...	...	...	...	...
Bouteloua gracilis	...	...	...	4.29	...	...	...	...	...	...	...
Calamagrostis inexpansia	11.42	0.58	10.41	9.24	8.98	4.52	16.07	16.33	32.68	38.78	28.32
Carex nebraskensis	5.71	4.04	18.55	37.62	54.48	10.55	57.14	28.24	8.79	16.12	19.94
Festuca arizonica	...	...	2.26	3.63	...	...	...	...	...	...	...
Glyceria striata	...	...	...	...	0.62	...	...	...	...	...	...
Juncus balticus	2.28	...	9.50	...	0.93	19.09	1.65	1.06	< 0.10	1.31	1.73
Muhlenbergia montana	...	...	...	12.21	...	...	...	...	...	...	...
Phleum pratense	...	...	...	...	0.62	5.02	2.33	3.81	4.04	3.48	4.05
Poa pratensis	20.00	27.45	20.36	4.95	7.43	59.04	19.09	44.42	47.98	32.02	40.75
Unidentifiable grasses	2.57	5.20	3.17	11.55	7.74	<0.10	3.02	3.51	4.39	3.70	2.60
Total grasses	42.84	82.93	81.90	87.03	91.32	100.00	99.32	98.63	97.90	95.42	97.40
Forbs:											
Arenaria fendleri	...	...	...	3.30	...	...	...	...	...	...	...
Artemisia frigida	...	1.15	4.07	5.94	...	...	...	...	...	...	...
Chenopodium album	...	11.85	9.05	...	...	...	...	...	...	...	...
Trifolium pratense	...	...	...	...	...	...	0.68	...	...	0.44	...
Unidentifiable forbs	57.14	4.04	4.89	3.30	8.67	...	...	1.37	2.10	4.14	2.60
Total forbs	57.14	17.04	18.10	12.54	8.67	...	0.68	1.37	2.10	4.58	2.60

* Samples collected during 1966 grazing season. Remainder of data from 1965.

portant in the diet in early spring than at any other time of the year. Forbs contributed from 30 to 58 percent of the diets during the period from late May to early July (table 2). Forbs were also of importance in December and January when the two herds were grazing native meadow range (table 3). At other periods of the year, forbs rarely contributed more than 20 percent to the samples from native ranges.

Fringed sagebrush, a species thought to receive little grazing use, was especially important in the diets of cattle grazing native bunchgrass in early spring (table 2). Samples collected on May 25 and June 25, respectively, contained 19.8 and 23.3 percent fringed sagebrush. Fringed sagebrush was the only individual species that exhibited consistent trends in the samples. If the species was present in a particular grazing unit, it increased steadily in the diet from the first to the last sample collected in the unit.

Samples were obtained from both fistulated steers grazing the same range only during the July 8 collection period on native bunchgrass range. It is evident from table 2 that the two animals selected forage quite similar in botanical composition.

The extreme variability observed in the botanical compositions of native-range forage samples from fistulated steers probably reflect the heterogeneity of the ranges sampled rather than changes in animal preference. Range sites in the native bunchgrass grazing units vary from swales supporting dry meadow vegetation to ridgetop sites supporting typical pine-bunchgrass vegetation. Likewise, the two native meadow units are characterized by a variety of different sites, with each site supporting a somewhat different species association. Although daily cattle movements were not studied specifically, incidental field observations indicated that the animals roamed widely throughout a particular grazing unit in a day's time. Therefore, throughout any 1 day, the cattle grazed over several range sites. The samples obtained during the 30-minute to 1-hour intervals allowed the fistulated steers for sample collection are possibly quite representative of the forage selected in a localized area, but they represent only a small part of the total daily diet. This may explain some of the large differences often observed between samples collected during subsequent days. Frequently, the animals were grazing in widely separated areas when each of the two samples were collected.

Summary and Conclusions

Forage samples collected by freely grazing ruminal fistulated steers were analyzed chemically and botanically to ascertain the quality of the diets selected by two herds of Hereford range cows managed under separate grazing systems. Crude protein in the diet of the herd grazing both native and seeded ranges on an integrated basis was adequate to excessive for 10 months of the 1-year study period, whereas crude protein in the diet of the herd grazing native ranges only was adequate for only 8 months.[4] The seeded ranges provided a 2-month advantage of adequate dietary protein because they started growth earlier in the spring, and became dormant later in the fall.

Seasonal trends in both dietary crude protein and dietary phosphorus indicated that the stage of forage maturity at time of consumption was of major importance in determining the general nutritive quality of the diets of both herds.

Botanical compositions of the diets were highly variable, particularly on native ranges. The variability was believed to reflect the heterogeneity of the ranges sampled rather than changes in animal preference.

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OCKY MOUNTAIN FOREST AND RANGE

Weight and Cubic-Foot Relationships for Black Hills Ponderosa Pine Saw Logs

Vern P. Yerkes[1]

Green weight per cubic foot of 223 Black Hills ponderosa pine logs was significantly correlated with selected variables. Log green weight per cubic foot and cubic foot volumes were predicted for individual logs using selected variables and weight.

Forest products industries today face an increasing dependence on smaller and lower quality logs for their raw materials. The Black Hills timber industries of South Dakota and Wyoming are no exception. Handling costs for these logs often determine whether they can be utilized economically.

Determining the volume of small logs accurately enough for purchase or contract handling is a vital and often costly phase of log production and sale administration. Although weight scaling has been proven an economical, accurate, and acceptable method of determining log volume on a board-foot basis in many areas, there are some conflicting reports on its reliability. The causes of these disagreements are largely unknown. A detailed examination of variables that affect log density[2] might help explain some of the results of earlier studies, and promote a better understanding and application of weight scaling. Also, the use of increasingly sophisticated and expensive handling equipment requires more precise knowledge of log densities for most efficient equipment and loading utilization.

Theoretically, if all other variables are constant, log density should be independent of either diameter or length. Therefore, density should be useful in a detailed investigation of other variables. Several authors report that size does significantly affect density of various species (Guttenberg et al. 1960, Landt and Woodfin 1959, Miller 1941, Schumacher 1946, Taras 1956)[3] indicating there is correlation between log size and variables that directly affect log density.

Calculated cubic-foot volumes are more closely related to log diameter and length and less subject to human error than are the more popular board-foot volumes. Because of this, and since there is an increasing interest in volume measures other than board-foot, cubic-foot volume was used to calculate log densities.

Of several factors which could directly affect the density of logs, the following were selected for study: Weighted average moisture content as a percent of ovendry weight; weighted average specific gravity, based on

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[2] *Density hereafter refers to the weight in pounds per cubic foot for green logs.*

[3] *Names and dates in parentheses refer to Literature Cited, p. 4.*

green volume and ovendry weight; percent heartwood, percent bark, and percent defect, expressed as a percentage of gross inside bark volume. Diameter inside bark small end (d.i.b.) was included to determine its relationship to other variables, and for use in predicting log density and volume.

This study was designed to (1) show how selected variables are related to each other and to log density, (2) determine the reliability of using selected variables to predict the density of logs, and (3) determine the reliability of using weight and other selected variables to predict the net cubic-foot volume of logs.

Methods

Data for this study were collected from 223 logs and segments that ranged from 5.1 to 16.5 feet in length, and from 6.9 to 23.8 inches d.i.b. small end. They were cut from 75 trees from a variety of sites during a summer season (table 1, fig. 1). Logs used were considered average for the Black Hills, with distribution of diameter classes comparable to an earlier study (Landt 1959).

Logs were weighed to the nearest 5 pounds on a hydraulic load cell immediately after felling. Smalian's formula was used to calculate cubic-foot volumes for outside bark, inside bark, and heartwood volumes. Volume of heart rot, the only defect considered, was calculated from its visible dimensions.[4] Moisture content and specific gravity of both heartwood and sapwood were determined from increment core samples taken near each bucking point in the tree (McMillen 1956, Mitchell 1958). Log specific gravity and moisture content values were weighted by volume of heartwood and sapwood. Density was calculated by dividing total weight of the green log (including bark) by net solid wood volume.

Results and Discussion

There was a complex, significant[5] correlation among all the variables used in the analysis of density, both among the independent variables and between independent variables and log density (table 2). This precludes a clearcut explanation of cause and effect between any one variable and changes in log density. For example, contrary to what one would expect, specific gravity is negatively correlated with log density. This can be explained, however, by an examination of the correlations among specific gravity, moisture content, percent heartwood, and log diameter. Specific gravity increases with log size. As log size increases, however, percent heartwood increases which reduces the percent of wet sapwood in the log. This in turn lowers the percent moisture of the log, and reduces the log density. The reduction of density due to lower moisture content is more than the increase due to higher specific gravity. The

[4] *Average end area times length. If rot did not extend through the log, it was assumed to extend one-half the length.*

[5] *Throughout this report, 95 percent level of significance is used; for degrees of freedom, 75 instead of 222 were used because of probable high correlation of measured variables between logs of the same tree.*

Table 1.--Maximum, minimum, and average values for 223 ponderosa pine logs

Item	Unit of measure	Maximum	Minimum	Average, all logs
Diameter inside bark, small end	Inches	23.8	6.5	10.8
Log weight	Nearest 5 pounds	2,855	190	768
Volume	Cubic feet	58.42	2.74	13.13
Density	Green weight per gross cubic foot volume	78.22	43.06	[1] 58.47
Weighted average moisture content	Percent, ovendry basis	168	44	111
Heartwood	Percent of gross wood volume	54.0	0.0	14.2
Specific gravity	Green volume, dry weight	.465	.329	.385
Bark	Percent of gross wood volume	56.4	10.1	25.8
Defect	Percent of gross wood volume			
All logs		28.1	0.0	1.3
Defective		28.1	.1	4.6

[1] Average density for all logs was calculated by dividing the sum of log weights by the sum of log volumes.

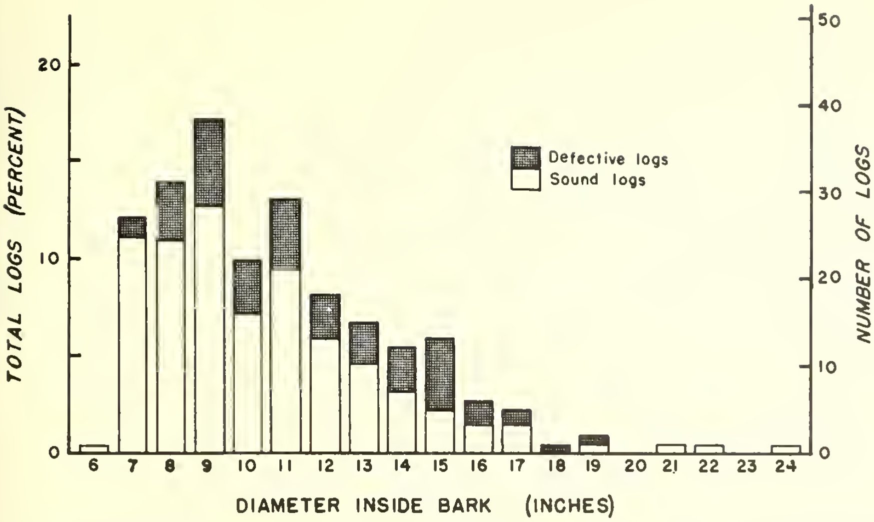

Figure 1.--Size class distribution for 223 Black Hills ponderosa pine logs.

net result is a negative correlation between specific gravity and density.

Analyses indicated no significant correlation between log position in the tree and density, percent heartwood, or percent moisture. Upper logs, however, did have significantly lower specific gravities than lower logs.

Preliminary plotting of raw data indicated that straight lines were reasonable estimates of the relationships between density and the three variables with which it was most highly correlated. Also, preliminary analysis revealed that percent defect did not significantly affect density, even for logs containing heart rot. Therefore, data for all logs were combined for development of the density prediction equation.

Multiple regression analysis of the data indicated that, for these logs, density could be estimated within acceptable levels of significance. Moisture content and percent heartwood individually were near equal in the amount of the variation in density they explained in a prediction formula (R^2 = 0.424 and 0.422, respectively). Together they explained a significantly greater amount of the variation (R^2 = 0.48). None of the other variables were significant additions to the formula.

When diameter was considered, it was a better single predictor of density than either moisture content or percent heartwood. Percent moisture was a significant addition to this formula, but percent heartwood was not. The addition of any or all of the other variables was not significant.

Following are the significant regression formulas for predicting density:

	R^2
$Y = 79.53 - 1.73X_1$	0.48
$Y = 61.88 - 1.26X_1 \quad 0.115X_2$	0.63

Where:

Y = density in weight per cubic foot

X_1 = diameter inside bark small end (inches)

X_2 = weighted average moisture content (percent)

Table 2.--Correlation matrix from regression of selected variables on weight per cubic foot and on each other for 223 Black Hills ponderosa pine logs (significant r is about 0.225)

Item	Percent moisture	Percent heartwood	Percent bark	Specific gravity	Percent defect	Diameter inside bark
Weight per cubic foot	0.651	-0.649	0.429	-0.364	-0.182	-0.694
Percent moisture		- .744	.423	- .478	- .333	- .476
Percent heartwood			- .595	.407	.366	.608
Percent bark				- .135	.619	- .434
Specific gravity					.315	.309
Percent defect						.135

The technique used in developing the cubic-foot volume prediction formulas was based on results of the density prediction analysis and practical considerations. Moisture content, percent bark, and percent heartwood were excluded as variables in the volume prediction equations because of their relationship to diameter, and because they are difficult to measure in the field.

Formulas for predicting net cubic foot volume of green Black Hills ponderosa pine logs are:

	Standard error y'x	R^2
$Y = -2.09 + 0.020X_1$	1.89	0.954
$Y = -6.19 + 0.015X_1 + 0.710X_2$	1.71	0.963
$Y = -6.82 + 0.014X_1 + 0.843X_2 - 0.175X_3$	1.53	0.970

Where:

Y = net wood volume (cubic foot)

X_1 = total log weight (pounds)

X_2 = log diameter inside bark small end (inches)

X_3 = percent defect

Total weight was the best single predictor of log cubic-foot volumes ($R^2 = 0.95$). Addition of diameter to the formula improved it a significant though minor amount ($R^2 = 0.96$). Defect was the third significant variable added to the prediction formula ($R^2 = 0.97$).

Conclusions

The net cubic-foot volume of Black Hills ponderosa pine logs can be estimated by their weight. In this study, weight alone not only explained 95 percent of the variability in the net cubic-foot volume of 223 logs, but also predicted their volume with a coefficient of variation of only 14 percent. When one considers the costs, errors, and other difficulties inherent in stick scaling logs of this size, the weight method of estimating volume becomes more attractive. If log size and percent defect were added to the formula, the cubic-foot volume estimation would be improved significantly. Until more efficient methods of measuring these variables are developed, however, weight alone will undoubtedly be most efficient.

Data collected are being analyzed further, in terms of board-foot volumes, to develop information that will be useful in field application of weight scaling.

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FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Regeneration of Mixed Conifer Clearcuttings on the Apache National Forest, Arizona

John R. Jones[1]

In 1958-59, seven blocks of mixed conifers were clearcut or commercially clearcut. Two were planted and one was spot seeded. In 1965, little postlogging regeneration could be found, natural or artificial. Advance regeneration had largely been destroyed by logging and slash disposal, and some which survived had been seriously browsed. Seedfall, seedbeds, weather, animals, and other possible factors are discussed and the management implications pointed out.

The mixed conifers of the Southwest are a complex of timber types, occupying a zone between the zone of ponderosa pine and that of Engelmann spruce and corkbark fir. The species involved are: Douglas-fir, Pseudotsuga menziezii var. glauca (Beissn.) Franco; white fir, Abies concolor (Gord. & Glend.) Lindl.; corkbark fir, A. lasiocarpa var. arizonica (Merriam) Lemm.; ponderosa pine, Pinus ponderosa Laws.; southwestern white pine, P. strobiformis Engelm.;[2] Engelmann spruce, Picea engelmannii Parry; blue spruce, P. pungens Engelm.; quaking aspen, Populus tremuloides Michx.; and Gambel oak, Quercus gambelii Nutt.

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[2] *Southwestern white pine was until recently regarded as a variety (Pinus flexilis var. reflexa) of limber pine. For brevity it will be referred to as white pine.*

Any particular stand may include from two to eight of the species, and may be a mosaic or a fairly homogeneous mixture.

Past logging has been selective. To examine the effects of clearcutting on water yield, forest regeneration, and other aspects of land management, seven blocks were either clearcut or "commercially clearcut" on the Burro Creek drainage of the Apache National Forest in 1958-59 (figs. 1, 2). Slash was burned or left untreated. In April 1961, 2-2 ponderosa pines were planted on two blocks. Another block was spot seeded with white pine.

By June 1965, little postlogging regeneration was present, natural or artificial. This paper discusses the factors that contributed to regeneration failure. The data are from studies of the Forest's plantations and seeding, and from experiments, surveys, and several years of observations.

Figure 1.--A clearcutting 5 years after broadcast burning.

Figure 2.--A commercial clearcutting 6 years after slash was handpiled and burned.

Study Area

There are substantial climatic and geologic differences between different mixed conifer areas in the Southwest.

The study area is in east-central Arizona between 9,100 and 9,800 feet elevation. The cutover slopes are mostly moderate, with some short, steep pitches and some gently sloping benches. The soils are derived from vesicular basalt; they are fertile, stony, and in places very shallow.

Precipitation records have been kept on the area since 1959, and temperature records since late 1962. Summers are cool; on most summer days temperatures do not rise above the 60's. Winters are generally rather mild, with occasional periods of cold. On most winter days temperatures rise into the 40's.

For the 6 years of record, average annual precipitation was 30.57 inches. Figure 3 illustrates the general relationships of monthly precipitation to potential evapotranspiration, and the unusually favorable moisture climate

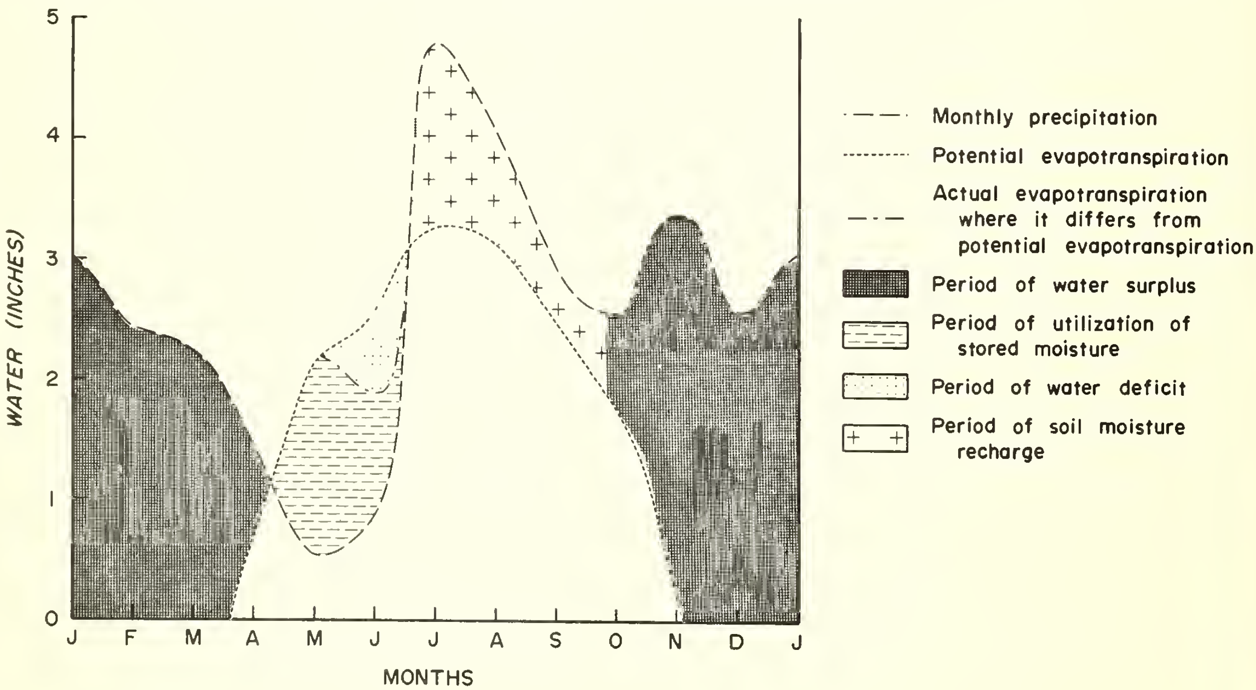

Figure 3.--Moisture climate at Burro Creek, station elevation about 9,300 feet, expressed by the method of Thornthwaite and Mather (1957).

of the study area. Its averages, however, conceal occasional autumn droughts and severe spring drying of the uppermost soil layers. It also ignores slope direction and moisture received as runoff from upslope.

North slopes, usually snow covered from late autumn into early April, retain partial snow cover well into April or May. South slopes, although often partly bare in winter, retain partial snow cover into April.

Spring precipitation is almost invariably low, falling as infrequent showers or storms.

The typical rainy season begins in late June or early July, ending as early as late August and as late as late September. Cloudy days are frequent. Measurable rain fell on 50 percent of July and August days during the 6 years of record.

Autumn precipitation is variable. It tends to fall in occasional storms separated by periods of clear, cool weather with low relative humidity.

The virgin forest was many aged, with a preponderance of mature and overmature trees, and commonly with fairly abundant seedlings and saplings. The order of species abundance, according to volume, was Douglas-fir, ponderosa pine, spruces (Engelmann and blue), white pine, corkbark fir, aspen, and white fir.

Factors That Affect Regeneration

Regeneration difficulties in western mountain forests can usually be traced to relatively few obstacles. Success hinges on recognizing and reducing those obstacles.

The most common obstacles to regeneration east of the Sierra-Cascades are so interrelated as to be almost inseparable. They are: inadequate seed supply, inadequate moisture, vegetative competition, and pests (Hayes 1966).[3]

[3] *Names and dates in parentheses refer to Literature Cited, p. 8.*

We shall examine what happened at Burro Creek with those four points as a frame of reference, subdividing pests into rodents and browsing animals.

Seed Supply

If germination and survival are high, the number of seed required is not great. If seed or seedling predation is high or moisture inadequate, a very large seed supply may fail to regenerate an area.

We know nothing of seed fall at Burro Creek from 1958 to 1960. In 1961, a grid of foot-square seed traps was laid out in uncut timber to evaluate seed fall for the years 1961-63 (table 1)--years which provided seed for regeneration surveyed in June 1965.

Another grid was laid out to measure seed fall in a 10-acre clearcutting for the same years (table 1). The total 3-year fall of 63,000 filled seed per acre, in addition to seed which fell during the previous posttreatment seed years, should have restocked the area had the environment been favorable and seed distribution uniform.

Seed distribution was not uniform, however. From 1961 to 1963, not enough seed fell to permit isolines to be drawn. A bumper crop

Table 1. --Filled seed per acre in the two study areas, 1961-63

Study area and species	Filled seed			
	1961	1962	1963	Total
	- - - Number per acre - - -			
Uncut stand:[1]				
Douglas-fir	72,000	8,000	109,000	189,000
Spruces	162,000	13,000	31,000	206,000
Corkbark fir	20,000	0	5,000	25,000
White pine	0	0	0	0
Ponderosa pine	1,000	0	1,000	2,000
Total	255,000	21,000	146,000	422,000
10-acre clearcutting:[2]				
Douglas-fir	2,700	1,800	10,800	15,300
Spruces	25,800	5,300	10,200	41,300
True firs	700	0	2,400	3,100
Ponderosa pine	1,600	600	1,100	3,300
Total	30,800	7,700	24,500	63,000

[1] Species listed in order of overstory abundance in trap area; white fir not present in trap area.

[2] White pine not listed since its large and wingless seed depend upon animals for distribution into open areas.

was produced by all species in 1964. That crop is not reflected in the regeneration data, since for the most part it had not germinated when the final survey was made. It did, however, provide a seed fall map (fig. 4) depicting seed dispersal patterns. Seed fall decreased sharply with increasing distance from the uncut timber. On the west side of the block, which presumably is the windward side and largely coincides with the upslope margin, seed fall was much heavier than on the east side. Within the band defined by the isoline for 400,000 filled seeds per acre, sample seed fall averaged over 500,000 filled seeds per acre, while the area enclosed by the 40,000 isoline averaged only about 10,000.

Presumably both the prevailing autumn winds and slope position modified the effect of distance from timber.

On the commercial clearcuttings, pole-sized residual Douglas-fir, corkbark fir, spruce, and white pine bore cones. Cones also were borne by both Engelmann spruce and blue spruce as little as 4 feet tall.

Almost all natural postlogging regeneration on clearcuttings grew within 100 feet of a timber margin, and a great majority of it within 1 chain. On commercial clearcuttings, seedlings also grew near seed-bearing residuals.

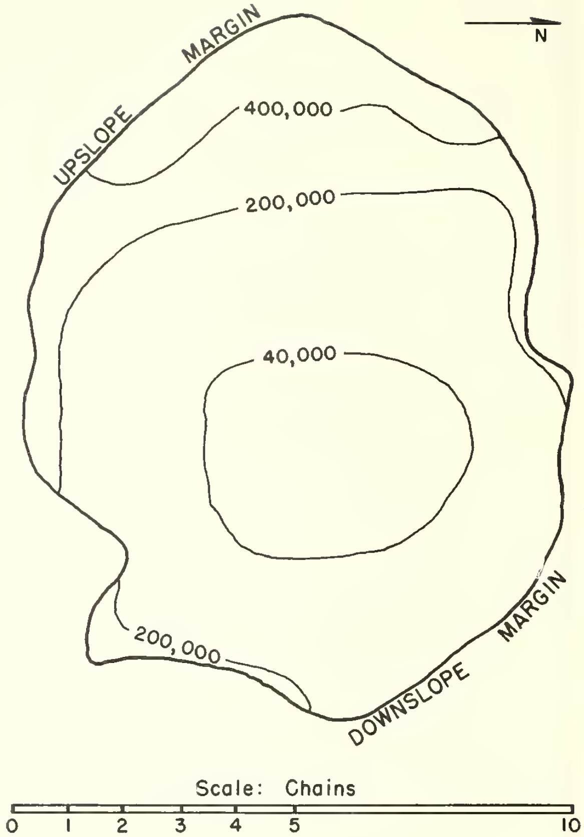

Figure 4.--1964 fall of filled seed per acre on a 10-acre clearcutting.

Rodents

Rodents must have eaten considerable seed. A 16-acre operational spot seeding of white pine, accompanied by rodent control, resulted initially in a very large number of seedlings. Without rodent control, comparable quantities of naturally distributed seed resulted in few seedlings. Later experimental spot seeding of white pine and ponderosa pine without protection resulted in germination of only 12 percent, even though the seed was covered with soil. On similar seed spots covered with screens, germination was 30 percent, even though mice tunneled under many screens to take the seed. Laboratory germination was 72 percent.

Predation was not restricted to seed. Some unprotected seedlings were clipped off.

On the other hand, considerable seed was not eaten, at least where the fall of fir seed was heavy. During the survey of June 1965, following the bumper cone crop of 1964, many newly germinated corkbark fir seedlings were found around seed trees in commercial clearcuttings. Appreciable numbers of new spruce and Douglas-fir seedlings, mostly transient, have been seen at other times where seed fall was heavy.

The kind of rodent may affect the eventual composition as well as the rate of regeneration; Abbot and Hart (1960) found that, in New England, deer mice and red-backed voles (Clethrionomys gapperi) greatly preferred spruce seed (Picea glauca (Moench) Voss) to that of balsam fir (Abies balsamea (L.) Mill.). The deer mouse (Peromyscus maniculatus) was believed to be the primary seed predator.

Rodent numbers are greater where slash provides cover (Krauch 1956), and increase greatly when vegetative ground cover becomes essentially complete (Tevis 1956). Deer mice eat very large numbers of insects as well as seeds, however (Hooven 1958), and control is desirable only at specific critical times.

Moisture

The soil was moist when the snow melted, a time that differed from year to year and with slope direction. Not much moisture was added until the summer rains began. The depth to which critical drying developed varied with plant cover and length of time between snow-melt and summer rains. On much of the cut-over area, only the top 2 to 3 inches dried out where substantial plant cover was lacking.

The autumn droughts also began with moist soil. Some were short and insignificant; others were long and severe.

Corkbark fir, white fir, and many white pine germinate in the spring and are exposed to the spring drought as newly germinated seedlings. Ponderosa pine, and apparently Douglas-fir and the spruces, germinate here mainly after the summer rains begin, and are only 1 to 2 months old when the fall drought usually arrives.

Large numbers of newly germinated white pine in seed spots survived the spring and fall droughts of 1961 and 1963. Ponderosa pine 1 to 2 months old survived 27 consecutive rainless days on seed spots in September and October 1963.

Few Douglas-fir, true fir, or spruce seedlings of any year survived to the following summer, and moisture stress may have been an important factor. Their general elevational distribution and smaller seedlings suggest that they are more sensitive than the pines to drought.

Herbaceous Competition

The problem of moisture is closely tied to herbaceous competition. There were almost no natural seedlings as old as 1 year where grass occupied the site, even near uncut timber. Seedlings were more frequent where vegetation was light or absent.

In October 1962, white pine and ponderosa pine were seeded on small prepared plots in an area heavily covered by seeded grass (fig. 5). Many seedlings survived the first year. Reoccupation by grass was complete by the end of the second summer, and there has been a constant attrition of tree seedlings since. Few of the survivors are growing in height amidst the tall, thick grass.

In the unusually favorable moisture climate at Burro Creek, on the other hand, grass competition has not killed many planted trees. The trees were planted before grass had occupied the areas. Survival in the plantation seeded with grass was about the same as in the plantation where grass invaded naturally and more slowly. In contrast to seedlings on seed spots, planted trees protected from browsing are growing fairly well despite heavy grass competition (fig. 6).

Browsing

Browsing by mule deer, elk, or both has been a very important factor in seedling survival and growth. Both animals were numerous. By the beginning of the second summer

Figure 5.--Grasses were sown on this clearcut area before it was spot seeded to ponderosa and white pines.

Figure 6.--Ponderosa pines 5 growing seasons after planting. The seedling on the left has been protected from browsing for 3 growing seasons. The others were unprotected; the four on the right are typical.

after planting, only 27 percent of the planted ponderosa pines were alive. Twelve percent of the losses were caused by browsing. Almost all the remaining losses were attributed to unknown causes. Of the survivors, 80 percent have since been killed by browsing. By September 1965, survival had dropped to 5 percent. Most unprotected survivors are in poor condition due to browsing, and probably will die (fig. 6). Even without the large, unexplained first-year losses, the plantations would almost certainly have failed because of browsing.

After the second growing season, an elk exclosure was built in each plantation. Most of the survivors within the exclosure recovered and are beginning to make substantial height growth (fig. 6).

Cattle browsing was not important at Burro Creek. Not numerous, cattle were fenced from one plantation but not the other. Browsing losses were about the same.

A game repellent, Goodrite Z.I.P.,[4] was applied to the planted trees in the spring of 1962 and the spring of 1963. It was not effective. Perhaps it repelled either deer or elk; clearly it did not repel both. In a study on the Coconino Plateau, Heidmann (1963) found ZAC and TMTD effective against mule deer but not against cattle.

Small advance regeneration that survived logging and slash disposal has also been browsed. Browsing has prevented many corkbark firs from making any height gains. Most Douglas-firs have made some headway. Neither Engelmann nor blue spruces were seriously browsed. There was little advance regeneration of other species.

White pine seedlings on seed spots show little sign of browsing.

[4] *Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*

Other Factors

In April 1961, 16 acres were seeded to white pine in spots spaced 3 by 3 feet. The following October about 30 percent of the spots were stocked, many with more than one seedling. Rodents had been controlled in the spring and again in the summer.

By the following summer, few seedlings could be found. The cause of the loss is not known. Survival had been excellent through the spring drought of 1961 and through at least the first fall drought of that year. Herbaceous cover, mostly forbs, was not heavy. Baiting, lack of slash, and the light vegetation makes it unlikely that rodents were a major factor. Mule deer and elk have not been greatly attracted to the survivors, and probably did not contribute importantly to the losses.

The seed was from the Lincoln National Forest, where snow cover does not last nearly as long as on the seeded area. It is possible that the seedlings were not adapted to the Burro Creek winters.

In the later experimental seeding of both pine species, there were appreciable but not critical losses to frost heaving. Cutworms, and what appeared to be basal heating, were minor factors. There were no drastic short-term losses like those on the large seeding.

The severe first-year losses of planted ponderosa pines have been mentioned. Planted in April 1961, 17 percent of these 2-2 transplants were dead and yellow by the following October. An additional 24 percent were in very poor condition. Almost all of the "poor" seedlings were dead when next visited the following July, and the survival of all seedlings was down to 27 percent. Eighty-one percent of the losses could not be explained.

In 1961 and 1962, each dead seedling on the eight study transects was dug up. Gophers or other rodents had not killed them, and soil insects appeared to have been unimportant. The seedlings had intact systems of coarse roots, and the loss of fine roots could easily be accounted for by decay after death.

A number of the seedlings that died had been poorly planted in the stony soil. The roots had been wadded or folded into inadequate holes, even though they had been planted deeply enough that their roots were below the layer of critical drying.

A number of survivors were dug up after five growing seasons. Their root systems were surprisingly small. Some clearly reflected poor planting. Grass competition may likewise have contributed to the small root systems. Their appearance also suggested damage, however, perhaps by either root disease or by gophers or soil insects after 1962.

Seed for planting stock usually is collected in the ponderosa pine zone at a substantially lower elevation. The planting sites, one on a northeast slope between 9,100 and 9,300 feet, the other on a southwest slope between 9,500 and 9,800 feet, are cold and wet, and may have been poor root habitats for the stock used.

Implications

Natural Regeneration

If natural regeneration is to be relied upon, adequate seed should be assured by cutting strips no wider than 3 chains. If larger clearcuttings are wanted, plan to regenerate artificially at least those parts farther than 2 chains from the upwind margin and 1 chain from other margins.

The seeds and new seedlings should be protected by controlling rodents just before a good seed fall and early the following summer. If it will be necessary to sow grass to avoid erosion on a planned clearcutting, do not clearcut. If heavy herbaceous cover develops before regeneration, spray with herbicide the summer preceding a good seed fall.

Spot Seeding

Sow the seed just before the first germination season following slash disposal. Control rodents just before seeding. Do not sow grass. If seeding has been delayed and substantial herbaceous cover has developed, spray with herbicide the summer before seeding. Although this study produced no real evidence that seed source is an important factor, a host of other studies indicate that it is. In the absence of data to the contrary, use seed from a local source and similar elevation, or from the most similar source available.

Planting

If an area is to be planted, seed source is an important consideration. Also, there must be no weak link in the chain of proper care between the nursery bed and the well-planted seedling.

Browsing animals are attracted to clear-cuttings. Where browsing animals are abundant, do not plant ponderosa pine unless you are prepared to protect the planted trees. It cannot be assumed that an annual repellent treatment will be effective. When repellents are used, inspect plantations for browsing periodically between late May and late July. Treat again promptly if necessary. Consider Engelmann or blue spruces as alternative planting species on suitable sites if browsing threatens to be a problem.

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Agriculture --- CSU, Ft. Collins

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 80

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Low-Cost Instrument to Measure Temperature or Resistance Accurately

Robert H. Swanson[1]

A linear, 10-turn potentiometer, with 1,000-digit readout dial, forms the ratio arms of a Wheatstone bridge for measuring resistance within 1 percent over a limited range.

The resistance of a thermistor is a function of its temperature. The change in resistance with temperature is large, on the order of 100 ohms per °C. out of an initial resistance of 1,000 or more ohms. A bridge circuit is useful to detect the resistance change accompanying a 0.1°C. temperature change (approximately 10 ohms).

A bridge that has been used for several years at the Rocky Mountain Forest and Range Experiment Station is described here (fig. 1). Resistance can be measured to 1 percent; temperature to 0.1°C. over a limited range. It was primarily designed for use with the Yellow Springs Instrument Company thermistor[2] No. 44003 (1,000 ohms at 25°C.), but it is usable with any resistance device whose output is in the range from 100 to 100,000 ohms.

The R_f value specified in the parts list (fig. 1) centers the measurement range of the bridge at 0°C. when used with YSI thermistor No. 44003. Temperature is readable to 0.1°C. from -10° to +10°C., and within 0.5°C. from -50° to +50°C. If other temperature ranges are desired, then R_f should be chosen so that the desired range falls between 200 and 800 units on the dial. If the R_f chosen is equal to or greater than the one-fourth maximum resistance to be read, then the desired range will read between 200 and 800 units. Accuracy depends only upon R_f and the linearity of the dial reading, N, versus the total resistance of R_d. For the parts specified, R_f is within 1 percent; and linearity of R_d, 0.1 percent.

A table of dial reading, N, versus resistance, R_x, can be constructed from the following equation:

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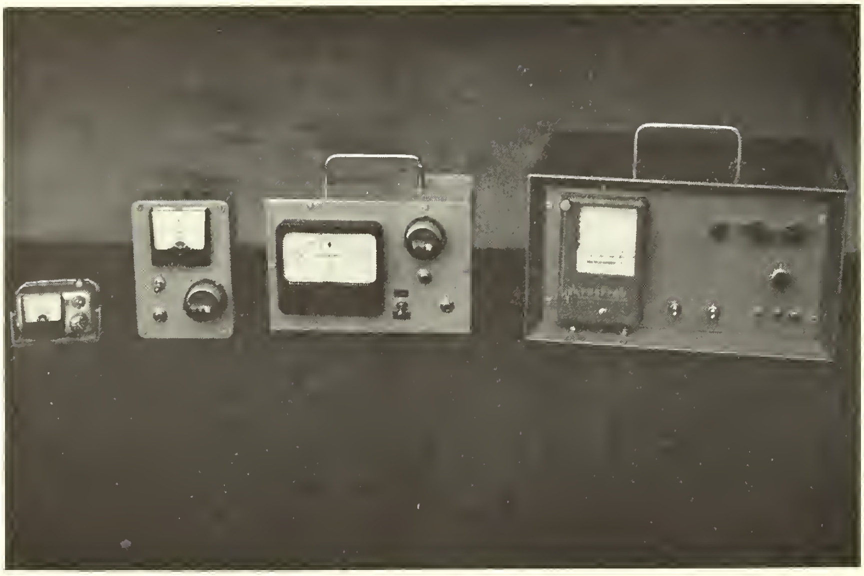
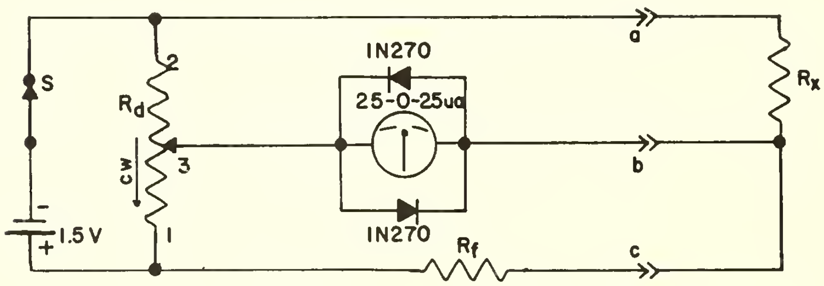
[2] *Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*



Carrying cases in which bridge has been constructed. Instrument on the right, with its built-in recorder in place of the direct-reading meter, is useful for recording off-balance deviations of the bridge. If a precision resistance decade is available to provide an external R_f, then this arrangement is useful for recording resistance differentials.



Schematic diagram and parts list.

R_d = *1,000-ohm, 10-turn potentiometer with dial (Borg model 205 with model 1310 dial or equivalent)*

R_x = *unknown resistance to be measured*

R_f = *1-percent reference resistor, 2,690 ohms (2,490 in series with 200 ohms, IRC type MEC T-2 or equivalent)*

Figure 1.--A limited-range bridge used with a thermistor to measure temperature.

$$N = \frac{1{,}000\ R_x}{R_x + R_f}$$

It can also be constructed by direct substitution of known resistance values for R_x, and tabulating the dial reading at balance. If the values specified in the parts list (fig. 1) are used, then table 1 (for resistance versus dial reading) and table 2 (for temperatures, with YSI thermistor No. 44003) can be used directly.

The unknown resistance, R_x, can be connected to the bridge in two manners. If the leads from the bridge to R_x are long, so the resistance of these leads is greater than 1 percent of R_x, then three leads are run to R_x. All three leads are then connected to the bridge as shown in figure 1. This type of connection nullifies the effect of any lead wire resistance, so that R_x can be read directly. If the leads to R_x are short, so their resistance is less than 1 percent of R_x, connect terminals b and c together at the bridge proper, and run leads from a and b to R_x.

Operation of the bridge is simple. Connect R_x to proper terminals, turn switch S to "on" position, and adjust R_d until the meter reads zero. The dial reading can then be converted to the resistance or temperature of R_x.

Table 1.--Resistance, R_x in ohms, versus dial reading, N

N	R_x	N	R_x
007	20	426	2,000
011	30	527	3,000
015	40	597	4,000
018	50	650	5,000
022	60	690	6,000
025	70	722	7,000
029	80	748	8,000
032	90	770	9,000
036	100	788	10,000
069	200	881	20,000
100	300	918	30,000
129	400	937	40,000
157	500	949	50,000
182	600	957	60,000
206	700	963	70,000
229	800	967	80,000
251	900	971	90,000
271	1,000	974	100,000

Table 2.--Dial reading at each degree C from -50° to +50°, for thermistor, YSI No. 44003

N	°C	N	°C	N	°C	N	°C
924	-50	760	-25	500	0	271	+25
920	49	750	24	489	+ 1	264	26
887	48	741	23	479	2	257	27
911	47	731	22	468	3	250	28
906	46	721	21	458	4	243	29
901	45	712	20	448	5	237	30
896	44	702	19	438	6	230	31
891	43	692	18	428	7	224	32
885	42	681	17	418	8	218	33
879	41	672	16	408	9	212	34
873	40	661	15	398	10	206	35
867	39	651	14	388	11	201	36
861	38	640	13	379	12	195	37
854	37	629	12	370	13	190	38
847	36	619	11	361	14	185	39
840	35	608	10	352	15	180	40
833	34	597	9	343	16	175	41
826	33	586	8	334	17	170	42
818	32	576	7	326	18	165	43
810	31	565	6	317	19	161	44
802	30	554	5	309	20	156	45
794	29	543	4	301	21	152	46
786	28	532	3	293	22	148	47
777	27	521	2	286	23	144	48
768	-26	511	- 1	278	+24	140	49
						136	+50

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U.S. FOREST SERVICE
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OREST SERVICE
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OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Percentage of Filled Fourwing Saltbush Seeds

H. W. Springfield[1]

Only slightly more than half of 16,000 seeds from 117 collections throughout Arizona and New Mexico contained embryos. Seed size varied considerably among collections; percent fill usually was highest in the larger seeds of any one collection. Cutting tests are recommended so that seeding rates can be adjusted to compensate for empty seeds.

Fourwing saltbush (Atriplex canescens (Pursh) Nutt.) is a good species for seeding on Southwestern ranges, but it has a reputation for low germination. Maximum germination reported by various investigators has been 27 percent,[2] 28 percent,[3] 30 percent,[4] and 33 to 54 percent,[5] depending on size of seed. Low percentages of filled seeds (seeds that contain embryos) partially explained relatively low germination percentages in recent studies.[6]

Further laboratory studies were conducted to gain additional information about factors that affect percent fill of fourwing saltbush seeds. The objectives of these studies were to (1) set standards of percent fill by examining seeds from a large number of collections, (2) determine if relationships exist between percent fill and year of collection, elevation of the collection site, or size of seed, and (3) determine the relationship between percent fill and laboratory germination of seeds from several collections.

A total of 117 collections of seeds from Arizona and New Mexico were examined. The seeds had been collected during the years

[1] *Range Scientist, located at Albuquerque, in cooperation with the University of New Mexico; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Bridges, J. O. Reseeding trials on arid range land. N. Mex. Agr. Exp. Sta. Bull. 278, 48 p., illus. 1941.*

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1960 to 1965 at 87 sites representing different elevations, climates, and soils. From 100 to 200 seeds of each collection were selected at random. The seeds were divided into three groups based on relative size. Ten seeds in each size class were measured to determine average length and width. All seeds were cut and examined with a hand lens to determine how many contained embryos; this number was converted to percent fill.

Germination data from a series of laboratory studies were available for 52 of the 117 seed collections. Percent fill of these collections was compared with percent germination. The relationship between filled seeds and germination was expressed through regression analysis. The relationships between percent fill and factors such as size of seed, year of collection, and elevation of the collection site were investigated but not analyzed statistically.

Results and Discussion

In most of the collections, nearly half the seeds were empty. The average of all 117 seed collections was 53.6 percent filled. Two-thirds of the collections had less than 60 percent filled, and a tenth of the collections registered less than 30 percent filled, as shown below:

Percent filled	Number of collections
1- 10	1
11- 20	3
21- 30	7
31- 40	14
41- 50	24
51- 60	26
61- 70	19
71- 80	16
81- 90	5
91-100	2

No relationship was found between percentage of filled seeds and elevation of the collection site. Elevations varied between 1,400 and 7,800 feet; most were 4,000 to 7,000 feet.

The percentage of filled seeds generally was higher for the larger seeds (table 1). The proportion of larger seeds containing embryos was highest in 105 of the 117 collections. Year of collection only slightly affected the overall average fill percentages for the three relative sizes of seeds.

Size of seed varied considerably among the different collections (table 2). Seeds classed as small in the Caballo collection, for example, were longer and wider than those classed as large in the Safford collection. Still, all sizes of the Safford seeds were much better filled than the Caballo seeds. Study of the data indicated percent fill was not related to size of seed in itself, but to relative size of seeds within collections.

Table 1.--Percentage of filled seeds of different relative sizes, collected from fourwing saltbush plants, 1960-65

Collection year	Filled seeds, by relative size			
	Large	Medium	Small	Average
	- - - - Percent - - - -			
1960	59.3	57.0	53.3	56.5
1961	57.6	52.7	40.8	50.4
1962	61.8	52.0	45.5	53.1
1963	66.5	59.4	43.8	56.6
1964	61.8	50.2	41.5	51.2
Average	61.4	54.3	45.0	53.6

Table 2.--Ranges in size and percent fill of seeds from three collection sites in New Mexico and Arizona

Collection site	Relative size	Length of seed	Width of wings	Filled seeds
		mm.	mm.	Pct.
Isleta	Large	5.5	14.8	94
	Medium	4.8	11.5	91
	Small	3.9	9.5	91
Caballo	Large	7.2	23.2	53
	Medium	6.1	18.2	25
	Small	5.2	14.0	12
Safford	Large	4.8	10.6	82
	Medium	3.8	8.2	75
	Small	3.2	6.5	65

The only two collections with more than 90 percent fill were from a single plant near Isleta. The percentage of filled seeds collected from this plant, and from individual plants at three other sites in New Mexico, are compared in table 3. The figures for the Isleta and Hatch seeds suggest percent fill may be governed primarily by genetic factors, or possibly by site conditions. Those for Corona and Deming, however, indicate that year-to-year variations in the weather and other environmental factors probably are important, too.

Germination tests on seeds from 52 of the collections indicated that percent fill accounted for 68 percent of the variation in germination (correlation coefficient, R = 0.825, fig. 1). A closer correlation between percent fill and germination might be expected, but other factors, such as embryo dormancy, age of seed, and less-than-optimum temperature and moisture for germination, undoubtedly lowered the germination percentages.

Table 3. --Percentage of filled seeds collected 3 years from the same plants at four sites in New Mexico

Collection site	Elevation	Filled seeds, by year collected		
		1961	1963	1964
	Feet	- -	Percent	- -
Corona	6,500	67	51	20
Isleta	4,900	92	86	92
Deming	4,300	78	30	59
Hatch	4,100	41	58	58

Conclusions

Relatively low seed fill seems to be characteristic of fourwing saltbush. Only slightly more than half of 16,000 seeds, representing 117 collections, contained embryos. This relatively low percentage should be considered in determining seeding rates. Cutting tests are recommended on samples of seed so that

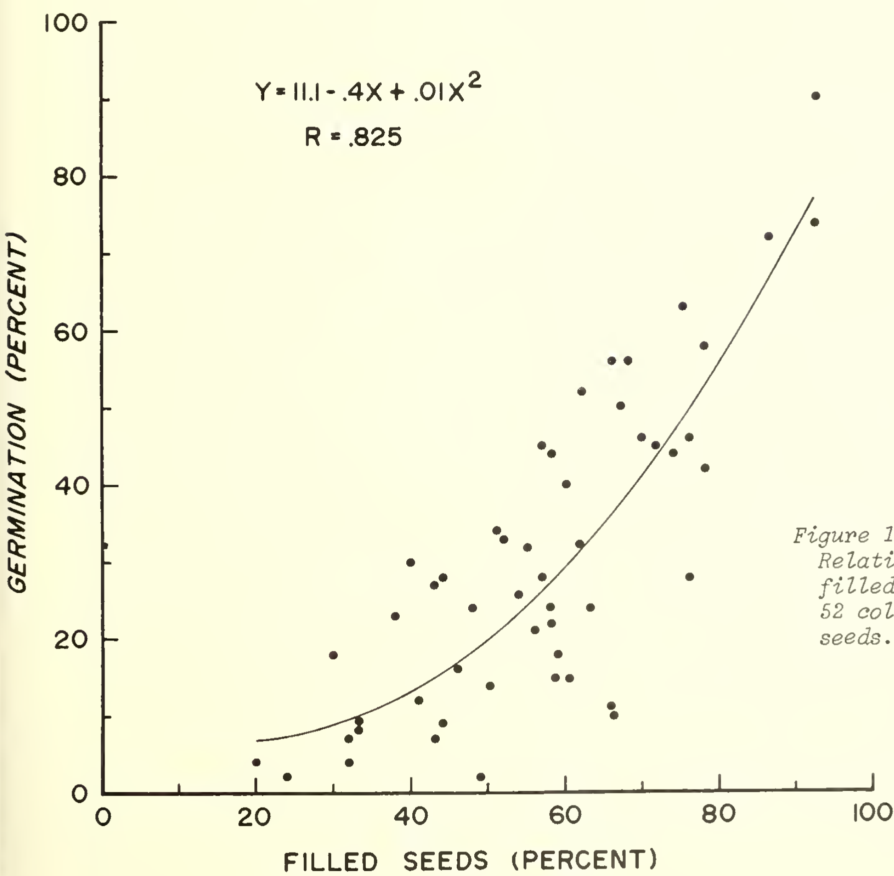

*Figure 1.--
Relationship between percentage of filled seeds and of germination for 52 collections of fourwing saltbush seeds.*

seeding rates can be adjusted for what very likely will be a high percentage of empty seeds. The results suggest fill percentages of less than 40 should be considered substandard.

Seeds from certain sources were consistently well filled for 3 years of collection; this suggests genetic factors may play an important role in seed fill. Sources such as these, provided the plants prove to be adapted and palatable, should be prime candidates for large-scale propagation. Enough information was obtained, however, to indicate that environmental factors also are important in seed fill; this suggests seed fill might be improved through cultural practices such as cultivation, irrigation, and perhaps fertilization. No relationship was evident between percent fill and elevation of the collection site.

The larger seeds within a given lot or collection usually were better filled than the smaller seeds. This relationship held true for 5 years, when all seeds were considered collectively. Recognition of this finding should result in improved efficiency of seeding operations. If cutting tests show the smaller seeds have appreciably less fill than the larger seeds, the smaller seeds could be screened out and discarded.

Although the percentage of filled seeds no doubt is a principal factor responsible for differences in germination among various collections of seed, other factors such as embryo dormancy, temperature, moisture, and age of seed also probably affect the germination of fourwing saltbush.

U.S. FOREST SERVICE
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Effect of Gibberellic Acid Spray on Seedlings of Eastern Redcedar, Bur Oak, and Red Oak

Ralph A. Read[1] and W. T. Bagley[2]

A 30 p.p.m. solution of gibberellic acid sprayed two or three times a week produced striking increases in height growth on the oaks, but not on redcedar.

Small amounts of gibberellic acid applied to growing plants are known to stimulate growth. Some of the responses involve: (1) cell elongation, (2) cell division, (3) leaf alterations, (4) seed germination, (5) breaking of bud dormancy, and (6) induction of flowering.

This note reports responses in terminal elongation (height growth) obtained on seedlings of eastern redcedar (Juniperus virginiana L.), bur oak (Quercus macrocarpa), and red oak (Q. rubra) when sprayed with a solution of 30 p.p.m. gibberellic acid in water. Potted seedlings 2 weeks after germination were treated for a period of 90 days in midwinter in the greenhouse. Incandescent lights were used morning and evening to provide a 12-hour photoperiod.

The treatments for redcedar and bur oak were: (1) check - no treatment, (2) sprayed once a week, (3) sprayed twice a week, and (4) sprayed three times a week. Red oak seedlings were sprayed twice a week, plus a check.

Seedlings were sprayed with a fine-spray atomizer which provided complete coverage of all foliage. No sticker spreader was added. In each treatment there were 14 seedlings of eastern redcedar, 14 of bur oak, and 8 of red oak. Height growth is shown in figure 1.

Redcedar increased rather slowly and steadily in height, as compared to the sudden flush of growth in oaks. Seedlings sprayed three times a week were only 2.5 centimeters (cm.) taller than the check after 90 days. Those sprayed once a week were only 1 cm. taller; and those sprayed twice a week were slightly shorter than the checks. The maximum difference between treatment means was not significant.

The response in bur oak was striking (fig. 2A). Spraying three times a week produced seedlings three times as tall as the checks. Buds broke dormancy very quickly, stems elongated for about 45 days, and new buds formed. Treated seedlings then flushed again, and finally ceased growth. Bud formation on the checks was not followed by a second

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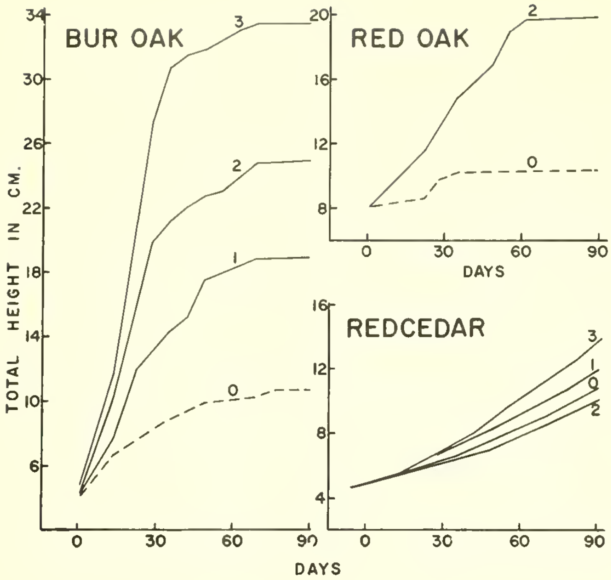

Figure 1.--Growth curves of bur oak, red oak, and eastern redcedar during the 90 days of treatment. Curve numbers refer to frequency of treatment per week.

growth flush. The once- and twice-per-week treatments were intermediate in height response between the best treatment and check.

Red oak sprayed twice a week grew twice as fast as the check (fig. 2B). The response in growth following bud burst was not quite so rapid as in bur oak.

Number of leaves were counted, and the area of the largest leaf on each seedling was measured. The following tabulation shows that seedlings of bur and red oaks treated with gibberellic acid had more and larger leaves than those not treated:

	Leaves (No.)	Largest leaf (Sq. in.)
Bur oak:		
Check (no treatment)	7.5	39
Treated once a week	8.8	46
Treated twice a week	11.0	50
Treated thrice a week	11.6	43
Red oak:		
Check (no treatment)	5.8	33
Treated twice a week	7.8	49

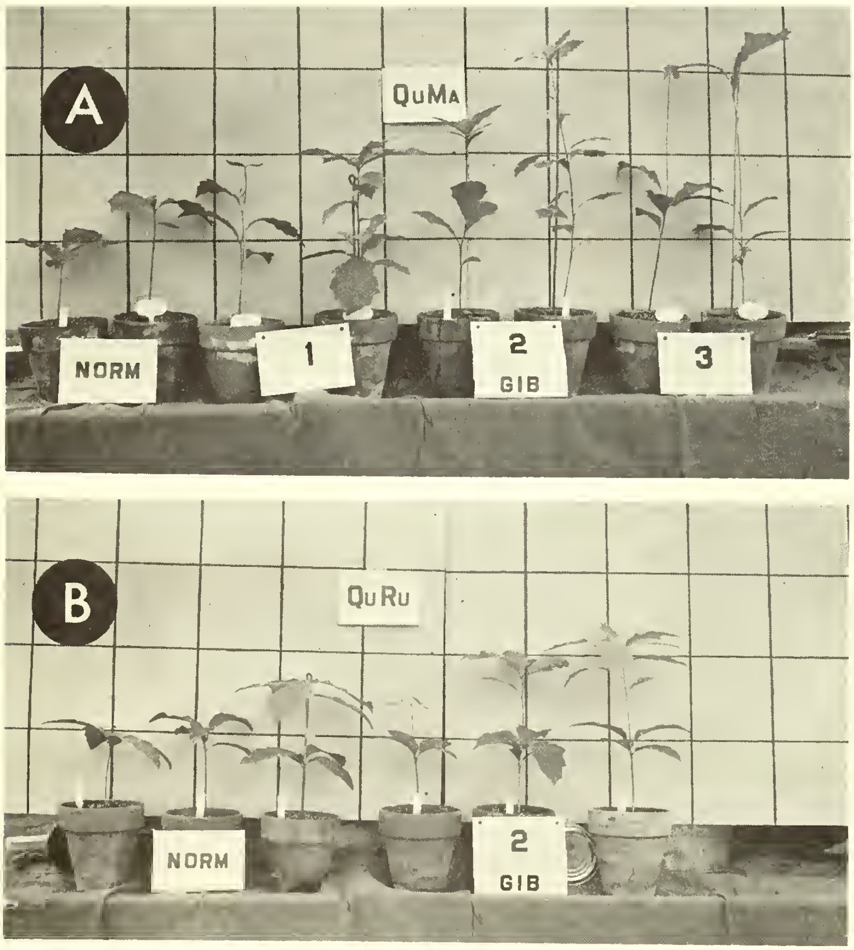

*Figure 2.--
Bur oak (A) and red oak (B) seedlings after 90 days treatment. "Norm" is the check; numbers refer to frequency of treatment per week.*

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OREST SERVICE
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OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Herbicides for Preparing Ponderosa Pine Planting Sites in the Southwest

L. J. Heidmann[1]

In 1961 and 1962, dalapon, bisester of dalapon, simazine, amitrole, amitrole-T, and ammonium thiocyanate were tested on perennial grasses in Arizona. All of the herbicides except ammonium thiocyanate effectively killed the grass. Dalapon, however, was the cheapest effective herbicide.

Competing vegetation is detrimental to the establishment of ponderosa pine (Pinus ponderosa Laws.). In northern Arizona, the most serious competitor is Arizona fescue (Festuca arizonica Vasey) which grows actively during the spring drought period in May and June. Pearson[2] and Heidmann[3] found survival of ponderosa pine seedlings to be significantly higher when grasses were removed. Soils retain moisture better under a mulch of herbicide-killed grasses than where the grasses are removed by scalping.[4]

Effect of six herbicides[5] on perennial grasses was tested in 1961 and 1962.

The Study

The study area, Wing Mountain, on the Coconino National Forest in northern Arizona, had been clearcut in the 1920's. Except for a few patches of saplings and small poles, the area is occupied by a dense stand of Arizona

[1] *Associate Silviculturist, located at Flagstaff, in cooperation with Northern Arizona University; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Pearson, G. A. Herbaceous vegetation a factor in natural regeneration ponderosa pine in the Southwest. Ecol. Monogr. 12: 315-338, illus. 1942.*

[3] *Heidmann, L. J. Effects of rock mulch and scalping on survival of planted ponderosa pine in the Southwest. U. S. Forest Serv. Res. Note RM-10, 7 pp., illus. 1963. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

[4] *Heidmann, L. J. Soil moisture under three site preparation treatments in Arizona. (In preparation for publication, Rocky Mountain Forest and Range Exp. Sta., Ft. Collins, Colo.)*

[5] *Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

fescue and mountain muhly (Muhlenbergia montana (Nutt.) Hitchc.). The aspect is northerly with a gentle slope. The soil is a clay loam containing many small pebbles but no large rocks.

The study design was a randomized block with five replications. Each block contained twenty 3-foot-square plots, which were randomly assigned the treatments shown in table 1.

All of the herbicides except simazine were applied in July 1961 after the grasses were actively growing. Simazine, a pre-emergent herbicide, was applied in April before growth had begun. Water was used as a carrier, with a wetting agent added to insure better plant

Table 1.--Treatments, rates of application,[1] and average costs for herbicide study, Wing Mountain, 1961-63

Treatment	Chemical name of herbicide	Rate of application	Material cost[2] per acre
		Lbs/acre	Dollars
Dalapon[3] (sodium salt)	2,2-dichloropropionic acid	5	6.78
		10	13.57
		15	20.24
Bisester of dalapon[4]	Diethylene glycol bis, 2,2-dichloropropionate	5	([4])
		10	([4])
		15	([4])
Amitrole[5]	3-amino-1,2,4-triazole	10	45.00
		20	90.00
		40	180.00
Amitrole-T[6]	3-amino-1,2,4-triazole plus ammonium thiocyanate	10	49.75
		20	99.50
		40	199.00
Simazine[7]	2-chloro-4,6-bis (ethylamino)-s-triazine	10	35.88
		20	71.75
		40	143.50
Ammonium thiocyanate[8]	Ammonium thiocyanate	10	2.65
		20	5.30
		40	10.60
Scalp	--	--	[9] 20.00-24.00
Untreated	--	--	--

[1] Pounds of active ingredient per acre, except bisester of dalapon, which is pounds acid equivalent.
[2] Based on net consumer price suggested by manufacturer or distributor; price varies with amount purchased, and other factors.
[3] Dowpon, 85 percent sodium salt of dalapon, furnished by Dow Chemical Co.
[4] Experimental compound M-1365 containing 6 pounds dalapon acid equivalent per gallon;furnished by Dow Chemical Co. Bisester of dalapon and 2-(2,4,5-trichlorophenoxy) propionic acid, propylene glycol (C_3H_6O to $C_9H_{18}O_3$) butyl ether esters are ingredients in the herbicide Garlon. Bisester of dalapon is not commercially available by itself.
[5] Amino-triazole, 50 percent amitrole, furnished by American Cyanimid Co., Inc.
[6] Cytrol-D, 2 pounds amitrole per gallon, furnished by American Cyanimid Co., Inc.
[7] Simazine 80-W, 80 percent simazine, furnished by Geigy Chemical Co.
[8] 98 percent ammonium thiocyanate, furnished by Halby Chemical Co.
[9] Estimate for complete mechanical site preparation in Southwestern Region, U.S. Forest Service.

coverage. Degree of grass kill was estimated at the end of the first and second growing seasons (1961, 1962) to the nearest 10 percent. Kill was coded by a system from 0 to 10, with 0 being no visible kill and 10 being complete kill. In 1962 the study was repeated, and grass kill was estimated at the end of the 1962 and 1963 field seasons. Mean grass kill after 2 years was analyzed by analysis of variance. Tukey's multiple range test was used to determine significance between means. [6]

A rain gage located within the study area was checked daily during the rainy season. Precipitation during the field season of 1961 was 9.43 inches, about normal, while in 1962 it amounted to 6.49 inches.

Results

All of the herbicides, except ammonium thiocyanate and the two lowest rates of amitrole, were as effective as scalping (table 2). In addition, all of the herbicides were significantly better than the untreated plots, except ammonium thiocyanate, at all rates in 1961 and the 10-pound rate in 1962.

A rate of 5 pounds of dalapon was as effective as rates of 40 pounds for the other herbicides. The bisester of dalapon gave as good a kill as the sodium salt.

[6] *Snedecor, George W. Statistical methods. Ed. 5, 534 pp., illus. Ames: Iowa State Coll. Press. 1956.*

Discussion

Herbicides should destroy unwanted vegetation at a reasonable cost without leaving residues toxic to tree seedlings if they are to be effective site preparation tools.

Most of the herbicide treatments in this study killed 80 percent or more of the perennial grasses (fig. 1). Dalapon, however, did the job with the least amount of material and at the lowest price. A rate of 5 pounds per acre of dalapon killed 86 percent of the grass in 1961 and 94 percent in 1962, at a per acre cost of $6.78. All rates of dalapon were cheaper than simazine at 10 pounds per acre, which killed 92 percent of the grass in 1961. This herbicide treatment was almost six times as expensive as 5 pounds of dalapon per acre. In 1962 the 10-pound rate of simazine killed only 48 percent of the grass. This may have been because rainfall was below normal in the spring of 1962, and the herbicide was not carried into the soil as effectively as in 1961 when moisture was more abundant.

Residues toxic to ponderosa pine seedlings were not investigated in this study. Exploratory studies and studies currently in progress have shown that dalapon and simazine at 10 pounds per acre caused no noticeable damage to ponderosa pine seedlings. Residual toxicity of all herbicides should be studied further.

Figure 1.--Row of 3-foot plots showing dead grass 2 years after herbicide treatment. Plot in foreground treated with dalapon.

Table 2. --Comparison of mean grass kill after 2 growing seasons, using Tukey's test[1]

Treatment No.	Treatment	Rate[2]	Mean grass kill 9/13/62	Significance[3]	Treatment	Rate[2]	Mean grass kill 10/1/63	Significance[3]
		Lbs/acre	Pct.			Lbs/acre	Pct.	
	SPRAYED SPRING AND SUMMER 1961				SPRAYED SPRING AND SUMMER 1962			
1	Scalp	--	100	a	Scalp	--	100	a
2	Simazine	40	100	a	Dalapon	10	98	ab
3	Simazine	20	100	a	Dalapon	15	98	ab
4	Amitrole-T	40	98	ab	Amitrole-T	40	96	ab
5	Bisester of dalapon	10	96	abc	Dalapon	5	94	ab
6	Dalapon	15	94	abc	Bisester of dalapon	10	94	ab
7	Bisester of dalapon	15	94	abc	Simazine	40	94	ab
8	Amitrole-T	20	92	abc	Amitrole-T	20	94	ab
9	Simazine	10	92	abc	Bisester of dalapon	15	92	ab
10	Dalapon	5	86	abc	Simazine	20	90	ab
11	Dalapon	10	84	abc	Bisester of dalapon	5	88	ab
12	Amitrole	40	82	abc	Amitrole	40	88	ab
13	Bisester of dalapon	5	80	abc	Amitrole-T	10	84	abc
14	Amitrole-T	10	66	bcd	Amitrole	20	74	bcd
15	Amitrole	20	64	cd	Amitrole	10	60	cde
16	Amitrole	10	44	de	Ammonium thiocyanate	40	56	de
17	Ammonium thiocyanate	40	30	ef	Simazine	10	48	ef
18	Ammonium thiocyanate	20	14	ef	Ammonium thiocyanate	20	28	fg
19	Ammonium thiocyanate	10	12	ef	Ammonium thiocyanate	10	16	gh
20	Untreated		0	f	Untreated		0	h

[1] In 1961, D = 32.3; in 1962, D = 24.6
[2] Pounds of active ingredient per acre except for bisester of dalapon, which is pounds acid equivalent.
[3] Means with same letter in common are not significantly different.

1967

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OCKY MOUNTAIN FORES

Helicopter-Applied Herbicides Control Shrub Live Oak and Birchleaf Mountainmahogany

C. P. Pase[1]

Four annual helicopter applications of 2,4,5-T to fire sprouts of chaparral held shrub live oak and birchleaf mountainmahogany cover to less than 5 percent, while unsprayed sprouts increased to 21 percent. No difference was found between emulsifiable and invert forms of 2,4,5-T, and 1:1 mixtures of oil soluble 2,4,5-T and 2,4-D. PBA and TBA were substantially less effective in retarding shrub growth.

Much of the dense, well-developed chaparral in Arizona grows on rough, broken terrain. Shrub control by basal stem spraying as reported by Cable[2] is generally not practical on large areas, and the terrain is often too rough for application with ground equipment. Operation of fixed-wing aircraft in the narrow canyons is risky, especially close enough to the ground for good spray distribution and control. In many chaparral areas, the use of helicopters appears to be the only effective and safe method of chemical application.

Lack of effective control of shrub live oak (Quercus turbinella Greene) and associated chaparral shrubs has been a serious obstacle in improving livestock forage and water yields in Arizona. This paper summarizes the response of shrub live oak and birchleaf mountainmahogany (Cercocarpus betuloides Nutt.) to helicopter-applied herbicides[3] on a small experimental watershed in central Arizona.

Study Area and Methods

The study area is located in the Mazatzal Mountains in central Arizona between 4,000 and 4,500 feet elevation. Soils are coarse textured and moderately deep, derived from deeply weathered pre-Cambrian granites. Rainfall averages 25 inches, with 72 percent falling in winter and 28 percent in summer. Rainfall during the study period varied from 18.36 to 32.61 inches.

In June 1959, an intense wildfire swept through the area, killing all aboveground vegetation. Shrub live oak dominated the dense prefire chaparral cover, with lesser amounts of birchleaf mountainmahogany, sugar sumac (Rhus ovata S. Wats.), Palmer oak (Quercus dunni Kellogg), Emory oak (Q. emoryi Torr.),

[1] *Plant Ecologist, located at Tempe, in cooperation with Arizona State University; central headquarters maintained at Ft. Collins, in cooperation with Colorado State University.*

[2] *Cable, Dwight R. Chemical control of chaparral shrubs in central Arizona. J. Forest. 55: 899-903. 1957.*

[3] *All herbicides applied in 1961 and 1962 were donated by Amchem Products, Inc. of Ambler, Pa. Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

pointleaf manzanita (Arctostaphylos pungens H.B.K.), and several others. Total shrub crown cover was approximately 70 percent. All shrubs, except pointleaf manzanita and desert ceanothus (Ceanothus greggii A. Gray), sprouted vigorously after the fire.

One 95-acre watershed was selected for chemical control of the sprouting shrubs, and an adjacent 80-acre watershed was left untreated as a check. The herbicide applied to most of the watershed was the butoxy ethanol ester of 2,4,5-T, one of the most promising chemicals for control of shrub live oak.[4 5] Other formulations, carriers, and dosage rates were also tested on smaller subdivisions of the watershed (table 1 and fig. 1).

Beginning in 1960, chemicals were applied in late May of each year for 4 consecutive years, when shrub live oak was in the full flush of growth. All flying was done early in the morning when air movement was at a minimum. Flagmen marked the contour strips for the helicopter pilot to insure uniform distribution of the chemical.

In October 1962, 5 months after the third spray treatment, 15 to 30 sample plots were randomly selected in each of the various treatment blocks and on the untreated check watershed to compare the treatment schedules (table 1) used for shrub live oak and birchleaf mountainmahogany. At each plot center, the nearest five shrub live oak and birchleaf mountainmahogany clumps were observed. Measurements used were: (1) average crown height of shrub, (2) length of tallest stem (to end of living woody tissue), (3) percent of all stems dead, (4) percent defoliated, and (5) number of plants killed.

Cover of all shrubs was measured each fall on 20 permanent, randomly located 10-foot by 100-foot belt transects on each watershed to determine effectiveness of 2,4,5-T against the most common shrubs. Transects were located only in block V in the treated areas, and on the check watershed.

In April 1964, 11 months after the fourth spray treatment, living and apparently dead shrub live oak and birchleaf mountainmahogany plants were counted on 50 random 0.01-acre plots in the block treated with the ester of 2,4,5-T (block V). No tallies were made in 1964 on the other treatment blocks, or on the untreated adjacent watershed.

Results and Conclusions

Reaction of shrub live oak and birchleaf mountainmahogany to 2,4,5-T.--Spraying with 2,4,5-T materially retarded the recovery of

[4] *Lillie, D. T., and Davis, E. A. Chemicals for control of chaparral. Modern techniques in water management. Ariz. Watershed Symp. Proc. 5: 9-11. 1961.*

[5] *Schmutz, Ervin M., and Whitham, David W. Shrub control studies in the oak-chaparral of Arizona. J. Range Manage. 15: 61-67. 1962.*

Table 1.--Treatment schedule for experimental watershed, by block number

Block No.	Size of area	Treatment[1]	Formulation	Rate of application	Diluent	Time when sprayed			
						1960	1961	1962	1963
	Acres			Lbs. /acre					
I	3.8	PBA	Water soluble	4.8	Water	X	X		
		2,3,6-TBA	Water soluble	4.8	Water			X	X
II	12.5	2,4,5-T	Invertemulsifiable	1.6	1:5 water-oil emulsion	X	X		
		2,4,5-T	Emulsifiable	1.6	1:9 oil-water emulsion			X	X
III	3.7	2,4,5-T	Emulsifiable	1.6	1:9 oil-water emulsion	X			X
		2,4,5-T & 2,4-D	Oil soluble	1.6	Diesel oil		X	X	
IV	3.7	2,4,5-T	Emulsifiable	1.6	1:9 oil-water emulsion	X			X
		2,4,5-T & 2,4-D	Oil soluble	3.2	Diesel oil		X	X	
V	71.3	2,4,5-T	Emulsifiable	1.6	1:9 oil-water emulsion	X	X	X	X
VI	80.5	Check -- no chemical treatment							

[1] PBA = dimethylamine salt of polychlorobenzoic acid.
2,3,6-TBA = dimethylamine salt of 2,3,6-trichlorobenzoic acid.
2,4,5-T = butoxy ethanol ester of 2,4,5-trichlorophenoxyacetic acid.
2,4,5-T & 2,4-D = 1:1 mixture of 2,4,5-T and butoxy ethanol ester of 2,4-dichlorophenoxyacetic acid (Dinoxol).

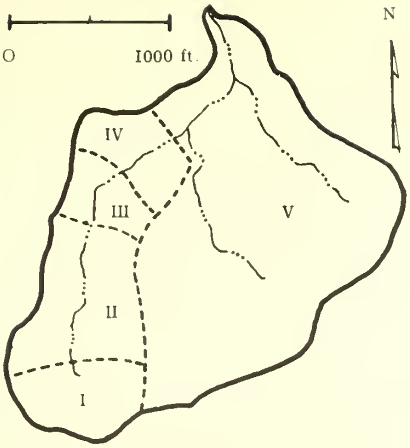

Figure 1.--Chaparral watershed showing arrangement of treatment blocks. Block VI is on an adjacent watershed. For description of treatments, see table 1.

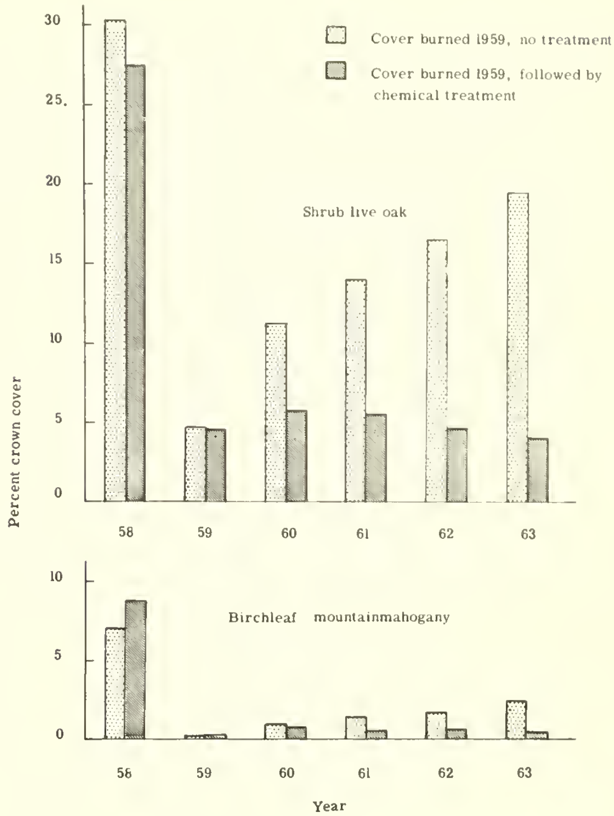

Figure 2.--Prefire crown cover of shrub live oak and birchleaf mountainmahogany (1958) and recovery after wildfire (1959-63).

fire sprouts of both shrub live oak and birchleaf mountainmahogany (fig. 2). Not only were the treated plants smaller as indicated by transect measurements, but they appeared less thrifty, often with more open crowns, especially after the third and fourth treatments. Canopy cover of both shrubs was reduced to near zero by the June 1959 wildfire. By the time of the first chemical spray in May 1960, virtually all shrubs had resprouted; oak cover was 5 percent and mountainmahogany was 0.2 percent. Repeated annual spraying with 2,4,5-T kept the cover of these two shrubs to about the level regained during the first postfire growing season. On a companion unsprayed watershed, shrub canopy increased to 21 percent after the fifth growing season following the fire.

Formulations with 2,4,5-T, and the mixture of 2,4-D and 2,4,5-T were about equally effective; response on all of these plots was about the same after three annual sprays (table 2). Effect of the chemical was more evident on height growth, percent of dead stems, and percent defoliation than on number of plants killed. Mortality of treated shrub live oak was low after three annual spray treatments, al-

Table 2.--Response of shrub live oak and birchleaf mountainmahogany to three annual herbicide treatments[1]

Block No.	Shrub live oak				Mountainmahogany			
	Average crown height	Dead stems	Defoliated	Dead plants	Average crown height	Dead stems	Defoliated	Dead plants
	Feet	- - -	Percent	- - -	Feet	- - -	Percent	- - -
I	[2] 2.66 a	1.7 a	--	0 a	2.39 a	1.1 a	--	0 ab
II	1.71 b	30.8 b	--	0 a	1.43 b	45.8 b	--	12 b
III	1.72 b	30.0 b	47.0 a	3 a	1.60 b	58.3 bc	74.0 a	30 b
IV	1.91 b	31.2 b	57.5 a	0 a	1.08 b	64.5 c	80.4 a	33 b
V	1.89 b	31.2 b	48.0 a	[3] 2 a	1.58 b	42.0 b	57.2 b	[4] 13 b
VI	2.98 a	2.4 a	.9 b	0 a	3.95 a	3.5 a	1.1 c	0 a

[1] For chemical formulations, rates, and carriers see table 1.
[2] Values followed by the same letter are not significantly different; P = 0.05.
[3] Percent dead plants increased to 42 percent 11 months after fourth annual treatment.
[4] Percent dead plants increased to 72 percent 11 months after fourth annual treatment.

though many low-vigor plants were barely "hanging on." Mortality of shrub live oak increased sharply to 42 percent 11 months after the fourth 2,4,5-T spray treatment. Surviving shrubs were greatly suppressed, and were often overtopped by vigorous growth of lovegrasses (Eragrostis spp.) and redstar morningglory (Ipomoea coccinea L.). Birchleaf mountainmahogany was even more severely affected by the fourth annual treatment, with 72 percent of shrubs apparently killed.

Spray distribution.--Coverage seems important, as more damage was evident on the ridges and upper slopes where the helicopter flew closer to the ground than in the narrow draws. Strips which may have had two passes showed greater damage than the surrounding area. Parts of shrubs protected by the overhang of other plants were not damaged. Many such plants were dead on one side only.

Reaction of other shrubs to 2,4,5-T.--Sugar sumac appeared especially sensitive to the 2,4,5-T spray treatment (fig. 3). While a few sugar sumac shrubs showed weak sprouts after the fourth annual spray application, most were completely dead aboveground. Most other shrubs--Emory oak, Palmer oak, hollyleaf buckthorn (Rhamnus crocea Nutt.), and yellow silktassel (Garrya flavescens S. Wats.)--were suppressed similarly to or slightly more than birchleaf mountainmahogany (fig. 3). Shrub live oak appeared more resistant than any other shrub on the study area.

Reaction of shrub live oak and birchleaf mountainmahogany to PBA and TBA.--In contrast to 2,4,5-T alone and mixed with 2,4-D, PBA followed by TBA did little other than cause abnormal growth on the terminals. No death loss was noted, and by the end of the growing season 4 months after spraying, all shrubs had apparently recovered from the spray treatment. The May PBA-TBA treatment greatly inhibited growth of redstar morningglory and narrowleaf morningglory (Convolvulus linearilobus Eastw.) during the following summer growing season. Both of these forbs were abundant on treatment block I in the summer of 1959, and on the surrounding area from 1959 through 1963.

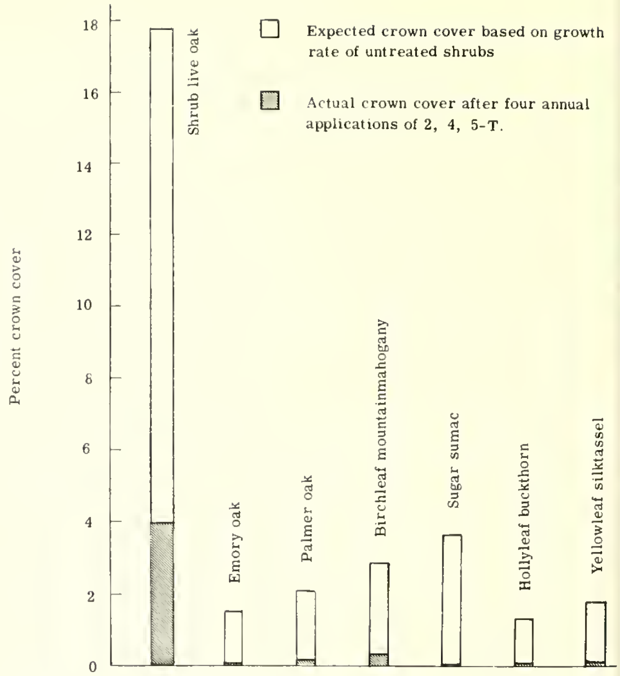

Figure 3.--Suppression of common chaparral shrubs due to four annual applications of 2,4,5-T.

Summary

A 95-acre watershed in central Arizona was chemically treated with 2,4,5-T, 2,4-D, and PBA-TBA by helicopter for control of chaparral sprouts. Four annual spring treatments were made, beginning 1 year after the area was burned by wildfire.

All formulations of 2,4,5-T alone and in combination with 2,4-D effectively suppressed shrub live oak and birchleaf mountainmahogany. Crown cover of the treated shrubs was held to about the equivalent of that from the first postfire growing season. Eleven months after the fourth annual treatment, 42 percent of the shrub live oak plants were actually killed. Birchleaf mountainmahogany was more susceptible than shrub live oak, and sugar sumac was especially sensitive. Other associated shrubs were about equal to birchleaf mountainmahogany in susceptibility.

PBA followed by TBA did not provide effective control of either major shrub at the rate tested. The only effect of the PBA-TBA treatment was a slight decrease in total length of stems, and abnormal growth of the terminals.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Moisture-Retention Capacity of Litter Under Two Arizona Chaparral Communities

R. M. Garcia and C. P. Pase[1]

Water-holding capacity of Pringle manzanita litter averaged 5.1 mm., and shrub live oak litter 4.8 mm., under dense, uniform canopies. Pringle manzanita litter held more water per gram of litter than did shrub live oak (2.00 vs. 1.80), but total litter produced was less (11.2 tons per acre vs. 12.1).

Retention of moisture in the litter layer affects the soil-moisture supply, and therefore plant growth and percolation water yield. Water in excess of the moisture-holding capacity quickly drains to the soil surface; that retained in the litter layer evaporates readily. On the plus side of the ledger, however, an abundant litter cover generally increases infiltration capacity and reduces soil erosion, and thereby plays an important role in protecting Arizona's steep chaparral watersheds.

Kittredge,[2] Helvey,[3] and Bernard[4] measured moisture-holding capacity of various chaparral and forest types in the United States. Kittredge, for example, reported that Eastwood manzanita (Arctostaphylos glandulosa Eastw.) and California scrub oak (Quercus dumosa Nutt.) had an average capacity of 1.3 and 1.0 grams of water per gram of litter, respectively. Where litter mass is large, this could result in a substantial interception of rainfall.

Moisture-retention capacity of chaparral litter was studied at three sites in the Tonto National Forest in Arizona. The first was a Pringle manzanita (Arctostaphylos pringlei Parry) community in the Mazatzal Mountains (elevation, 5,700 feet; mean annual precipitation, 24.3 inches). The almost pure Pringle manzanita stand had a canopy cover of 90 percent; average shrub height was 7 feet (fig. 1). The other two study sites, one a manzanita and the other a shrub live oak (Quercus turbinella Greene) community, were adjacent to each other on the Sierra Ancha Experimental Forest (elevation, 5,300 feet; mean annual precipitation, 24.7 inches). Canopy cover of the Pringle manzanita community was 85 percent, with an average shrub height of 6 feet. The predominantly shrub live oak community had a canopy cover of 95 percent, with shrubs averaging 6 feet in height.

Sixteen 5-inch-diameter, disturbed-litter samples were randomly selected from each site. Litter depth was measured at two peripheral points for each 5-inch plot, and averaged. The "L" layer consisting of intact litter and "F" layer consisting of partially decomposed litter were collected together; rock

Figure 1.--
Mature stand of Pringle manzanita at 5,700 feet elevation in Mazatzal Mountains. Herbaceous cover is absent under such stands.

fragments and soil aggregates were removed by hand.

Water-holding capacity was determined as outlined by Kittredge and modified by Bernard. Litter samples in metal cylinders with cheesecloth bottoms were soaked in water for 48 hours, then drained on damp sand for 48 hours. Cylinders were covered with plastic to reduce evaporation. The drained litter was weighed and ovendried at 102°C. for 48 hours.

Results

Pringle manzanita litter held significantly more moisture than shrub live oak ($P = 0.05$):

Vegetation type	Water per gram of litter	Water retained in litter
	(grams)	(mm.)
Pringle manzanita (two sites)	2.00	5.1
Shrub live oak (one site)	1.80	4.8

The Mazatzal manzanita site did not differ significantly from the Sierra Ancha manzanita site in either field moisture capacity or in litter mass. Moisture-holding capacity of both oak and manzanita was greater than Kittredge reported for related species in California.

Little "matting" or aggregation of the litter elements occurred, even during decomposition, which suggests that most of the water held was in the thin film coating individual leaf and twig fragments, and in absorbed water. Arrangement of the litter appeared to have little effect on water-holding capacity, and therefore "disturbed" and "undisturbed" litter samples would be expected to yield reasonably similar results.

Litter mass in the "L" and "F" layers was 12.1 ± 1.1 tons per acre under shrub live oak, and 11.2 ± 1.1 tons under Pringle manzanita. Average depth was 52 and 37 mm., respectively.

Because the litter mass was slightly greater under shrub live oak, the total water retained per unit area was not significantly different between the two communities.

Within each community, litter weight varied substantially more than did water retained per gram of litter, even though the communities were of uniformly high crown cover. Coefficients of variation for litter under manzanita and oak were 56 and 35 percent, respectively. Coefficients of variation for grams of water retained per gram of litter, on the other hand, were only 11 and 12 percent, respectively.

Field moisture capacity as determined by this method probably represents the upper limit for rainwater held in the litter mass. Size and duration of storm, and interval between storms, of course, would directly influence the amount of precipitation retained.

[1] *Forestry Research Technician and Plant Ecologist, respectively, located at Tempe, in cooperation with Arizona State University; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Kittredge, Joseph. Litter and forest floor of the chaparral in parts of the San Dimas Experimental Forest. Hilgardia 23: 563-596, illus. 1955.*

[3] *Helvey, J. D. Rainfall interception by hardwood forest litter in the southern Appalachians. U.S. Forest Serv. Res. Pap. SE-8, 9 pp., illus. 1964. Southeastern Forest Exp. Sta., New Orleans, La.*

[4] *Bernard, John M. Forest floor moisture capacity of the New Jersey pine barrens. Ecology 44: 574-576, illus. 1963.*

U.S. FOREST SERVICE
RESEARCH NOTE RM - 86

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Cost Implications Of Camper And Campground Characteristics In Central Colorado

Wendell Beardsley [1]

Large campgrounds (20 or more units) are probably less expensive to operate and maintain--but not necessarily to construct--than smaller ones. Occupancy is determined by physical setting, not size or construction investment. Travel-trailers, tent-trailers, or pickup-campers were used by 58 percent of the families.

Money for campgrounds might be used more effectively if relationships can be found between costs of campground construction, operation, and maintenance, and the amount and type of use campgrounds receive. To relate investments to visitor occupancy, a study was conducted in the Front Range of the Rocky Mountains in Colorado during the summer of 1965. Specifically, relationships between the following factors were analyzed:

1. Investment in construction.
2. Annual operation and maintenance expenditures.
3. Occupancy by recreationists.
4. Size of campgrounds.
5. Location of campgrounds.

[1] *Research Forester, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, in cooperation with Colorado State University, when research was conducted; now with Intermountain Forest and Range Experiment Station, Ogden, Utah.*

From observations of campers throughout the study, other information was obtained which is pertinent to policy and planning decisions. Data were gathered for the place of origin of groups (from vehicle license plates), the type of camping equipment used, and multiple occupancy of family units.

Procedures

Twenty-one campgrounds were selected at random from the Roosevelt, Pike, and Arapaho National Forests. A 20-percent sample of campgrounds was selected within each of three size classes on each of the three Forests.

Occupancy of family units in each of the selected campgrounds was determined as follows: On an approximately random schedule, the investigator visited 14 of the 21 campgrounds each weekend between July 10 and September 5. This gave six visits to each site during the period. The observer's time of arrival at each site was the moment of observation at which occupied units and characteristics of campers were recorded. The "weekend" was defined as the period from Friday at 5:00 p.m. to Sunday at 4:00 p.m. The times of visits to each site were distributed among the days of the weekend and over the times of day as completely as the travel circuit would permit.

Cost information on campground construction, operation, and maintenance was provided by District Ranger and Forest Supervisor offices. Construction investment was defined as the capital outlay that would be required for replacement of all facilities and site preparation at current construction standards and price levels.

Results

Size of Campgrounds Related to Investments

Construction investment per family unit in the different campgrounds was extremely variable. The variability in most cases appeared to result from physical characteristics of the site, such as rockiness. The variable nature of the data has obscured any meaningful relationship to size of campground (number of units). The hypothesis that larger campgrounds would have lower per-unit costs cannot be supported by the data whether or not interior campground road costs are included in the investment figures.

As the size of campgrounds increases, operation and maintenance expenditures per unit per year have a weak tendency to decrease (fig. 1). The hypothesis that larger campgrounds permit economies through greater efficiency in use of equipment and personnel can be tentatively accepted. There will be exceptions, however, due to other variables.

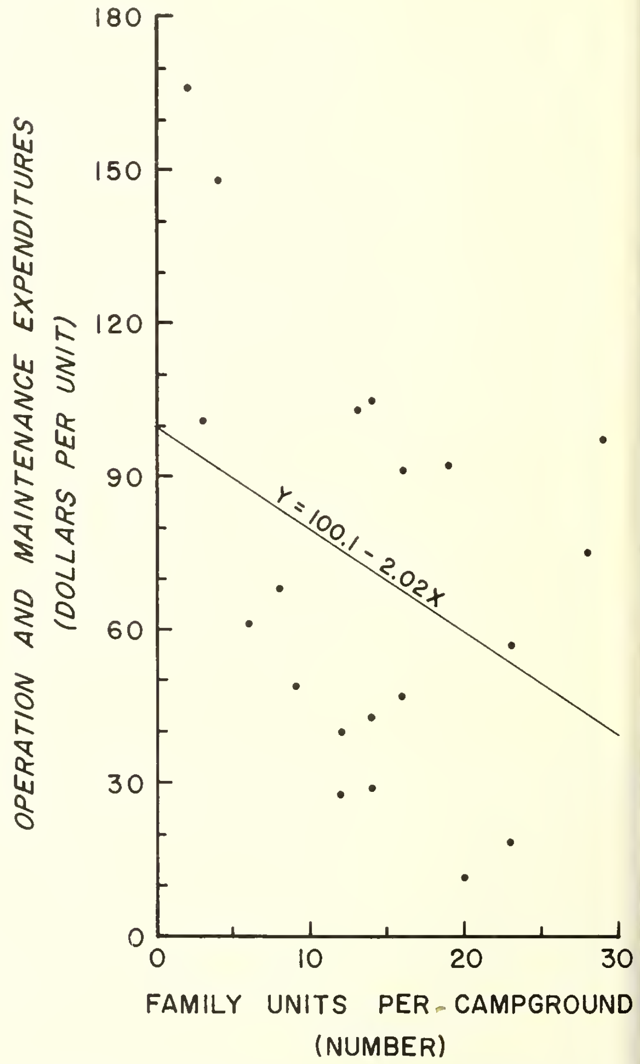

Figure 1.--Operation and maintenance expenditure per unit related to size of campground (up to 30 units per campground).

Occupancy in Relation to Other Variables

Several variables were investigated as possible determinants of occupancy. The data indicated no relationship between level of occupancy of campgrounds and any of:

1. Distance from urban centers (Denver, Colorado Springs, or Fort Collins).
2. Elevation of sites.
3. Presence of other campgrounds nearby.
4. Presence of a surfaced highway to the campground.
5. Presence of a through-travel tourist route.
6. Number of family units in campgrounds.
7. Per-unit investment in construction of the campgrounds.

Level of occupancy of campgrounds was found to be highly dependent upon the presence or absence of a recreationally usable water surface within 1/4 mile.[2] In the five campgrounds not near water, an average of 20 percent of the units were occupied, while the 16 campgrounds which were near water had 60-percent occupancy of family units.

Operation and maintenance expenditures, per family unit, rose with increased levels of occupancy (fig. 2). Operation and maintenance expenditures varied considerably between campgrounds with nearly the same occupancy levels, however, and relationships are not precise enough for predicting such costs.

[2] *Greater than 0.995 probability of relationship by chi-square test.*

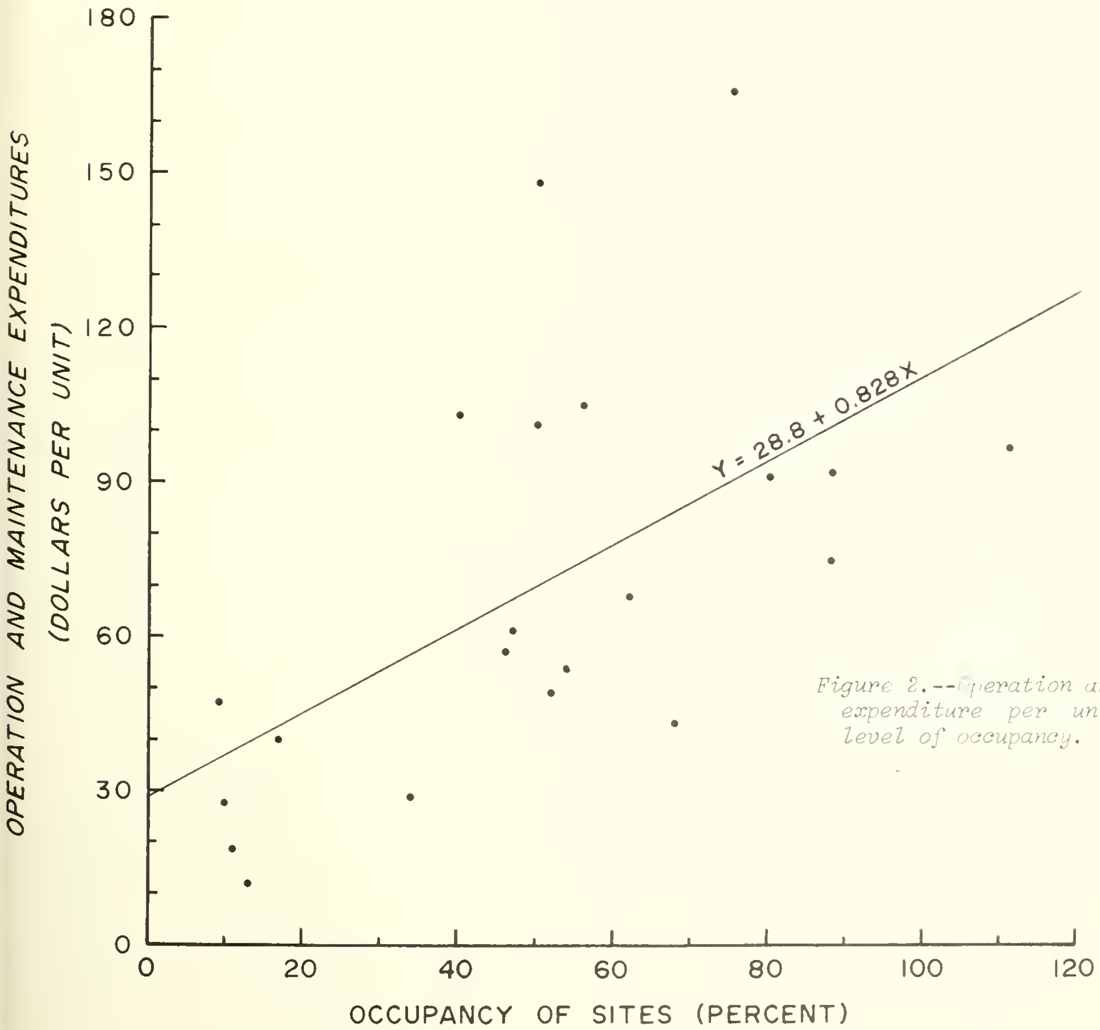

Figure 2.--Operation and maintenance expenditure per unit related to level of occupancy.

Visitor Characteristics

Of the 1,062 vehicles observed, the majority of visitors were from Colorado:

	Vehicles (No.)	Total (Pct.)
Colorado urban areas:		
Denver (Arapahoe, Adams, Jefferson, Denver Counties)	441	41.5
Colorado Springs (El Paso County)	56	5.3
Fort Collins (Larimer County)	45	4.2
Boulder (Boulder County)	41	3.9
All other Colorado counties	82	7.7
Total	665	62.6
Out of State:		
Texas	41	3.9
Kansas	39	3.7
Illinois	27	2.5
California	24	2.2
Missouri	22	2.1
Oklahoma	19	1.8
All other	225	21.2
Total	397	37.4

Interestingly, nonresidents were distributed among campgrounds quite differently than Coloradoans.[2] In those campgrounds located adjacent to a surfaced highway and with readily visible entrance signs along the highway, nonresident campers were observed twice as frequently as in poorly signed or more remote sites.[3] Colorado residents were divided almost equally between the two classes of sites:

	Camp units	Vehicles Colorado	Out of State
	- - - - (Pct.) - - - -		
Adjacent to a surfaced highway and well signed	52.9	48.0	66.0
Not adjacent to a surfaced highway or poorly signed	47.1	52.0	34.0

[3] *Of the campgrounds not adjacent to a surfaced highway, none was within 4 miles of a highway.*

Two factors seem to explain the observed differences in the distribution of visitors. First, most nonresidents are tourists in transit, and may be unwilling to deviate far from their travel route. Second, they may be unfamiliar with the area or lack adequate knowledge of off-highway sites, and therefore tend to occupy units in campgrounds encountered along the highway. Alternately, Coloradoans may tend to seek out the more remote sites.

Of the total number (944) of occupied campground units observed in the study, 87 (9.2 percent) were being used by two or more families. Most often, two or three families were observed camping or picnicking together, crowded into a unit designed for one family. Single and multiple occupancies of individual units were observed with the following frequencies:

	Occurrences	Families represented
	- - (Pct.) - -	
Number of families occupying a unit:		
1	90.8	80.7
2	7.4	13.2
3	1.2	3.1
4 or more	.6	3.0
Total	100.0	100.0

Of the 87 occurrences of multiple occupancy of a single unit, only 20 occurred at times when no empty unit was available in the campground. In the other 67 cases, two or more families were observed using a single-family unit despite the availability of other unoccupied units in the campground. Among the "multiple occupant" group, the ratio of residents to nonresidents was similar to that for all visitors observed during the study.

Multiple occupancy has been reported by several other researchers. In Oregon, Burch found that 27 percent of the occupied campground units were being used by two or more families.[4] In California, Bury reported multiple occupancy of 20 percent of the units in

[4] *Hopkins, Walter S. Outdoor recreation on small woodlands. Presented at 62nd Ann. Meet. S. Agr. Workers Ass., Dallas, Texas, 12 pp., 1965.*

use;[5] and in Utah, the figure was 18 percent.[6]

Although tents exceeded any other single type of camping equipment, combined use of travel-trailers, tent-trailers, and pickup-campers considerably exceeded use of tents. For the 1961 summer season on six campgrounds in California, Bury reported that 35 percent of the visitor groups were sleeping in "trailers or coaches" and 45 percent in tents.[5] For the 1962 season in the central Rockies, travel-trailer and pickup-camper use combined was 45 percent, and tent use was 43 percent of the total.[7] In the present study, combined travel-trailer, tent-trailer, and pickup-camper use was 58 percent of overnight camping equipment being used, while tents were 38 percent:

[5] *Bury, Richard L. Do campers fit our campgrounds? Trends in Parks and Recreation 1(1): 15-16, 1964.*

[6] *Unpublished data on file at the Intermountain Forest and Range Experiment Station, Logan, Utah.*

[7] *Love, L. D. Summer recreational use of selected National Forest campgrounds in the central Rocky Mountains. U. S. Forest Serv. Res. Paper RM-5, 23 pp., illus, 1964. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

		Percent
Tents		37.6
Travel-trailers	31.8	
Pickup-campers	16.9	57.5
Tent-trailers	8.8	
Buses		2.2
Cars		1.1
Unknown		1.6

Campers using travel-trailers and tent-trailers were observed almost twice as frequently in campgrounds adjacent to a surfaced highway, while campers using other, more mobile types of shelter were almost equally divided:

	Travel-trailers, tent-trailers	Tents, pickup-campers, buses, cars
	- - - (Pct.) - - -	
Adjacent to a surfaced highway	65.6	49.0
Not adjacent to a surfaced highway	34.4	51.0

Summary and Conclusions

Several results of this study appear to have meaningful implications for the forest recreation planner or administrator, especially in

the Front Range area of the Colorado Rocky Mountains. The study indicated the following:

1. Large campgrounds were not necessarily less expensive to construct, on a per-unit basis, than small ones. Factors such as the required amount of rock and earthmoving were of much more importance and obscured any economies of scale. The results show, however, that the larger campgrounds (20 or more family units) are probably less expensive to operate and maintain than smaller ones.
2. Neither larger campgrounds (in number of family units), nor those for which construction investment per unit had been high (possibly indicating a higher degree of "development"), showed higher levels of occupancy than smaller or less expensive sites. The most heavily used sites were those that were judged by the investigator as esthetically most pleasing. This suggests that the physical setting of each campground determined its level of utilization.
3. The proximity of campgrounds to urban areas, other campgrounds, surfaced highways, through-travel routes, or elevation of campgrounds did not affect site occupancy.
4. The presence of a water surface nearby was particularly important in assuring high levels of utilization of campgrounds. The pleasing environment of campgrounds near lakes or streams was often casually mentioned by campers who had stopped the investigator to ask a question. Although a variety of camping opportunities is needed, campgrounds near water definitely are preferred, and relatively there is an oversupply of units away from water. Campground construction near streams or lakes should have highest priority.
5. Although the relationship needs further study and verification, the study results showed higher per-unit operation and maintenance costs for higher levels of utilization of campgrounds.
6. Fifty-five percent of the families observed in Front Range campgrounds on summer

weekends were from the Denver, Colorado Springs, Fort Collins, or Boulder urban areas.

7. Nonresident visitors were more concentrated in sites along surfaced highways; Colorado residents were equally divided. Programs designed to acquaint nonresidents with off-highway campgrounds might widen their range of choices. If transient tourists prefer near-highway campgrounds as overnight sleeping areas, different designs, administration, and interpretive programs may be called for.
8. Noncamper groups (fishermen, picnickers, etc.) numbered 103 (9.7 percent) of the total 1,062 groups observed.
9. At the time they were observed, about 10 percent of all campground family units contained two or more families. As many as seven families were observed using a single-family unit. A minimum of 10 percent and perhaps as many as 30 percent (as indicated from other studies) of the units in each campground should be designed for two or more families.
10. Travel-trailers or tent-trailers were used by 41 percent of the families observed. Pickup-campers were being used by an additional 17 percent, while 38 percent were using tents. Parking-spur and family-unit designs must be planned with increasing attention to the nontenting camper. This is particularly applicable to campgrounds located adjacent to surfaced highways, where trailers were observed twice as frequently as in sites not near highways. Tent and pickup-camper use was equally divided, regardless of the presence of a highway.

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A Cylindrical Screen Cage For Rearing Bark Beetles

Charles J. Germain and Noel D. Wygant[1]

Describes a 4-legged cage 12 inches in diameter and 24 inches high, made from 20-mesh wire screen and a tractor funnel. A mason jar fits over funnel outlet to collect the emerging beetles.

A cage that has proved to be well adapted for rearing the Engelmann spruce beetle, Dendroctonus obesus (Mann.), and the Black Hills beetle, Dendroctonus ponderosae Hopk., is illustrated in figure 1. The cage accommodates billets up to 12 inches in diameter and 22 inches long, uses very little bench space, and is convenient to tend. The cage is suitable for rearing pure colonies as well as for study of insect emergence from billets cut from naturally infested trees. Rearing a colony of beetles requires (1) plugging the funnel throat with a screen disc, (2) placing paper toweling on which the beetles can crawl in the funnel, (3) putting a green billet in the cage, and (4) charging with 6 to 8 pairs of beetles per square foot of bark. The screen plug and paper toweling are removed after the beetles

[1] *Biological Technician and Research Entomologist at the Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Figure 1.--A cage for rearing bark beetles.

enter the billet and before the progeny begin to emerge. The cage can also be used to collect frass for attraction tests.

We used 20-mesh bronze screen to give maximum stiffness to the cylinder, and to confine the smaller associated insects that may be present. To prevent excessive loss of moisture from the billets where the relative humidity is low (below 50 percent), the ends of the billets can be sealed with melted paraffin wax, or a polyethylene garbage can liner can be placed over the cylinder.

Description

The bottom of the cage consists of a 12-inch diameter tractor funnel with the outlet

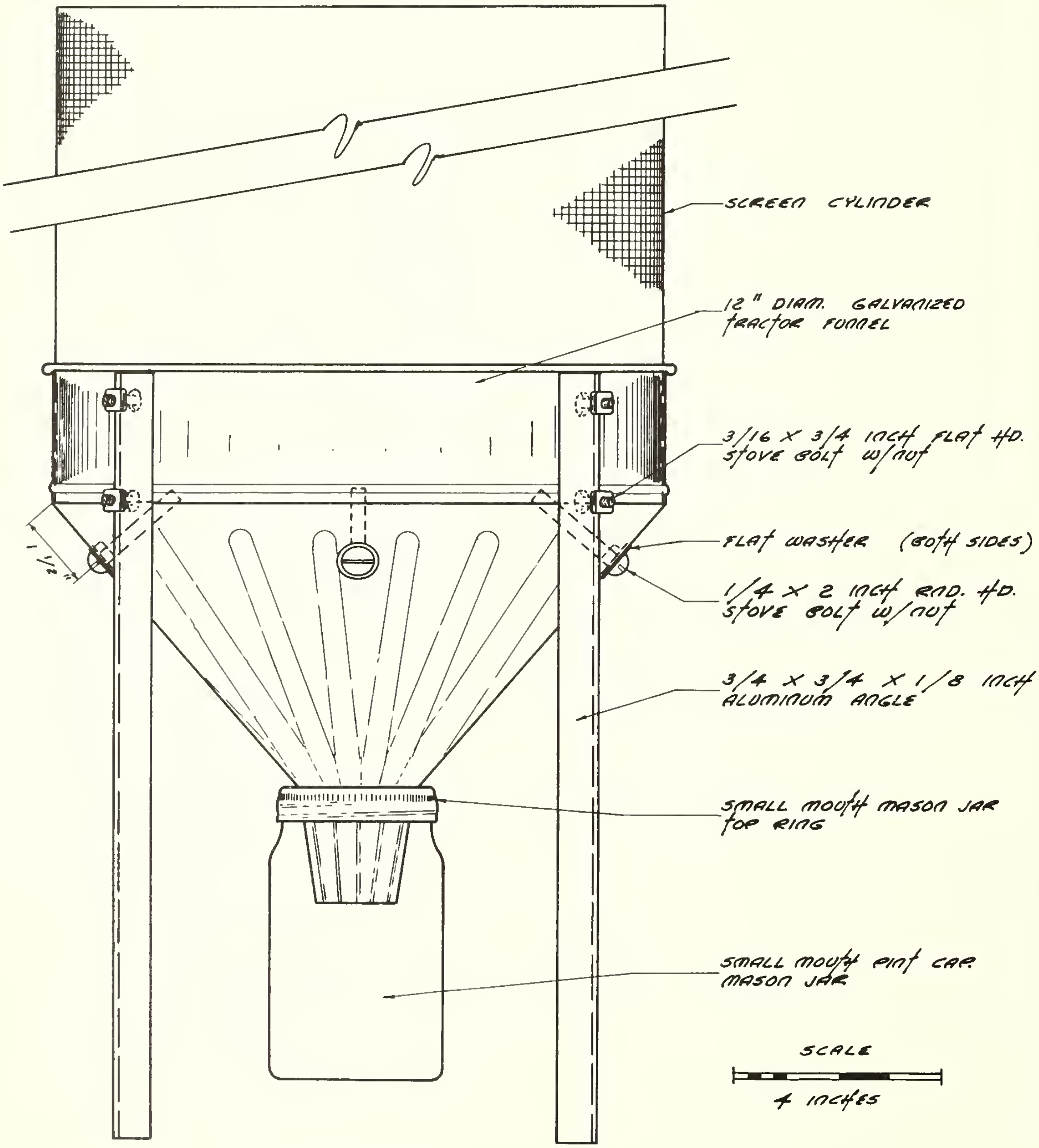
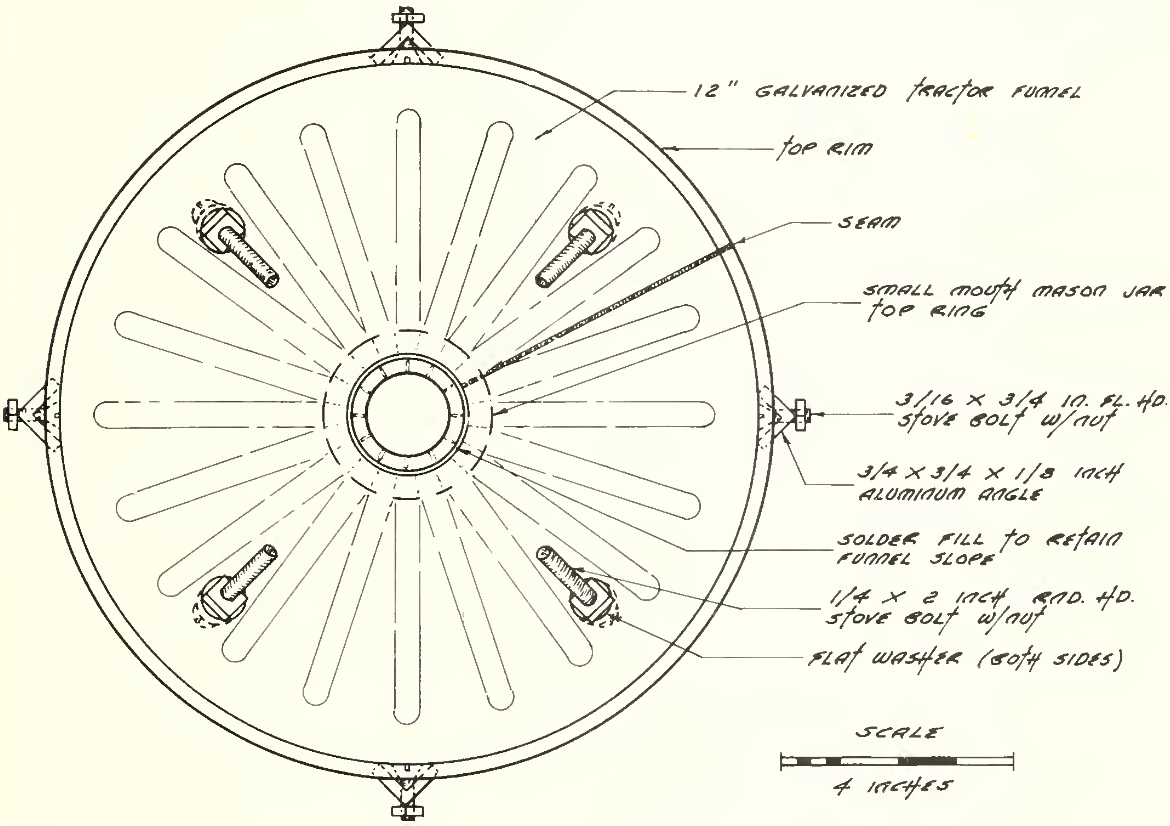


Figure 2.--Funnel, side view.

modified to accept a small-mouth, pint-capacity mason jar (fig. 2). The funnel is supported by four 15-inch legs attached to the top rim of the funnel with stove bolts, at equal intervals around the funnel circumference. The removable screen cylinder, closed at the top, is 24 inches high, with a diameter of 12 inches. It fits snugly inside the top rim of the funnel (fig. 3). Bolts of wood are supported by four 2-inch-long stove bolts secured to the funnel slope at even intervals, and pointing inward.



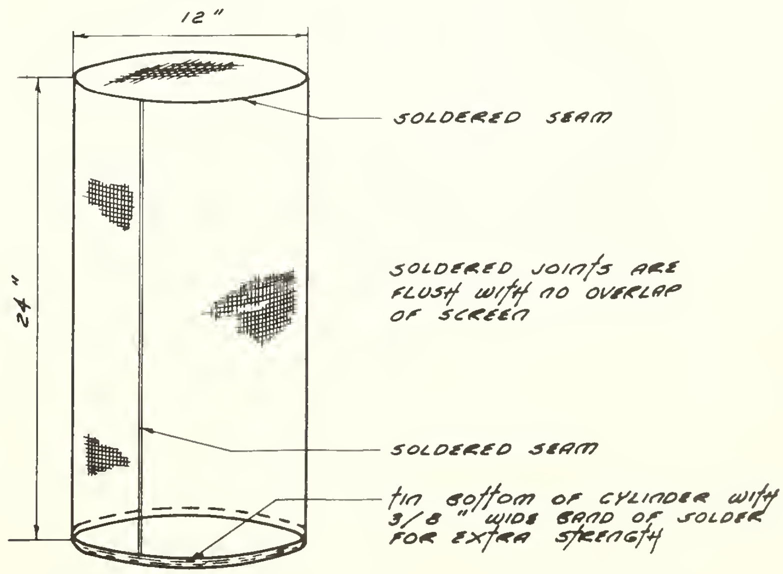


Figure 3.-- Funnel, top view (above). Screen cylinder - no scale (right).

Material List

1	Funnel, galvanized tractor, 12 inches in diameter
5 feet	Angle, aluminum, 3/4 by 3/4 by 1/8 inch
4	Bolts, roundhead stove, with nuts, 1/4 by 2 inches
8	Bolts, flathead stove, with nuts, 3/16 by 3/4 inch
8	Washers, flat, 1/4-inch hole diameter
1	Jar, small-mouth mason with top ring, pint sized
50 inches	Screen, insect, 24 inches wide

Construction

1. Remove paint and labels from funnel with an industrial-type paint remover.
2. Remove strainer screen from funnel. (Strainer screen is inserted when infesting bolts with insects, but removed for emergence.)
3. Cut 1-3/4 inches from funnel outlet with a hacksaw or tinsnips; smooth rough edge with metal file.
4. Slide small-mouth mason jar ring on funnel outlet as far as it will go, and solder in place. (Scrub all soldered areas with wire brush and running water because acid residue from solder will corrode metal parts.)
5. Fill in with solder, where inside of funnel slope meets top of funnel outlet. (This prevents the lodging of insects during emergence.)
6. Cut four 15-inch pieces of aluminum angle, and drill two 3/16-inch holes in each leg as in diagram.
7. Attach legs at four even intervals around funnel circumference. Tighten stove bolts until flat heads are flush with inside of funnel rim.
8. Drill funnel and insert support bolts as in diagram. (If billet is too small in diameter to rest on the stove bolts, an 8-inch by 8-inch piece of plywood or hardboard placed on bolts will provide a stable floor.)
9. Cut a piece of screen 37-11/16 inches long, form cylinder, and solder seam with no overlap. (Tin open-bottom edge of screen cylinder with solder; about a 3/8-inch-wide strip completely around is sufficient for added strength.)
10. Cut a disc of screen 12 inches in diameter, and solder to top of screen cylinder with no overlap.

The cylinder, funnel, and mason jar now form the completed cage. Excelsior or shredded paper is placed in the mason jar.

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OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Veneer Volume And Grade Recovery From Ponderosa Pine In The Southwest

Roland L. Barger[1]

A study of sample logs from standing trees (26,100 board feet gross scale), sorted into eight quality classes, showed that all classes of lower quality ponderosa pine sawtimber are generally suitable for veneer. The poorest quality class produced more than 20 percent Grade C and better veneer; less than 2 percent of the veneer produced failed to meet minimum commercial standards. A closely integrated sawmill-veneer mill operation, however, would be the most economical, because logs could be sorted for use in the process or product for which they were best suited. Veneer residue and other unsuitable materials could be converted to pulp chips.

A Need for Evaluating Plywood Potential

Ponderosa pine (Pinus ponderosa Laws.) has long been recognized as a preferred species for high common, shop, and select grades of lumber. Much of the ponderosa pine sawtimber in the Southwest is of lower quality, and, as in other ponderosa pine regions, yields predominantly lower common grades of lumber. Most markets for lower grade lumber have been lost to panel products, notably plywood. Plywood offers lower in-place costs for sheathing, subflooring, forming, and similar construction uses, upon which the lower common grades of lumber depend. Under these circumstances, ponderosa pine sawtimber has received renewed attention as potential veneer material.

Appraising the feasibility of producing plywood from ponderosa pine requires reliable veneer volume and grade recovery information. A veneer recovery study was conducted to develop such information for southwestern ponderosa pine. The study was sponsored by the Southwest Pine Association, and was conducted at the Boise-Cascade plywood plant in Yakima, Washington.[2] Cooperating with the Association in the study were the Rocky Mountain Forest and Range Experiment Station, the Forest Products Laboratory, and Region 3 of the U. S. Forest Service, and the American Plywood Association. The veneer recovery study is the most intensive study conducted to date on southwestern ponderosa pine. This report briefly describes the study, the procedures employed in the field and the mill, and the recovery obtained.

[1] *Wood Technologist located at Flagstaff in cooperation with Northern Arizona University; central headquarters are maintained at Fort Collins in cooperation with Colorado State University.*

[2] *Southwest Forest Industries, Inc., a member firm of the Southwest Pine Association, initiated and implemented the study. The selection and logging of sample material was accomplished under the direction and supervision of Mr. Le Von Dunford, Director, Timber Management and Engineering, SFI. SFI, Inc., also arranged for transporting sample logs to Yakima, and for processing the material through the Boise-Cascade mill at that location.*

Basic Objectives

The primary purpose of the study was to determine veneer volume and grade recovery from a sample of southwestern ponderosa pine sawtimber. A further objective was to determine which types or classes of relatively low-quality logs are best suited to veneer production. To satisfy these objectives, veneer recovery information was required from each of several grades or classes of logs. Grades of material best suited to veneer, and grades less suited to veneer, could thereby be identified.

Field and Mill Procedures

Field Selection of Sample Logs

Study logs were selected from sample trees on three sale areas, representing a range of sizes and grades common to the region. The three sample areas included:

1. Apache National Forest, Black River Unit--an area of relatively high-quality old-growth timber.
2. Sitgreaves National Forest, Twin Unit--a relatively low-quality old-growth stand, with high incidence of defect.
3. Sitgreaves National Forest, Lake Unit--a high-quality stand of blackjack and young mature timber.

Timber on the Black River and Lake Units averaged four logs in height, while timber on the Twin Unit averaged two logs in height.

All study logs were selected from standing trees, to facilitate examining the tree and to positively identify sample log position in the tree (fig. 1). All sample material was selected and cut in 17.5-foot logs, each containing two 8.5-foot veneer logs plus trim allowance. A total sample of 288 veneer logs was selected for the study. The veneer logs were graded and classified separately, and segregated into eight quality classes based upon position in the tree and external physical characteristics. Sampling was conducted to achieve adequate representation in each of the eight classes, from each sample area. Minimum scaling diameter limits of 10 inches for blackjack and 12 inches for old growth were observed. Table 1 briefly describes the eight veneer log-quality classes, the major physical characteristics of each class, and the sample volume in each class.

Figure 1.--Logs for the study of veneer recovery were selected and classified in standing trees, in order to achieve the desired sampling distribution and better describe the sample material.

Table 1.--Classification and physical characteristics of sample ponderosa pine veneer logs. All classes, specifications, and descriptions apply to 8-foot veneer logs.

Veneer log class	Class description[1]	Average scaling diameter	Average log taper	Log grade[1]				Log scale	
				1	2	3	5-6	Gross	Net
		Inches		--- Percent ---				Board feet	
1	Old-growth butt log, Grade 3 or better	21.6	2.1	28	8	64	--	3,700	3,120
2	Old-growth second log, Grade 3 or better	20.7	2.3	8	25	67	--	1,930	1,750
3	Old-growth butt log, Grade 5 or 6, Dead knots 3 inches or less in diameter	18.5	2.0	--	--	--	100	2,490	2,410
4	Old-growth second log, Grade 5 or 6, Dead knots 3 inches or less in diameter	17.2	2.0	--	--	--	100	4,050	3,540
5	Old-growth middle logs, Dead knots 3 inches or less in diameter	18.5	.9	--	2	9	89	5,710	4,390
6	Old-growth upper logs (last merchantable log) Dead knots 3 inches or less in diameter	13.3	1.2	--	--	2	98	2,170	1,870
7	Blackjack butt and second logs	17.0	1.8	--	--	4	96	4,010	3,810
8	Blackjack middle and upper logs	14.0	1.0	--	--	--	100	2,580	2,510
	Combined classes	17.6	1.6	3	2	10	85	26,100	23,400

[1] The saw-log grades indicated are those of the Pacific Northwest six-grade system commonly used in grading ponderosa pine.

Mill Procedure

The sample logs totaling 26,100 board feet gross scale, were shipped to the Boise-Cascade plant in Yakima, Washington, for processing into veneer (fig. 2). The plant is a typical softwood plywood plant with a monthly capacity of approximately 10 million square feet. Approximately 80 percent of the output is in sheathing grades of plywood. The veneer end of the mill is equipped with a high-speed 8-foot lathe with retractable chucks, a 4-foot lathe, and steam dryers.

Just prior to the mill run, the logs were debarked, bucked into 8.5-foot veneer logs, and segregated into the eight quality classes. They were placed in heating vats, steamed at a vat temperature of 160° F. for 10 hours, and conditioned in the closed vats for an additional 2 hours.

The groups or quality classes of logs were processed in a series of batch runs, with grade and volume recovery information obtained separately for each group. All material was peeled on the 8-foot lathe into nominal 0.1-inch veneer (0.104 inch green thickness). Eighty percent of the logs were peeled to a 6-inch core, and most of the remainder to a 6.25-inch core. Only 2 percent yielded cores larger than 6.5 inches. The green veneer was clipped and immediately fed into the dryers. All veneer was dried on a 10.5-minute schedule at 350°-360° F. Veneer was graded and tallied at the outfeed end of the dryers by representatives from the American Plywood Association.[3]

[3] *Mr. Harold Evans and Mr. Paul Garrison, of the American Plywood Association, supervised the mill procedures used in the study, and graded and tallied all veneer produced.*

Figure 2.--Decks of test ponderosa pine veneer logs await processing at the plywood plant. The left deck contains classes 1 and 2 logs, the center deck classes 3 and 4 logs, and the right deck class 5 logs.

Recovery Results

Veneer Volume and Grade Recovery

All veneer produced in the study was graded according to the full range of commercial standard grades, A through D. Veneer that did not meet minimum (Grade D) commercial standards was identified as "Grade X." Veneer that required redrying was also identified separately. Table 2 summarizes the recovery information for each of the eight veneer log-quality classes. Figure 3 illustrates veneer typical of two of the commercial grades, GradesC and D.

The selected sample purposely included representation of all classes of ponderosa pine material believed to be at all suitable for veneer. Some of the classes of material, such as Grade 3 butt logs, are obviously also well suited to the production of sawn products for which strong demand still exists. In an integrated operation, these classes of material would be omitted from the veneer operation if possible. The effect of omitting any class, or classes, can readily be determined from the recovery information presented for individual log classes. Table 3 illustrates the veneer grade and volume recovery from several selected combinations of log-quality classes.

Figure 3.--Grade C veneers, represented by the two panels on the right, may have knots up to 1-1/2 inches across and holes up to 1 inch across. Grade D veneers, represented by the three panels at left, may have knots without limit and holes up to 2-1/2 inches across.

Table 2.--Veneer grade and volume recovery from southwestern ponderosa pine, by veneer-log quality class

Veneer log class	Grade recovery						Volume recovery factor[1]
	A and A-patch	B and B-patch	C	D	X	Redry	
	Percent						
1	17.5	7.5	32.6	40.0	1.7	0.7	2.77
2	12.3	11.0	24.2	48.4	2.6	1.5	2.96
3	13.4	7.5	55.8	21.9	1.2	.2	2.62
4	8.5	6.0	35.7	48.2	1.6	0	2.52
5	8.7	4.3	12.4	71.4	1.7	1.5	2.60
6	.2	.2	27.8	69.5	2.3	0	2.56
7	9.9	7.6	47.3	27.8	1.6	5.8	2.97
8	1.2	1.8	20.5	73.6	1.2	1.7	2.83

[1] Recovery factors are based upon total veneer recovered and gross Scribner log scale, and indicate square feet of 3/8-inch plywood recovered per board foot log scale.

Table 3.--Veneer grade and volume recovery from selected combinations of veneer-log quality classes

Veneer log classes, combined	Grade recovery						Volume recovery factor
	A and A-patch	B and B-patch	C	D	X	Redry	
	Percent						
All old-growth, classes 1 through 6	10.5	6.0	29.3	51.7	1.7	0.8	2.65
All blackjack, classes 7 and 8	6.5	5.4	36.9	45.6	1.4	4.2	2.91
Low-quality old-growth, classes 3 through 6	8.2	4.7	29.1	55.6	1.7	.7	2.57
Old-growth middle and upper logs, classes 5 and 6	6.3	3.1	16.6	70.9	1.9	1.2	2.59
All butt and second logs, classes 1 through 4 and 7	12.2	7.6	39.4	37.3	1.7	1.8	2.75
All middle and upper logs, classes 5, 6, and 8	5.0	2.8	17.6	71.6	1.7	1.3	2.65

Chip Volume Recovery

Veneer residue and material unsuited to other utilization purposes can be converted to pulp chips. During the mill run of sample logs, all unusable roundup from the blocks and clipped waste from the green veneer was chipped. In addition, 18 of the cores were oversize or otherwise unsuitable for further utilization, and were chipped. Total chip recovery was 10.23 units,[4] or approximately 0.4 unit per MBF, log scale. Had all of the cores been chipped, they would have added approximately 0.2 unit per MBF to the chip recovery.

The probable chip recovery per MBF by source can be calculated from the average block size and taper of the sample material. Calculated chip recovery from roundup, clipper waste, and cores is as follows:

	Chip recovery per MBF (Units)[4]
Source:	
Roundup	0.27
Clipper waste	.10
Cores (18 chipped)	.03
Total actual recovery	.40
If all cores chipped	.20
Total possible recovery	.60

General Discussion

The recovery information obtained in the study is valid for each log-quality class; that is, class results indicate the recovery to be expected from each type of log. Combined results are not necessarily representative of southwestern ponderosa pine as a whole, however, since study logs were not selected in proportion to their occurrence in the stand. They were instead selected to obtain adequate representation within each class. When the proportion of a stand fitting each quality class can be estimated, the class recovery results can be applied to estimate recovery potential for the stand as a whole. More often, however, an operator will want an estimate of recovery for a particular type or class of logs, rather than for the entire stand.

The participating Southwest Pine Association firms particularly wished to determine whether veneer volume and grade recovery from ponderosa pine timber was adequate to support a sheathing-grade plywood operation. Sheathing grades of plywood utilize Grades C and D veneer. An operation producing predominantly Grade C-D five-ply interior sheathing would require at least 20 percent Grade C veneer, with the remainder meeting Grade D specifications. In this context, the veneer volume and grade recovery from the sample material are excellent. The poorest quality class of logs produced more than 20 percent Grade C and better veneer. Most quality classes produced substantially more than this. Equally encouraging and important, less than 2 percent of the veneer produced failed to meet minimum commercial standards (Grade X). Volume recovery factors, ranging from 2.52 to 2.97 square feet (3/8-inch basis) per board foot log scale, exceeded the average volume recovery commonly experienced in the industry.

The satisfactory grade recovery obtained, and the absence of "X Grade" veneer, are largely due to the knot restrictions written into the quality class descriptions. Although most of the sample logs were from the lower grades of sawtimber material (table 1), logs with dead knots too large to produce commercially acceptable veneer were excluded. Restrictions on dead knot size are the most important merchantability criteria to be applied to ponderosa pine veneer logs, particularly in old-growth timber. Restricting dead knots in lower grade old-growth logs to 3 inches or less in diameter insures that practically all veneer will meet minimum Grade D standards. Green knot restrictions are not so necessary, since most green knots stay in the veneer and thereby meet commercial standards.

The "grade mix" of veneer logs in the test sample is obviously better than it need be to support a C-D Grade five-ply interior sheathing product. As table 3 shows, various combinations of log classes excluding the better

[4] *One unit of pulp chips is an amount weighing 2,400 pounds, ovendry.*

quality saw log material will provide adequate recovery in Grade C and better veneer. Middle and upper logs meeting minimum specifications for their respective quality classes will provide adequate grade recovery for such an operation.

The grade recovery data provide some insight into the factors determining quality in ponderosa pine veneer logs. Knot and knothole characteristics form the primary basis for veneer grades; consequently, log knot characteristics are the major determinant of grade recovery. Since limbs or knots increase in frequency with height in the tree, log position is a good indicator of quality. This is reflected in the large grade recovery differences between log positions in the tree. Butt and second log classes combined produced 59 percent Grade C and better veneer, while all middle and upper log classes produced 25 percent Grade C and better veneer (table 3). Saw log grades, as applied in defining the first four quality classes, do not appear to be significantly related to veneer grade recovery.

The log quality classes used in the study were particularly designed to describe specific types of logs in standing trees. The results are most useful in appraising the potential of southwestern ponderosa pine stands for veneer logs. The classification system is not adaptable to grading individual veneer logs on the merits of the log alone. A simplified grading system based upon log characteristics alone is desirable, as a predictor or indicator of grade recovery from the individual log. The strong influence of knot characteristics upon grade recovery suggests that a workable grading system for ponderosa pine veneer logs could be developed based on knot characteristics alone.

Conclusions

The results of the study indicate that the classes of lower quality ponderosa pine sawtimber tested are generally suitable for veneer. Grade recoveries are more than sufficient for a C-D Grade product, and volume recovery is above that generally experienced by the industry. Better quality saw log material need not be included in the veneer log grade mix. However, before the results can be interpreted as indicative of a local production opportunity, it will be necessary to determine whether the required log volumes are economically available in the grades tested.

The study indicates that care should be exercised in the selection of veneer material, however, to omit material not suited to veneer. Part of the lower quality sawtimber resource is not suited to veneer, primarily because of excessively large dead knots, and should be diverted to other uses. The total sawtimber resource can be utilized to greatest economic advantage in a multiproduct operation. In a closely integrated sawmill-veneer mill operation, log selection or sorting can be of mutual advantage in diverting material to the process or product for which it is best suited.

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OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Phenology of Arizona Fescue and Mountain Muhly in the Northern Arizona Ponderosa Pine Type

Henry A. Pearson[1]

In northern Arizona, height growth of Arizona fescue, a cool-season grass, increased greatest during May while mountain muhly, a warm-season grass, increased greatest during July and August. Flower stalks developed earlier for fescue than muhly.

To design grazing systems, the range manager should know how the forage species develop. Arizona fescue (Festuca arizonica Vasey) and mountain muhly (Muhlenbergia montana (Nutt.) Hitchc.) are important range grasses in the ponderosa pine type; therefore, plant phenology of these two species is of interest to livestock and wildlife managers whose industry involves the pine grazing areas. Plant phenology is useful (1) in predicting time of range readiness and amount of forage growth, (2) as a guide to forage quality, and (3) as an aid in designing grazing systems. The pine type in Arizona is grazed during the summer, usually from June to October.

The purpose of this paper is to provide plant development information about Arizona fescue and mountain muhly in the ponderosa pine type of northern Arizona.

Height and stages of development of 40 plants each of Arizona fescue and mountain muhly were recorded at weekly to biweekly intervals during the snow-free months from 1963 through 1965. The study area, located 13 miles northwest of Flagstaff, Arizona, has an elevation of 7,600 feet and an average annual precipitation of 23 inches.

[1] *Range Scientist, located at Flagstaff, in cooperation with Northern Arizona University; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

Plant Development

Two distinct growing seasons occur in northern Arizona during or following two high precipitation periods. Mean monthly precipitation on the study area, 1963-65, was as follows:

	Precipitation (Inches)
March	2.11
April	2.98
May	.89
June	.16
July	2.62
August	4.01
September	3.07

One growth period is characterized by cool-season grasses; the other by warm-season grasses. For Arizona fescue, a cool-season grass, height increased 7.8 inches from April 15 to June 30 and

2.8 inches from July 1 to September 15 (fig. 1). Mountain muhly, a warm-season grass, increased in height 3.3 and 5.2 inches during these same periods of time, respectively. Overwinter green height of Arizona fescue leaves was less than 2 inches and mountain muhly was less than 1.3 inches. Phenological development of the two species was as follows:

	1963	1964	1965
Arizona fescue:			
Heads showing	July 22	July 10	July 8
Flowers in bloom	Aug. 19	Aug. 11	Aug. 2
Seeds mature	Sept. 22	Sept. 9	Sept. 10
Mountain muhly:			
Heads showing	Sept. 5	Sept. 4	Aug. 15
Flowers in bloom	Sept. 25	Sept. 24	Sept. 7
Seeds mature	Oct. 10	Oct. 6	Sept. 27

Flower stalks of Arizona fescue appeared between July 8 and 22. Mountain muhly flower stalks appeared between August 15 and September 5. Seeds matured from September 10 to September 22 and from September 27 to October 10 for fescue and muhly, respectively.

Temperature and Moisture

Apparently the soil temperature determines when herbage growth starts in the spring. The spring thaw begins when the maximum air temperatures attain 50° F., usually about the beginning of March.[2] Maximum monthly temperatures in 1963 reached 50° F. by February whereas it was April before 50° F. was attained during 1964 and 1965. Evidently the start of muhly and fescue growth is related to the time of the spring thaw since these species were at least 0.5 and 2.0 inches taller, respectively, by May 1 in 1963 than 1964 or 1965, and continued to be taller until about June 15. The growth rate slowed in June 1963;[3] apparently moisture was the limiting factor. No precipitation fell in

[2] *Jaenicke, Alexander J., and Foerster, Max H. The influence of a western yellow pine forest on the accumulation and melting of snow. Monthly Weather Rev. (March) 43: 115-126. 1915.*

[3] *Pearson, Henry A. Studies of forage digestibility under ponderosa pine stands. Soc. Amer. Foresters Proc. 1964: 71-73, illus. 1964.*

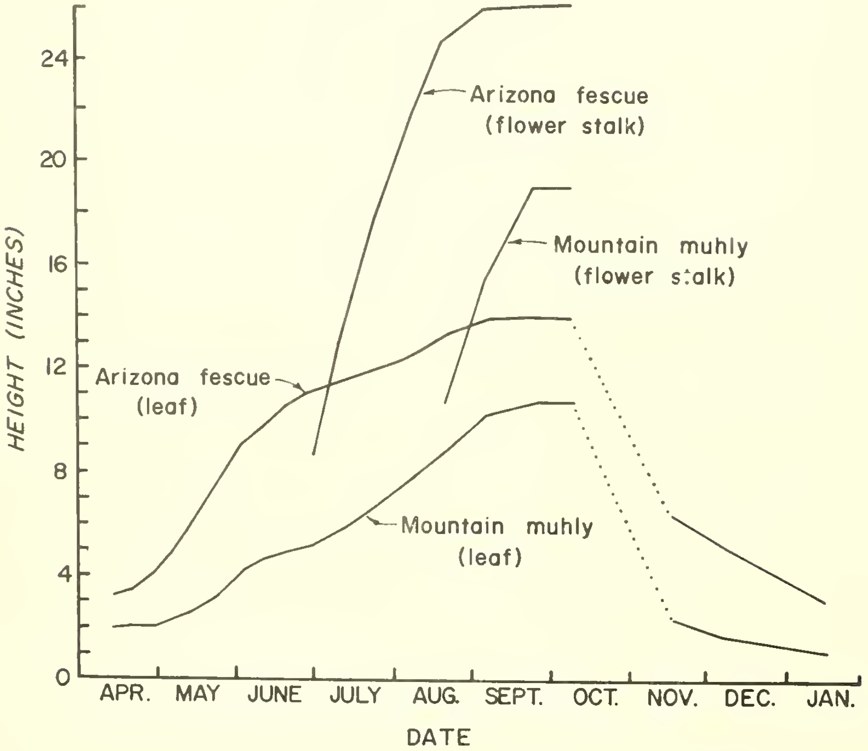

Figure 1.--Average height of Arizona fescue and mountain muhly for 3 years (1963-65). Dashed lines indicate rapid drying of tops.

June 1963, whereas it did in 1964 and 1965. Precipitation during July 1963 was also much less than the other years. Growth during the summer responded accordingly.

The rate of fescue growth from May through July is apparently related to the precipitation falling in a prior month:

	Leaf growth	Preceding month's precipitation
	(Inches)	
July 1963	0	0
June 1963	.8	.05
July 1964	1.4	.22
July 1965	2.1	.27
June 1964	3.2	.66
June 1965	3.3	1.96
May 1963	4.1	1.50
May 1965	4.3	4.92
May 1964	4.8	2.40

During late summer some other factor such as flowering apparently is more important than precipitation since the relationships of precipitation and growth for fescue did not continue past July. Mountain muhly did not respond similarly to the precipitation during spring and early summer, but height growth of this species was apparently related to precipitation during July and August:

	Leaf growth	Same month's precipitation
	(Inches)	
July 1963	0.5	0.90
Aug. 1965	1.7	1.61
Aug. 1964	2.3	5.55
July 1964	2.5	3.27
July 1965	2.8	3.69
Aug. 1963	3.6	4.87

These seasonal differences between species indicate that the period of growth is at least partially controlled by physiological mechanisms peculiar to certain grasses.[4]

[4] *Jameson, Donald A. Phenology of grasses of the northern Arizona pinyon-juniper type. U. S. Forest Serv. Res. Note RM-47, 8 pp., illus. 1965.*

Tree Overstory

Different densities of ponderosa pine occupied the various sites where the grasses were measured. Therefore, although not strictly phenologic in nature, the relationship between the trees and grass heights was considered.

Growth rate and final height of Arizona fescue were greatest in open areas and decreased as the pine overstory increased. During May 1963-65, relationship of leaf growth under different ponderosa pine overstories was:

Canopy cover (Percent)	Growth per month (Inches)
1.4	5.9
3.5	5.0
7.9	5.0
14.1	4.1
20.4	4.8
25.8	4.4
29.8	4.4
42.2	3.3

Leaf height, measured in 1965, also was related to the pine overstories:

Basal area (Sq. ft. per acre)	Leaf height (Inches)
0	21.0
25	18.0
33	17.3
96	14.1

Mountain muhly growth rates were not related to tree overstory.

The difference between these two grass species is probably due to their growing season in relation to the pine growing season. Competition for moisture between pine seedlings and fescue has been indicated,[5] but not between pine and muhly. Competition between Arizona fescue and older pine trees has not been cited although the period of maximum ponderosa pine growth coincides with maximum growth of fescue.[6] The retarded growth of fescue under

[5] *Pearson, G. A. Herbaceous vegetation a factor in natural regeneration of ponderosa pine in the Southwest. Ecol. Monogr. 12: 315-338, illus. 1942.*

[6] *Pearson, G. A. Management of ponderosa pine in the Southwest. U. S. Dep. Agr. Agr. Monogr. 6, 218 pp., illus. 1950.*

pine trees indicates that factors necessary for growth of fescue are used instead by the trees. On the other hand, maximum growth of muhly occurs after the growth of pine ceases.

Summary

In designing a sound grazing system, growth and development of the important range species should be considered. Phenological measurements of Arizona fescue and mountain muhly in the ponderosa pine type of northern Arizona were recorded from 1963 through 1965. Two growth periods occur in northern Arizona, an early spring growing season characterized by cool-season grasses, and a summer growing season during or following the summer rains characterized by warm-season grasses. Arizona fescue achieves peak growth rate during May, mountain muhly during July and August. Height growth ceased during September for both species. Flower stalks develop earlier for fescue than muhly. Arizona fescue growth decreased as the tree overstory increased, while mountain muhly growth was apparently not affected by the pine trees.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Lessons from Artificial Regeneration Studies in a Cutover Beetle-Killed Spruce Stand in Western Colorado

Frank Ronco [1]

Eleven specific lessons were learned about factors that affect seed germination, seedling establishment, and plantation success with Engelmann spruce and lodgepole pine.

This paper summarizes results from several separate but related studies of seeding and planting Engelmann spruce (Picea engelmannii Parry) and lodgepole pine (Pinus contorta Dougl.). The studies were made in a cutover stand of beetle-killed spruce on the White River National Forest in western Colorado. The 50-acre stand was at 10,500 feet elevation on a gentle northwest slope. A dense ground cover of forbs, grasses, and sedges developed after the area was salvaged logged in 1948.

Description of Studies

Seeding Studies

Seeding trials for spruce and pine were made in 1957, 1958, and 1959. Each trial contained 800 one-foot-square seed spots arranged in 5 blocks of 160 seed spots. Each block was subdivided into 4 treatments of 40 seed spots arranged in 4 equal rows. Spots in each row were 1 foot apart, and rows were 2 feet apart. There were 200 seed spots in each treatment.

All blocks were cleared to mineral soil before they were sown, and were weeded regularly to reduce vegetative competition. Seed spots were sown in late spring or early summer, with 15 seeds the first 2 years and 20 seeds the last year. The amount of viable seed sown, based on laboratory tests of treated seed, varied in each trial (see table 2). All seed was treated with an Endrin-Arasan-latex emulsion by the United States Fish and Wildlife Service.

Seeds were sown the same way in all treatments—soil was thoroughly loosened to a depth of about 1/8 inch, seed was mixed in, and the spot was packed lightly and uniformly. The following treatments (fig. 1) were applied to seed spots:

Shade—A cedar shingle 6-8 inches wide was placed on the south side of the seed spot.
Mulch—Seed spot was covered with a 1/2-inch layer of sawdust.
Shade-mulch—A combination of the above treatments.
No treatment—Used as a control.

Individual study objectives determined when treatments were applied. In 1957 it was desired to test treatment effect on survival only, whereas in 1958 and 1959 both germination and survival data were wanted. Treatments were applied in all trials when seed was sown, except in 1957, when seed spots were treated 3 weeks after they were sown, or 2 weeks after the first seedlings appeared.

The area between blocks and a 400-foot-wide buffer strip was baited with 1080-impregnated wheat on a 50- by 50-foot grid about 2 days before sowing. Seedling survival in each trial was checked biweekly during the first growing season. The 1957 pine trial was checked monthly in succeeding years.

[1] *Silviculturist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Figure 1.--Seed spots with shade treatment (left) and mulch treatment (above).

Treatment effect on germination was obtained from the 1958 pine and 1959 spruce seedings, while the 1957 pine seeding produced usable data on survival due to treatment. Spruce sown in 1957 and 1958 and pine sown in 1959 germinated so poorly that data were not analyzed.

Planting Studies

From 1957 through 1962, eight spruce and six pine planting studies were started to test the effect of different environmental factors on survival. Seedlings were hand planted in the spring by the deep-hole method on areas cleared to mineral soil and weeded at regular intervals. In those studies where shade treatment was applied, shingles were used as described in the seeding studies. Shingles were removed each fall to prevent snow from crushing them against the seedlings and causing possible injury.

Survival counts were made biweekly during the first growing season after planting. During succeeding years, survival was recorded in early spring and late fall.

Lessons Learned

1. Sawdust mulch can improve germination

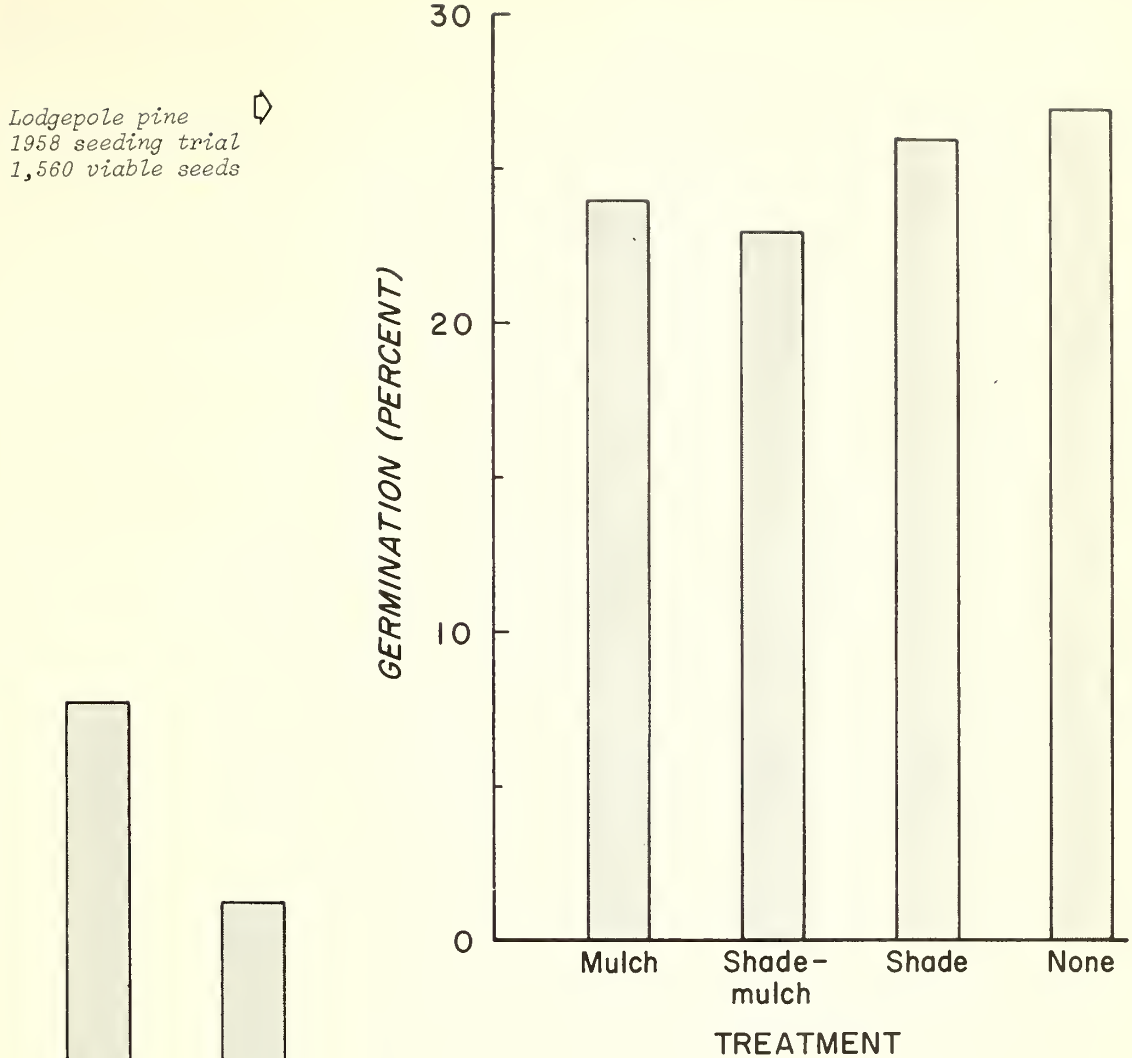
A sawdust mulch improved the germination of spruce seed, but germination of pine seed was not benefited by treatment (fig. 2). Since pine emergence did not begin until September 1 in 1958, soil and air temperatures during that period were probably below optimum for germination, regardless of treatment. The slightly higher initial germination in untreated seed spots, which would average warmer than mulched and shaded spots, tends to support that conclusion.

2. Time of germination of spring-sown seed is geared to summer precipitation

Although total rainfall was nearly the same during different trial years, its distribution markedly influenced the onset of germination (table 1). In 1957, rainfall was adequate and well distributed from 1 week before to 6 weeks after sowing. As a result, germination began the second week after sowing and was mostly completed by the end of the third week. Precipitation was less favorably distributed in 1958 and 1959, however, and as a consequence, germination was delayed for 7 or more weeks. In both those years, the start of germination was preceded by a period of about 2 weeks when weekly rainfall was about 1.5 inches.

3. A substantial portion of sown seeds may remain dormant for 1 year

Average total germination of sound seed was satisfactory in four out of six seeding trials, but the proportion of initial to holdover germination varied considerably (table 2). As soils remained dry through the summers of 1958 and 1959 until about September 1, after which temperatures were low, poor first-year germination probably resulted from adverse conditions rather than from embryonic dormancy.



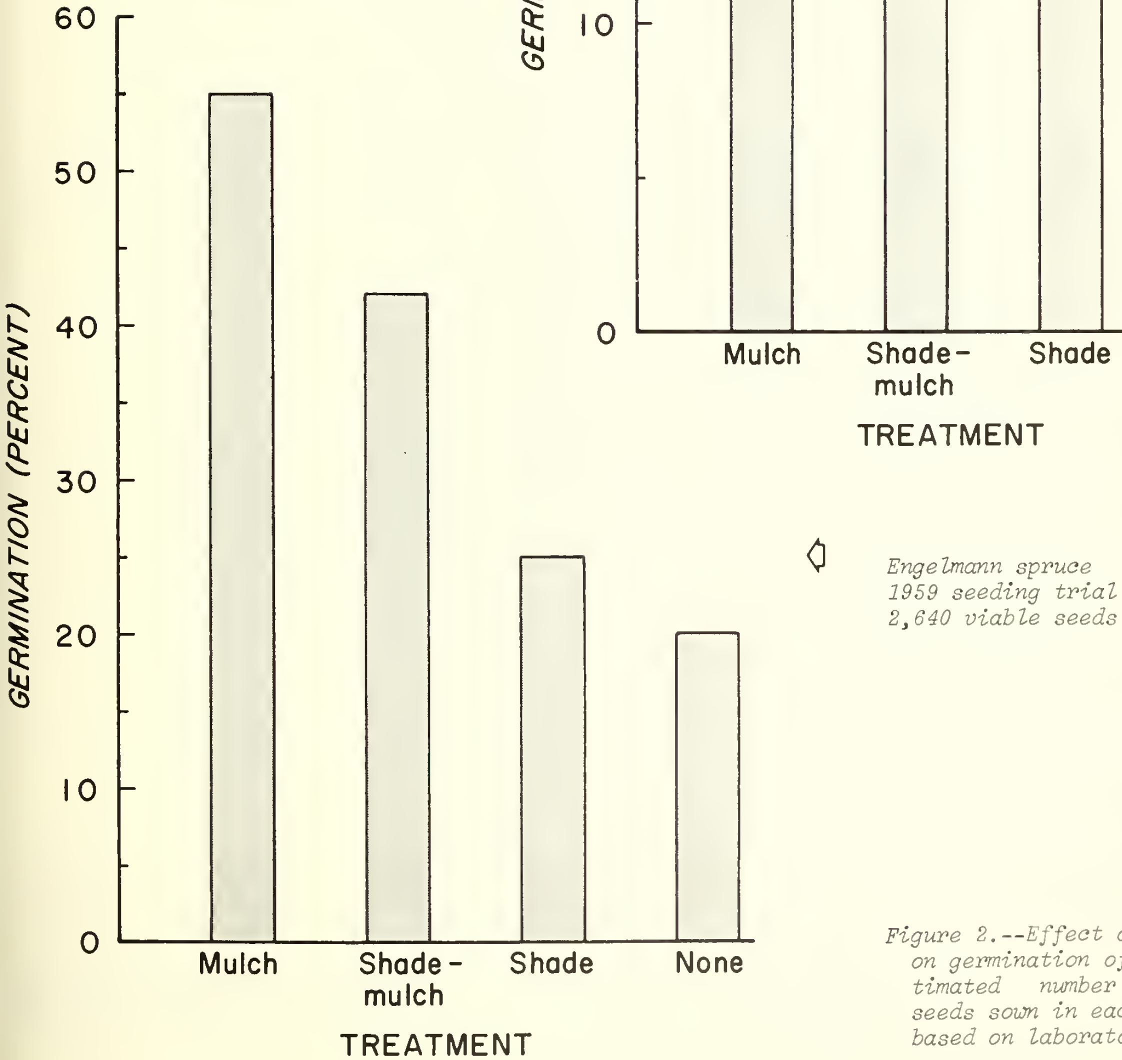


Figure 2.--Effect of treatment on germination of seeds (estimated number of viable seeds sown in each treatment based on laboratory tests).

Table 1.--Relationship of precipitation to proportion of germinated seeds that emerged at weekly intervals following sowing

Weekly periods before and after sowing date	Rain			Germinated seeds			
	1957	1958	1959	1957 Pine	1958 Pine	1959 Pine	1959 Spruce
	- - - Inches - - -			- - - - - - Percent - - - - - -			
Before sowing:							
2	0.24	([1])	0.74				
1	.78	0.36	1.10				
After sowing:							
1	1.46	.04	.20				
2	.44	.02	.07	([2])			
3	.62	0	.09	86			
4	.27	.38	.13	--			
5	.42	1.20	.62	9			
6	.66	.06	1.71	--	([2])		
7	.25	.27	.26	3	47	([2])	([2])
8	([1])	.03	.54		--	11	56
9	.40	1.18	.17		--	--	--
10	([1])	1.25	([1])		23	10	13
11	--	--	.06		--	--	--
Holdover germination				2	30	79	31
Total	5.54	4.79	5.69	100	100	100	100

[1] Trace.
[2] Limited.

Table 2.--Summary of seed sown and germination for all treatments in lodgepole pine and Engelmann spruce seeding trials

Species and year sown	Seed sown		Germination of viable seeds		
	Total	Viable[1]	Initial	Holdover	Total
	Number		- - - Percent - - -		
Lodgepole pine:					
1957	12,000	9,240	56	1	57
1958	12,000	6,240	44	19	63
1959	16,000	5,280	16	58	74
Engelmann spruce:					
1959	16,000	10,560	35	16	51

[1] Based on laboratory germination tests of treated seed.

4. Most seedling mortality is caused by frost heaving, mice, and damping-off fungi

In addition to the large number of seedlings killed by mice (table 3), many living seedlings were partially defoliated when rodents clipped seedcoats from cotyledons to which they were still attached.

5. Sawdust mulch and shade increase both survival and stocking of seeded lodgepole pines

After 3 years, average stocking in treated seed spots was nearly three times more than in untreated spots, even though percent survival was relatively low (table 4).

Table 3.--Causes of mortality in lodgepole pine and Engelmann spruce seedings during the first growing season after spring sowing

Causal agent	Germinated seeds			
	1957--Pine	1958--Pine	1959--Spruce	Average[1]
	Percent			
Damping off	13.9	13.4	17.2	14.8
Unidentified	18.1	7.8	12.0	13.7
Mice	3.1	4.6	18.2	8.2
Frost heave	5.7	23.3	0	8.1
Heat	2.4	2.5	1.4	2.1
Trampled	3.5	.6	0	1.7
Leafhoppers	1.3	0	0	.6
Man	.2	.7	.4	.4
Gophers	.7	0	0	.3
Hail	.1	0	0	.1
Total	49.0	52.9	49.2	50.0

[1] Based on totals for both species and 3 years.

Table 4.--Yearly survival and 3-year stocking percentages in the 1957 pine seeding trial

Treatment	Germinated seeds	Survival[1]			Stocked seed spots,[2] 1959
		1957	1958	1959	
	No.	Percent			
Shade	1,286	56	14	11	30
Mulch	1,342	48	15	9	28
Shade-mulch	1,408	59	19	13	45
None	1,243	40	5	3	11
Average or total	5,279	51	13	9	28

[1] Based on number of seeds that germinated.
[2] Based on 200 seed spots sown in each treatment.

6. Successful seeding establishment cannot be expected when germination occurs late in the growing season

None of the seeds that germinated in the 1958 and 1959 pine trials, or the 1959 spruce trial, survived overwinter. Seedlings apparently did not harden off sufficiently to withstand the adverse fall and winter weather. In 1959, for example, peak germination occurred about September 1, but seedlings were still emerging when snow covered the area 2 weeks later. Late-germinating seedlings have little resistance to frost heaving (see table 3, 1958 pine trial).

7. Pocket gophers can destroy established plantations

Although mountain pocket gophers (Thomomys talpoides) destroyed some seedlings each year, losses were highest during a population peak the third and fourth winters when other environmental factors were no longer causing serious seedling mortality (fig. 3).

Nearly all seedlings destroyed by gophers were clipped just above ground level, but a few died from root destruction by burrowing animals. The higher proportion of total spruce mortality caused by gophers during winter as compared to summer may have been

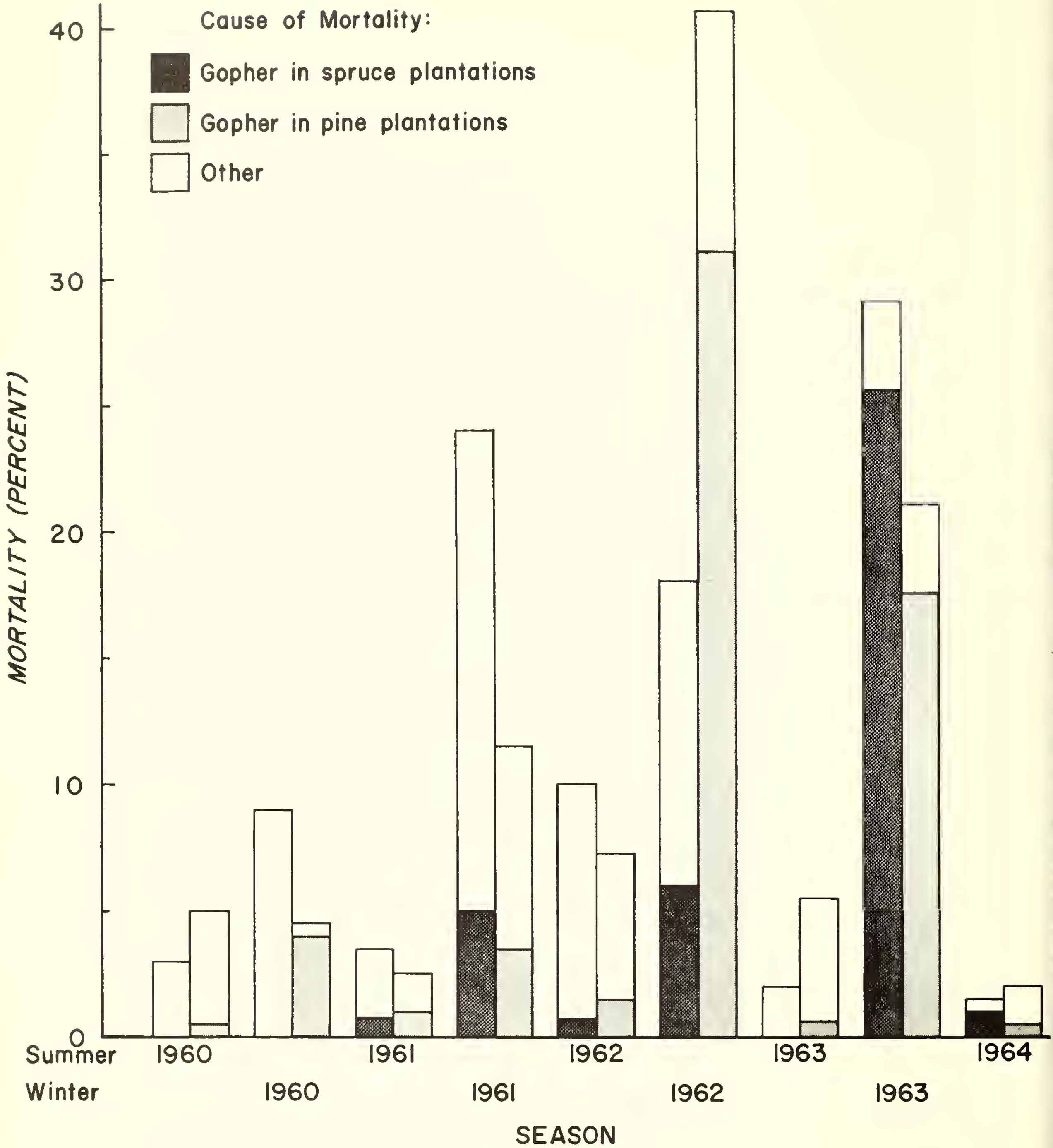


Figure 3.--Percent of total mortality by seasons caused by gophers and other factors after planting Engelmann spruce and lodgepole pine seedlings.

the result of woody plants becoming more important as food during the winter when green herbaceous vegetation was less abundant.[2] [3]

Plantations can be lost if gophers are not controlled, but the timing of control measures should be based on animal population surveys; population peaks are irregular, and planting sites vary in their capacity to support gophers. Gopher populations can be controlled indirectly by using herbicides to reduce forage plants,[4] or directly by trapping or poisoning with strychnine or 1080-treated grain.[2] [5] [6]

8. New growth on planted spruces is extremely sensitive to frost

Low temperatures during the growing season killed new growth, even after it had fully expanded and set terminal buds. Injury was limited to current plantings in light frost years, but in 1962 and 1964, heavy frosts caused damage in plantations that were several years old (table 5). Regardless of plantation age, shaded seedlings suffered less damage than those grown in the open. Shade was more effective in reducing the number of injured seedlings in older than in current plantations.

Table 5, which shows only the percentage of injured seedlings, does not appraise total damage. All new shoots were generally killed on open-grown seedlings, while shaded seedlings, in contrast, rarely had more than one dead shoot (fig. 4).

Frost damage appeared to be inversely proportional to the amount of protection. In a study at the Fraser Experimental Forest it was found that open-grown seedlings had an average of eight frost-killed shoots, whereas the average on seedlings grown under shingles was less than one; seedlings grown under a canopy of cheesecloth suffered no damage.

Frost damage may have greater consequences than just loss of foliage. Until planted seedlings establish new roots and recover from planting shock, photosynthesis and subsequent food production are limited. Since reserve food, already depleted by preplanting storage, is used to form new shoots, the net result of frost damage is to reduce stored foods and the capability of the plant to replace those reserves. When summer foliage losses from frost are preceded or followed by winterkilling of branches by snow mold, a large percentage of the photosynthetic mechanism of a seedling may be lost.

Although frost injury occurs when nighttime temperatures drop below freezing, lethal temperatures in tissue are probably due to foliage becoming even colder than ambient air as it loses heat by radiation to clear skies. Frost damage can be greatly reduced or eliminated by planting seedlings against stumps or logs, which not only reduce radiation from the seedling to the sky, but also warm them by reradiating heat absorbed from the sun, and from the soil as it cools at night. Crowns of trees and shrubs also offer good protection.

[2] *Colorado Cooperative Pocket Gopher Project. Pocket gophers in Colorado. Colo. Agr. Exp. Sta. Bull. 508-S, 26 pp., illus. 1960.*

[3] *Ward, A. Lorin, and Keith, James O. Feeding habits of pocket gophers in mountain grasslands, Black Mesa, Colorado. Ecology 43: 744-749, illus. 1962.*

[4] *Keith, James O., Hansen, Richard M., and Ward, A. Lorin. Effect of 2,4-D on abundance and foods of pocket gophers. J. Wildlife Manage. 23: 137-145, illus. 1959.*

[5] *Hansen, Richard M. New dispenser aids gopher control. Colo. Agr. Exp. Sta. Pam. 1-S, 8 pp. 1959.*

[6] *Ward, A. Lorin, and Hansen, Richard M. The burrow-builder and its use for control of pocket gophers. U. S. Fish and Wildlife Serv. Spec. Sci. Rep.: Wildlife No. 47, 7 pp. 1960.*

Table 5. --Percentage of live Engelmann spruce seedlings injured by frost (injury recorded when a seedling had one or more dead current shoots)

Year injury recorded	Open-grown seedlings		Shade-grown seedlings	
	Older[1] plantations	Current plantations	Older[1] plantations	Current plantations
	Percent			
1957	--	0	--	0
1958	0	0	0	--
1959	0	57	0	27
1960	0	33	0	23
1961	0	72	0	8
1962	100	100	8	54
1963	0	--	0	--
1964	20	--	0	--

[1] Includes all plantations established in years prior to the year frost injury was recorded.

Figure 4.--Mid-August frost injury to an open-grown spruce seedling planted in June. All new growth was dead, and appears as lighter foliage in the photograph.

9. Planted pines are not injured by frost

Even though pines were grown adjacent to spruce plantations, neither shaded nor open-grown seedlings suffered frost damage.

10. Shade reduces incidence of snow mold

Open-grown spruces suffered more injury from snow mold than shade-grown spruces (table 6), but treatment had no effect on incidence of snow mold on pines. Little damage was found in pine plantings, however, except during the 1961-62 winter when snow mold was especially bad. During that winter, 21 percent of the 1,362 surviving pine seedlings suffered damage, which was equally divided between open-grown and shaded seedlings.

11. Survival of planted spruces was increased by shad ing, but pine survival was as good in the open a under shade

It has been demonstrated that spruce seedling mor tality was heaviest during the first winter after planting and that it could be reduced significantly by shadin during the growing season.[7] Pine mortality, which aver aged considerably less than spruce, was not reduced b summer shading.

[7] *Ronco, Frank. Planting in beetle-kille spruce stands. U. S. Forest Serv. Rocky Mour tain Forest and Range Exp. Sta. Res. Note 6 6 pp. 1961.*

Table 6.--Percentage[1] of live seedlings injured by snow mold in all Engelmann spruce planting trials (injury was recorded when a seedling had one or more branches killed)

Winter	Open-grown seedlings	Shade-grown seedlings
	- - - - Percent - - - -	
1957-58	32	19
1958-59	0	0
1959-60	24	0
1960-61	0	0
1961-62	30	19
1962-63	5	1
1963-64	0	0
1964-65	10	13

[1] The percent value in any given year includes the surviving seedlings from all trials planted up to 5 years previously.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Hybrid Poplar Performance at 10 Years in the Nebraska Sandhills

Ralph A. Read[1]

Hybrids containing Populus deltoides and P. nigra cv. Caudina appear to offer the best chance of performing satisfactorily in the Nebraska sandhills region.

Fast-growing broadleaf trees such as the hybrid poplars are needed for wet-meadow sites in the Nebraska sandhills for livestock-protection windbreaks. Conifers are generally not adapted to these sites.

Poplars long have been cultivated in widely different regions of the world because they produce wood and shelter protection very rapidly. Growing poplars on the Great Plains was a natural for the early settlers because dormant cuttings of native cottonwoods from further east were easily transported. The watercourses within the Plains were also well endowed with cottonwoods, and furnished a nearby source of cuttings. Early essays on tree culture for the Plains extolled the virtues of poplar for quick protection and wood products (Harrison 1911).[2]

Interest in poplar hybrids has increased recently in the United States (Schreiner 1959). During the late 1930's the Northeastern Forest Experiment Station began clonal tests of poplar hybrids, and during the period distributed hybrid cuttings for extensive field testing.

A report for West Virginia (Eschner 1960) showed that the 10 best of 50 hybrid clones tested averaged 3 to 4 feet height growth per year; other clones were complete failures or grew at a very slow rate. All of the best clones for West Virginia contained **Populus maximowiczii** as one of the parents. Seven of the best 10 clones tested on strip-mine spoils in Pennsylvania (Davis 1964) were hybrids of **P. maximowiczii**.

On eastern Ohio spoil banks (Funk 1963), however, hybrids of the native **P. deltoides** × **P. nigra** cv.[3] Caudina were judged best along with **P. maximowiczii** and other **P. nigra** hybrids. Some of the hybrids, particularly those having **P. nigra** cv. Plantierensis and **P. trichocarpa**, as one parent, performed poorly in Ohio; they grew slowly, had abundant disease cankers, and were of poor form.

In North Dakota (George 1953), several Asiatic poplars including **P. maximowiczii** failed within the first 10 years. At Mandan, N. Dak. however, among the most successful was a clone called Northwest poplar, considered to be a

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[2] *Names and dates in parentheses refer to Literature Cited, p. 8.*

[3] *cv. = cultivar (Soc. Amer. Forest. 1958, p. 21).*

hybrid of native **P. deltoides** var. **occidentalis** (formerly **P.** sargentii) and **P. balsamifera** (formerly **P.** tacamahaca).

In the late 1940's in South Dakota (Nagel 1955), a staminate selection of the native cottonwood (**P. deltoides** complex) was developed, which has shown high resistance to Melampsora leaf rust. Known as Siouxland, this selection was tested and released for use by windbreak planters.

To further the efforts to find suitable poplar materials for the Plains, we obtained cuttings of 23 clones of poplar hybrids from the Northeastern Station in 1955 (table 1). All hybrids tested were derived from species, varieties, cultivars, or hybrids in two sections of the genus: Aigeiros, the black poplars, and Tacamahaca, the balsam poplars. The cuttings were grown into rooted trees at the U.S. Forest Service Bessey Nursery in the sandhills. Additional cuttings were made in early spring from the 1-season whips, and these were planted in the nursery to produce rooted trees for the following season. This procedure was repeated 2 years.

Average rooting and height growth from cuttings of the 23 clones during three consecutive

Table 1. --Parentage of the 23 poplar hybrids tested, by taxonomic section, location, and species (clones from Northeastern Forest Experiment Station, 1955)

Clone numbers	Aigeiros (black)		Hybrid	Tacamahaca (balsam)	
	EURASIA *nigra*	U.S. *deltoides*	*P. laurifolia* × *P. nigra italica* = × *berolinensis*	ASIA *maximowiczii*	U.S. *trichocarpa*
9	*nigra*				*trichocarpa*
296, 300	cv. Betulifolia				*trichocarpa*
53	cv. Caudina			*maximowiczii*	
51, 52	cv. Plantierensis			*maximowiczii*	
273	cv. Italica	var. *occidentalis* [1]			
237	cv. Volga	*deltoides*			
241	cv. Plantierensis	*deltoides*			
222, 228, 355	cv. Caudina	*deltoides*			
215, 216, 346		*deltoides*			*trichocarpa*
253		cv. Angulata			*trichocarpa*
37		var. *occidentalis*	× *berolinensis*		
245, 246		cv. Angulata			
46, 50			× *berolinensis*	*maximowiczii*	
41, 388				*maximowiczii*	*trichocarpa*

[1] Known also as *P. sargentii*

growing seasons, 1955-57, are shown in table 2. Three clones of hybrid **P. deltoides** × cv. Caudina (NE-222, NE-228, and NE-355) grew fastest, averaging 6 feet or more height growth in 1 season. All clones rooted well and produced good quality trees for field planting, with only small differences in height and stump size.

The 1-year dormant rooted stumps were lifted, and planted in the spring at two field locations in 1956, two in 1957, and one in 1958. One-year rooted trees of Siouxland and common cottonwood were included in some field plantings. Each field test consisted of 20 rooted stumps of each clone planted 6 feet apart in rows 12 feet apart.

Table 2.--Parentage, and average rooting and height growth of cuttings from 23 hybrid poplar clones at Bessey Nursery, Nebraska, during three consecutive growing seasons

Clone number	Parentage (pistillate × staminate)		Rooting[1]	First-season height[1]
			Percent	Feet
NE- 41	*P. maximowiczii*	× *trichocarpa*	96	5.5
NE- 388	*P. maximowiczii*	× *trichocarpa*	88	4.4
NE- 46	*P. maximowiczii*	× × *berolinensis*	94	4.4
NE- 50	*P. maximowiczii*	× × *berolinensis*	98	3.6
NE- 51	*P. maximowiczii*	× cv. Plantierensis	94	5.1
NE- 52	*P. maximowiczii*	× cv. Plantierensis	90	4.6
NE- 53	*P. maximowiczii*	× cv. Caudina	91	5.7
NE- 9	*P. nigra*	× *trichocarpa*	97	5.3
NE- 296	*P.* cv. Betulifolia	× *trichocarpa*	93	5.3
NE- 300	*P.* cv. Betulifolia	× *trichocarpa*	98	5.3
NE- 37	*P. sargentii*	× × *berolinensis*	97	4.9
NE- 273	*P. sargentii*	× cv. Italica	93	5.7
NE- 253	*P.* cv. Angulata	× *trichocarpa*	97	5.1
NE- 245	*P.* cv. Angulata	× *deltoides*	93	4.8
NE- 246	*P.* cv. Angulata	× *deltoides*	80	4.7
NE- 215	*P. deltoides*	× *trichocarpa*	97	5.4
NE- 216	*P. deltoides*	× *trichocarpa*	92	5.9
NE- 346	*P. deltoides*	× *trichocarpa*	81	5.2
NE- 237	*P. deltoides*	× cv. Volga	99	5.8
NE- 241	*P. deltoides*	× cv. Plantierensis	93	5.8
NE- 222	*P. deltoides*	× cv. Caudina	98	6.4
NE- 228	*P. deltoides*	× cv. Caudina	93	6.5
NE- 355	*P. deltoides*	× cv. Caudina	88	6.4
Siouxland South Dakota selection of *P. deltoides*			88	5.0

[1] Average of 3 years' data (1955, 1956, 1957); based on 20 or more cuttings of each clone each year.

The 20-tree row segments of each clone were not replicated, and none of the plantings were replanted in following years.

Practically all rooted stumps of all clones leafed out and began height growth soon after field planting. Large differences in performance began to show up before the end of the growing season, however, and by 1962 some clones had died. Two of the plantations, after growing well for several years, were removed in land use adjustments by the private landowners.

The relative 1962 ratings of hybrids in the three remaining plantations are shown in table 3. Survival, average total height, and maximum

Table 3.--Ratings in 1962, and survival and heights in 1966, of hybrid poplars in three Nebraska sandhills plantations

Clone number	1962 ratings			1966 survival and height						Maximum height (1957 plantation only)
	1956 plantations	1957 plantations	1958 plantations	1956 plantations		1957 plantations		1958 plantations		
				Pct.	Ft.	Pct.	Ft.	Pct.	Ft.	Ft.
NE- 41	Dead	Dead	Fair					0		
388	Dead	Dead	Fair					20	11	
46	Dead	Dead	Poor					0		
50	Dead	Dead	Poor					10	9	
51	Dead	Dead	Poor					0		
52	Dead	Dead	Poor					0		
53	Dead	Dead	Poor					0		
9	Poor	Poor	Poor	0		20	13	60	[1] (9)	16
296	Good	Fair	Fair	10	18	70	25	80	20	30
300	Poor	Fair	Fair	0		90	22	50	16	36
37	Fair	Good	Fair	0		80	22	70	(9)	33
273	--	Fair	Poor	--	--	80	22	10	11	26
253	Poor	Poor	Poor	0		10	24	0		24
245	Fair	Good	Fair	0		80	28	80	(12)	30
246	Fair	Fair	Poor	10	16	50	24	20	(4)	29
215	Fair	Fair	Fair	40	15	50	24	40	(4)	30
216	Poor	Fair	Fair	0		50	20	50	20	25
346	Poor	Fair	Fair	0		50	24	60	(8)	31
237	Fair	Fair	Poor	0		60	21	0		36
241	Fair	Fair	Good	0		40	19	80	(9)	24
222	Good	Best	Best	30	20	90	42	80	23	45
228	Good	Fair	Fair	0		60	40	30	20	45
355	Good	Good	--	20	17	70	34	--	--	38
Siouxland	Good	Fair	--	10	17	30	34	--	--	38
Common	Best	--	Good	60	25	--	--	40	21	39

[1] Parentheses indicate trees that previously were taller, but died back and sprouted from base.

height of individual trees in 1966 are also presented. Sites were cultivated to reduce weed and grass competition only during the first 2 years after planting. Lack of subsequent care doubtless was responsible for the relatively poor showing of some of the hybrids, and substantiates other research which showed that intensive cultivation is necessary for best hybrid poplar performance (Schreiner 1945). Despite the lack of maintenance, three of the hybrid clones showed promise.

NE-222, NE-228, NE-355, all hybrids of **P. deltoides** × cv. Caudina, made the best showing in all plantations. These hybrids not only survived well, but grew tallest (fig. 1). They were the same three clones that grew tallest on rooting in the nursery. The 1957 plantations of NE-222 and NE-228 averaged over 40 feet in height in 10 years (table 2, fig. 2). In addition, they had straighter boles, finer lateral branches, and narrower crowns than native cottonwood (figs. 3, 4). These clones rated moderate to heavy with leaf rust while in rooting beds. Incidence of rust on these clones in the field was not evaluated. They have appeared to be relatively free of stem and branch cankers to date.

The South Dakota Siouxland **P. deltoides** selection was about as good as NE-355 in height growth once established, but initial field survival was low. The common cottonwood obtained from commercial nurseries in Nebraska was best in the 1956 plantation. Since this plantation was cultivated only once, it appears that common cottonwood, in contrast to the hybrids tested, can survive and grow reasonably well with little care.

Three other hybrids performed moderately well, and should be further tested on other sites. NE-245, cv. Angulata × **P. deltoides** hybrid, despite heavy leaf rust infection in rooting beds, showed good growth in the 1957 plantation (fig. 5). NE-296, cv. Betulifolia × **P. trichocarpa**, and NE-215, **P. deltoides** × **P. trichocarpa**, had

Figure 1.--Hybrid poplar clone NE-222 showing an average height of 35 feet, 7 years after field planting.

Figure 2.--Hybrid NE-222 (center) and NE-228 (right) 10 years after field planting.

Figure 3.--Hybrid NE-222 shows retention of many fine lateral branches on the lower bole which makes it desirable as a windbreak tree.

Figure 4.--Common cottonwood loses its lower branches early and therefore becomes quite open beneath.

Figure 5.--Hybrid NE-245 (lower right) produced trees 26 to 30 feet tall in 10 years. Note the staminate catkins developing on the tree at left. Hybrid NE-296 (lower left) tends to produce an extremely bushy lower bole in addition to adequate height growth. These characteristics are needed in windbreak trees.

no leaf rust in rooting beds, and were moderately fast growing with good stem and crown form characteristics. These three clones also appeared relatively free of stem and branch cankers.

All clones other than those specifically mentioned either died during the first several years in the field, or were so badly afflicted by disease cankers that they can be considered nonadapted for use in the Plains. In contrast to performance in the eastern United States, where hybrids of **P. maximowiczii** have shown promise, it appears that hybrids containing **P. deltoides** and **P. nigra** cv. Caudina stand the best chance of performing satisfactorily in the Nebraska sandhills region.

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Windfall After Clearcutting on Fool Creek

—Fraser Experimental Forest, Colorado

Robert R. Alexander[1]

A 10-year study in spruce-fir and lodgepole pine forests identifies windfall risks so cutting units and boundaries can be located to reduce windfall losses after clearcutting.

Windfall is an important cause of mortality after initial cuttings in mature to overmature stands of Engelmann spruce (Picea engelmannii Parry), subalpine fir (Abies lasiocarpa (Hook.) Nutt.), and lodgepole pine (Pinus contorta Dougl.) in the central Rocky Mountains.

Experience has shown that partial cutting increases the risk of windfall losses in both spruce-fir and lodgepole pine forests, and that risk increases with the exposure of the remaining trees.[2 3 4] Generally, less damage has been associated with clearcutting because only the boundaries between cut and leave areas are exposed to the wind. Losses after clearcutting can be heavy, however, especially where trees along clearcut margins are exposed to above-average windfall risk.[5]

This paper reports the results of 10 years of observations on the relative effects of various factors on blowdown after clear-cutting part of the Fool Creek drainage of the Fraser Experimental Forest, Colorado.

STUDY AREA

The study area is a 714-acre drainage that lies to the east of the main ridge on the Fraser Experimental Forest (fig. 1). Elevations range from 9,600 to 11,500 feet. The main stream flows from south to north. Slopes generally face northwest, north, and northeast. Slope gradients vary from 10 to 60 percent, with an average of about 25 percent. Soils are Bobtail and Darling gravelly sandy loams developed in place from gneiss and schist, and Leal sandy loams developed from glacial till.[6] Average depth of weathered material in which trees can root is about 14 inches.

Weather is typical of the subalpine mountains in Colorado, with long, cold winters and short, cool summers. Annual precipitation averages about 30 inches, most of which falls as snow from October to May. Summer rains are frequent, but of low intensity. Winds of sufficient velocity and duration to blow down trees can occur at any time of the year, but are more likely during the months of October through March. Wind records taken in 1954 and 1955 at 10,500 feet elevation on the west ridge of Fool Creek indicate that both prevailing winds

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[2] *Alexander, Robert R. Mortality following partial cutting in virgin lodgepole pine. U.S. Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Sta. Paper 16, 9 pp., illus. 1954.*

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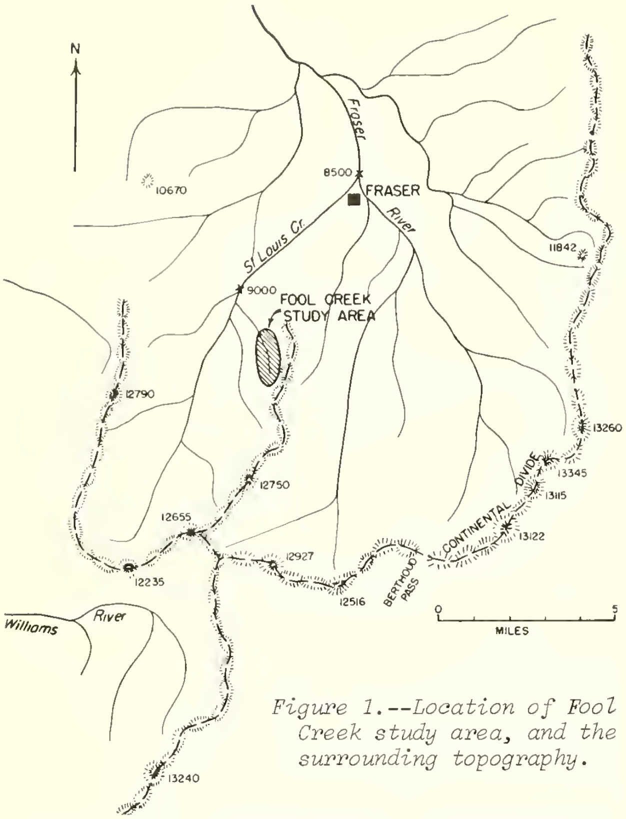


Figure 1.--Location of Fool Creek study area, and the surrounding topography.

and winds of highest velocity are from the west and southwest.

Fool Creek originally supported a mature to overmature stand of 250- to 300-year-old spruce, fir, and lodgepole pine. Merchantable forests covered 550 acres of the drainage, with 55 percent of the area in the lodgepole pine type, and 45 percent in the spruce-fir type. Lodgepole pine was predominant on the slopes at lower elevations and on exposed ridges and upper slopes at higher elevations, while spruce and fir dominated the stream courses and moist, protected slopes at higher elevations. On the 550 acres of merchantable timber, the sawtimber volume (in trees 9.6 inches d.b.h. and larger) averaged 12,000 board feet per acre. The 164 acres without merchantable timber, near timberline, supported an open, scrubby growth of spruce and fir that had been partially burned over nearly 100 years ago.

Before logging, approximately 4 miles of main haul road and 8 miles of spur logging roads were constructed. The main haul road is on the west side of the drainage; logging spur roads are about 600 feet (slope distance) apart, and are located on the contour (fig. 2). Nearly 35 acres were cleared of timber for road construction.

CUTTING PATTERN

The area of merchantable timber was divided into four approximately equal blocks. Timber was removed from 183 alternate clearcut strips located at right angles to the contour, without any consideration of the potential risk of windfall. Four different widths of clearing were used—1,2,3, and 6 chains. The four widths were repeated in each block. Average maximum length of the clearings was about 600 feet, the slope distance between logging spur roads (fig. 2).

All live trees 4 inches d.b.h. and larger were felled on the clearcut units. No trees were cut within 90 feet of the main stream. A total of 243 acres was clearcut in addition to the 35 acres cleared for road construction. Total volume removed (in sawlogs, poles, posts, and pulpwood) was 3.5 million board feet. Cutting was started in 1954, and was completed in 1956.

WINDFALL MEASUREMENTS

Information on number and pattern of windfalls was collected annually for the 10 years, 1956-65. Observations were made on 2,844 windfalls along 2,440 chains of total cutting-boundary perimeter. The following information was recorded for each windthrown tree:

1. Species.
2. Diameter at breast height (d.b.h.).
3. Direction of fall.
4. Year of blowdown.
5. Evidence of defect or injury to root system.

In addition, the following information was available for the perimeter of each clearcut unit:

1. Length.
2. Aspect.
3. Location and orientation with respect to prevailing wind direction.
4. Position on the slope.
5. Slope gradient.
6. Soil depth.
7. Soil drainage.
8. Any special topographic situations.

Definitions

In this paper, the windward cutting boundary is defined as the protected edge over which stormwinds from the west and southwest enter the clearing, and the leeward cutting boundary is the exposed edge over which stormwinds leave the clearing. Upwind slopes face the west and southwest stormwinds; downwind slopes face away from those stormwinds. To compare windfall with the factors that influence it, **numbers of windthrown trees are expressed as average annual loss per chain of cutting boundary.**

RESULTS

The average annual windfall loss along the 2,440 chains of cutting boundary on Fool Creek was 0.12 tree per chain, or 1 tree for each 8.33 chains of perimeter. Windfall losses were related to (1) exposure to the wind, (2) cutting unit characteristics, and (3) tree characteristics.

Exposure To The Wind

Direction of Fall

Approximately 70 percent of the windthrown trees were felled by stormwinds from the west, southwest, and south. Average direction of fall was N45°E (fig. 3). The only exception to this general pattern of windfall came in 1957, when stormwinds from the southeast caused most of the blowdown. Losses in 1957 were particularly heavy in 2- and 3-chain-wide units located on dry, upper, north- and northeast-facing slopes on the west side of the drainage (fig. 4). Winds moving upslope across those units blew down more than 400 trees.

Leeward and Windward Cutting Boundaries

About two-thirds of the windthrown trees blew down along leeward cutting boundaries (N, NE, E, SE). Those boundaries were subjected to the greatest force of stormwinds from the west and southwest. The average annual loss was 0.15 tree per chain of perimeter. Trees along the windward cutting boundaries (NW, W, SW, S), where the average annual loss was 0.09 tree for each chain of perimeter, were normally protected from the full force of stormwind from the west and southwest by adjacent uncut timber to the windward. The stormwinds that blew from the southeast in 1957, however, exposed the cutting-boundary perimeters that were normally the windward boundaries to the full force of the wind. Much of the loss along windward cutting boundaries came in 1957 when the change in direction of stormwinds turned normally windward boundaries into leeward boundaries (fig. 4).

Figure 2.--Aerial view of the Fool Creek pattern of cutting strips and road network.

Aspect

More trees were windthrown on downwind aspects than on upwind aspects. As shown in the following tabulation, the heaviest losses were on northeast- and east-facing slopes. Windfall was below average on north-facing slopes and all upwind aspects (SW, W, and NW). There are no south- or southeast-facing slopes on Fool Creek.

Aspect	Perimeter (Chains)	Windthrown trees per chain of perimeter (No.)
Downwind slopes:		
North	514	0.06
Northeast	572	.17
East	126	.27
All	1,212	.13
Upwind slopes:		
Southwest	32	.05
West	160	.09
Northwest	1,036	.10
All	1,228	.10

Topographic Position on the Slope

The topographic position of cutting-unit boundaries had the most pronounced influence on blowdown of all the factors observed. Cutting boundaries on ridgetops suffered extremely heavy windfall. The average annual loss was nearly one tree for each chain of perimeter (fig. 5). Fewer trees blew down on other topographic positions, and they were about evenly distributed between upper, middle, and lower slopes. No cutting boundaries were located along stream bottoms.

Cutting Unit Characteristics

Size of Opening

Windfall was not directly related to size of opening. The 6-chain- and 2-chain-wide units suffered the most damage. Losses were about average on 3-chain-wide units. Fewest trees

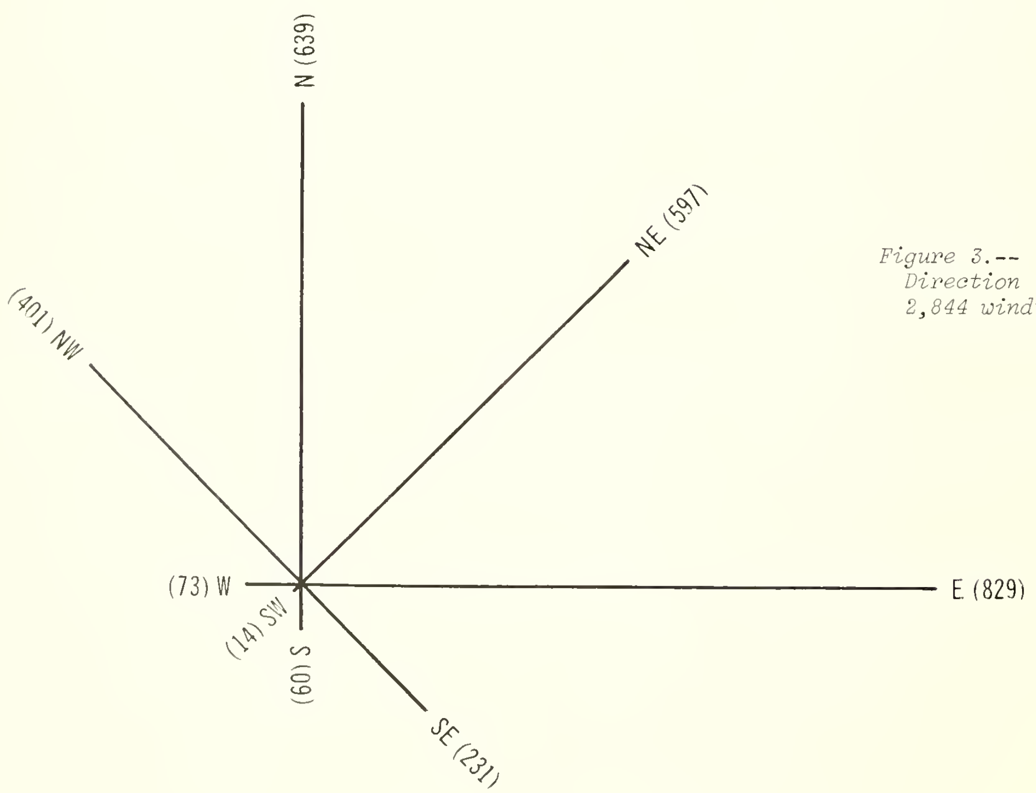


Figure 3.--Direction of fall of 2,844 windthrown trees.

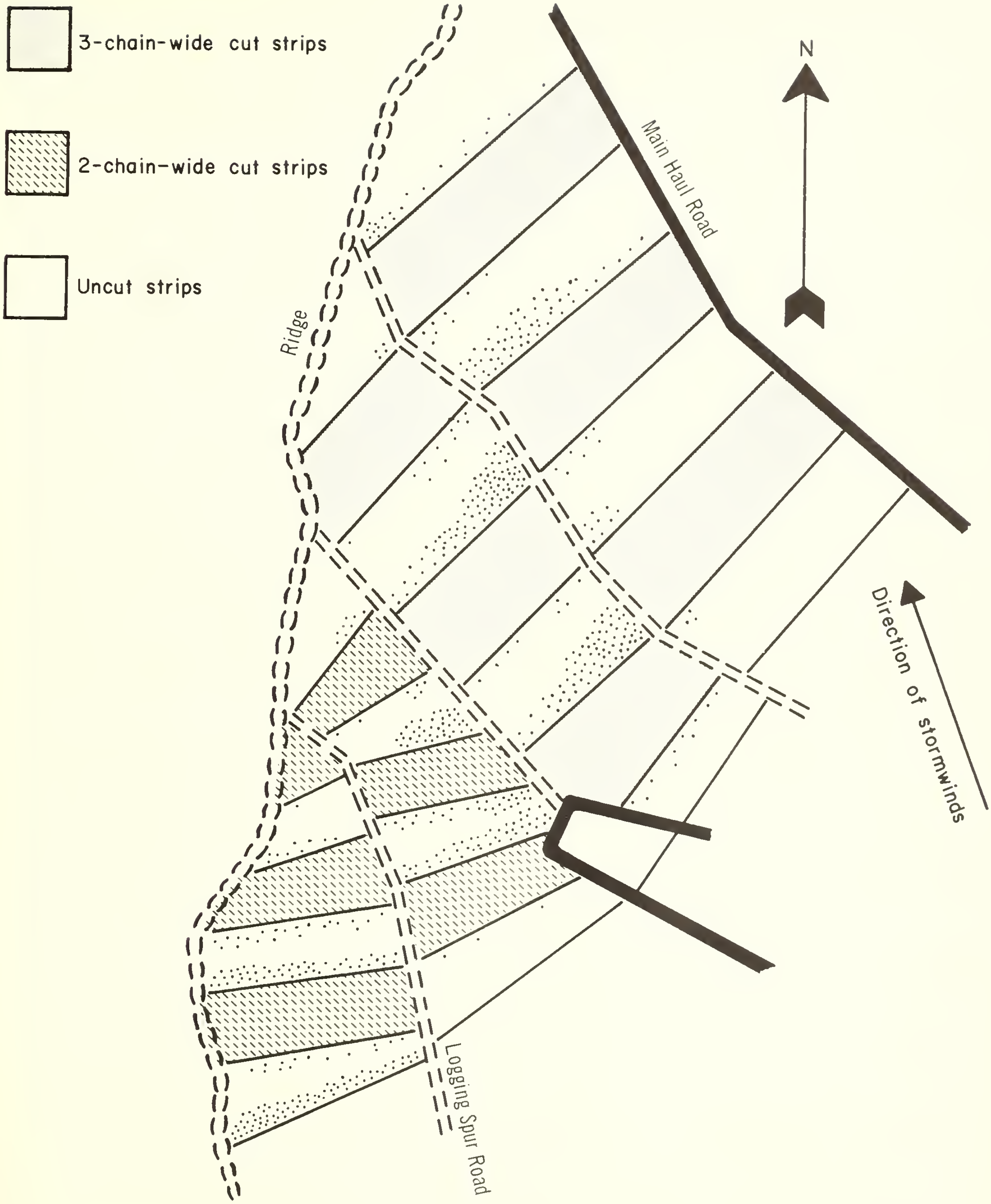


Figure 4.--Stormwinds blowing from the southeast in 195, caused heavy damage to the windward cutting boundaries of 2- and 3-chain-wide units located on upper slopes on the west side of Fool Creek. Location of windthrown trees is shown by dots.

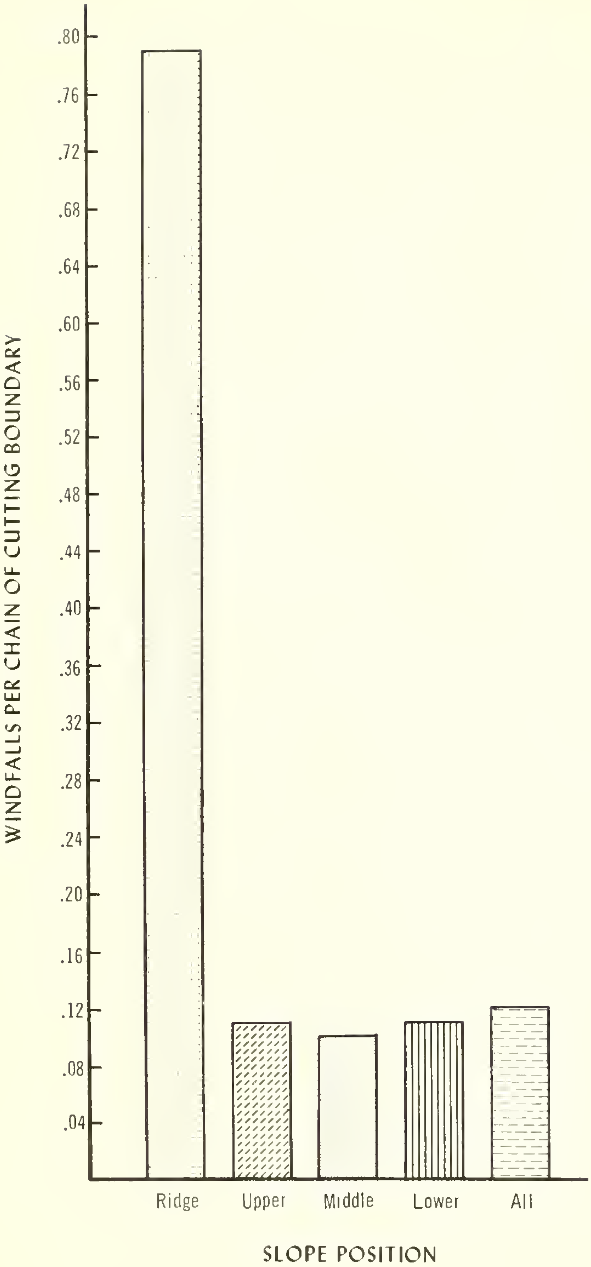


Figure 5.--Windfall in relation to topographic position on the slope.

blew down on 1-chain-wide units (fig. 6). The higher windfall losses on 6-chain-wide units were due in part to the location of the cutting boundaries of some units on ridgetops. Much of the blowdown on 2-chain-wide units was on the upper slopes on the west side of the drainage,

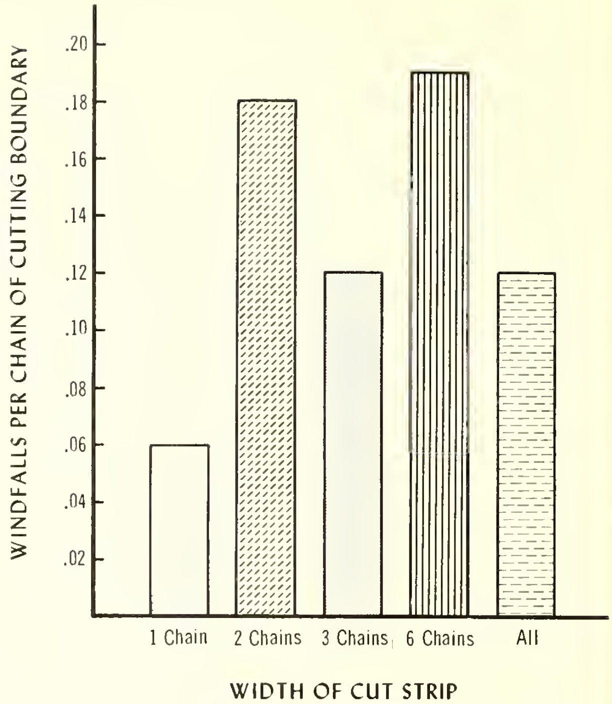


Figure 6.--Windfall in relation to size of opening.

where units were heavily damaged in 1957 by stormwinds from the southeast.

Direction of Cutting-Unit Boundaries

The direction of cutting-unit boundaries influenced blowdown. Cutting boundaries oriented in an E-W and NE-SW direction suffered more damage than boundaries oriented in a N-S or NW-SE direction (fig. 7). With stormwinds from the west and southwest, the E-W and NE-SW boundaries were parallel or near parallel to the direction of windstorms, while the N-S and NW-SE boundaries were more nearly perpendicular.

Time Since Cutting

Windfall diminished as time since cutting increased. About two-thirds of the trees that blew down were windthrown the first 2 years after logging (fig. 8).

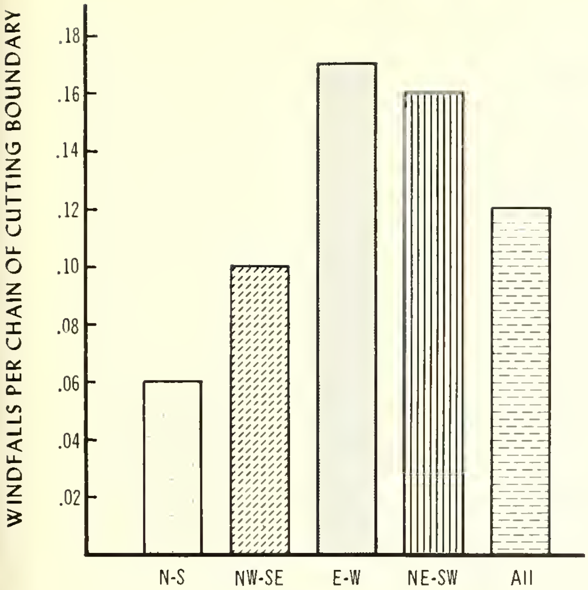


Figure 7.--Windfall in relation to direction of cutting boundaries.

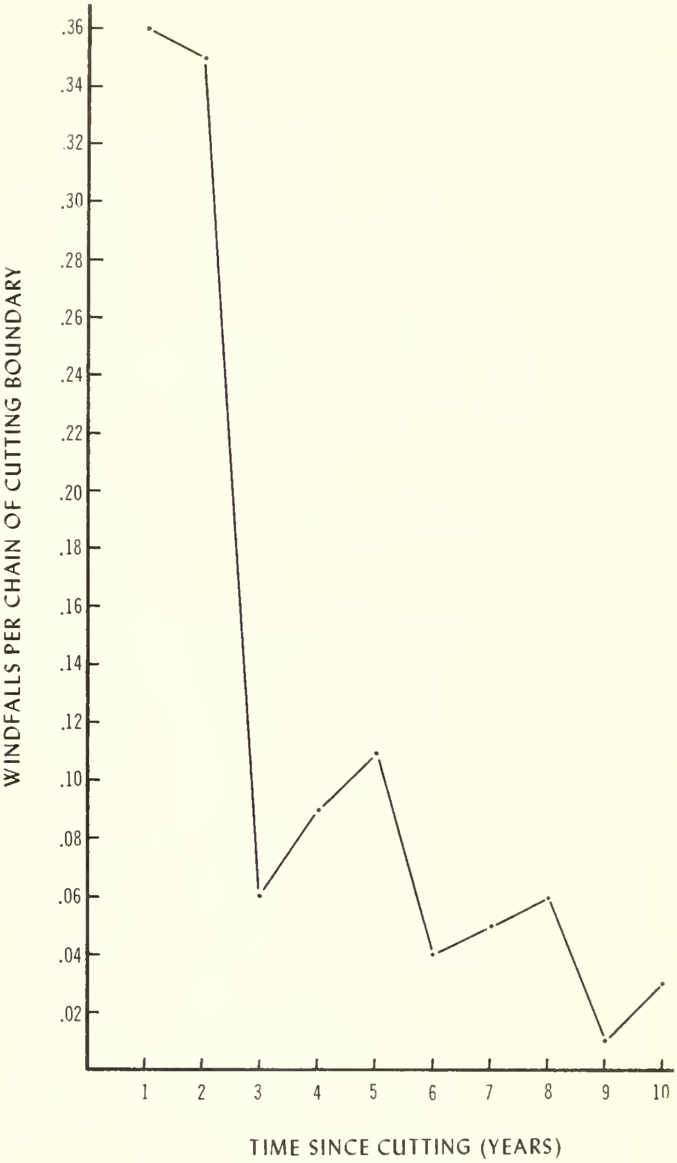


Figure 8.--Windfall in relation to time since cutting.

Soil Depth and Drainage

Trees growing on soils where the average depth of the solum was 13 to 24 inches were more windfirm than trees growing on shallower soils.

Trees growing in situations that dry rapidly were more windfirm than trees growing in places where drainage was slow. Fewer trees were uprooted where drainage was slow than where rapid. However, many of the trees that blew down in rapidly drained situations were on ridgetops and other exposed places. Furthermore, no cutting was permitted along the main stream and natural overflow areas, so many slowly drained areas where windfall risks are high were avoided.

Tree Characteristics

Species and Tree Size

Nearly two-thirds of the windthrown trees were lodgepole pine. The remaining windfalls were about evenly distributed between spruce and fir. Lodgepole pine is not more predisposed to windthrow than either spruce or fir; on Fool Creek, it grows on the drier slopes and ridgetops that are more exposed to the wind, while spruce and fir occupy the more protected locations.

About half of the spruce and lodgepole pine, and more than three-fourths of the fir that blew down along cutting boundaries were smaller than 9.6 inches d.b.h. However, all sizes of lodgepole pine, spruce, and fir appeared about equally susceptible to blowdown. Trees in the different size classes were windthrown in about the same proportion that they occurred in the uncut stands.

Defect-Injury

Defect was associated with the loss of about one-third of all the windthrown lodgepole pine and fir, but with less than 20 percent of the windthrown spruce. Root and butt rots that weakened roots to the point where they were broken off at or below the ground surface were the most important factors predisposing all species to windthrow.

Logging injury was associated with only a negligible amount of windfall, usually when supporting roots were cut during road-building operations.

DISCUSSION AND CONCLUSIONS

Windthrow along the boundaries of clearcut units cannot be eliminated entirely, but it can be reduced if we avoid locating cutting boundaries where windfall hazards are high. The results of this and other studies suggest several ways that wind damage can be reduced.

Stormwinds that cause blowdown in the Rocky Mountains normally come from the west and southwest.[5] Occasionally, however, windstorms of destructive force blow from other directions, such as the 1957 storms from the southeast. The frequency of those storms is not known. They occurred once in 10 years on Fool Creek, and there is no evidence of any such storms before cutting.[7] It does not seem practical to attempt to anticipate storms from unusual directions. Cutting units should therefore be laid out for maximum protection from westerly and southwesterly winds.

The leeward cutting boundaries suffered the most damage because they were directly exposed to the force of windstorms. With normal stormwinds, those are the **north, northeast, east,** and **southeast** boundaries of cutting units. Reduction of windthrow should be a major consideration in locating leeward boundaries. Windward cutting boundaries generally suffered less damage. A normal amount of care in locating those boundaries should be sufficient to keep windfall to a minimum.

The heavier losses on downwind slopes on Fool Creek appear to be in disagreement with earlier studies of windfall in the central Rocky Mountains, where heavier damage was recorded on upwind slopes.[5] However, about one-third of the losses on downwind slopes on Fool Creek occurred in 1957 when the change in direction of stormwinds turned what were normally downwind aspects into upwind aspects.

The relationship of windthrow to topographic position on the slope suggests that under no circumstances should cutting boundaries be located on ridgetops, especially on the tops of secondary ridges that are to the lee of a main ridge, and therefore exposed to accelerated winds.

Windfall damage on ridgetops was illustrated on Fool Creek in two 6-chain-wide units on a moderate northwest-facing slope. The leeward cutting boundaries of those units were located on the east ridge of the drainage at approximately right angles to westerly and southwesterly winds. Stormwinds moving upslope across the clearings hit those boundaries with full force. Nearly all of the trees along the original perimeter on the ridge and for a distance 1 to 2 chains down the lee slope were blown down (fig. 9).

A change in slope gradient influenced blowdown in at least one instance. On the east side of Fool Creek, there is a series of 1-chain-wide units on a gentle northwest-facing slope about midway between the main stream and the east ridge. Those units lie to the northeast of a series of 2-chain-wide units on the same general contour level, and above a series of 6-chain-wide units that are below a spur logging road. As slope gradient changed from moderate to gentle, the size of clearcut opening was decreased from 2 chains wide to 1 chain wide. That left the lower one-third of two of the 1-chain-wide units on an exposed point, unprotected by standing timber to the windward (fig. 10). Stormwinds blowing from the southwest struck those exposed boundaries with full force. All of the trees on those two units were blown down for a distance of 3 to 4 chains upslope from the logging spur road. This particular situation could have been avoided by cutting all the trees on the point. Flexibility in locating cutting boundaries is limited, however, when clearings are as small as 1 chain wide.

Although windfall per chain of cutting boundary was heaviest on the 6-chain-wide units, the wider strips had fewer chains of perimeter exposed per unit of area cut. For example, it would require six times as much cutting boundary

[7] *Alexander, Robert R. and Buell, Jesse H. Determining the direction of destructive winds in a Rocky Mountain timber stand. J. Forest. 53: 19-23, illus. 1955.*

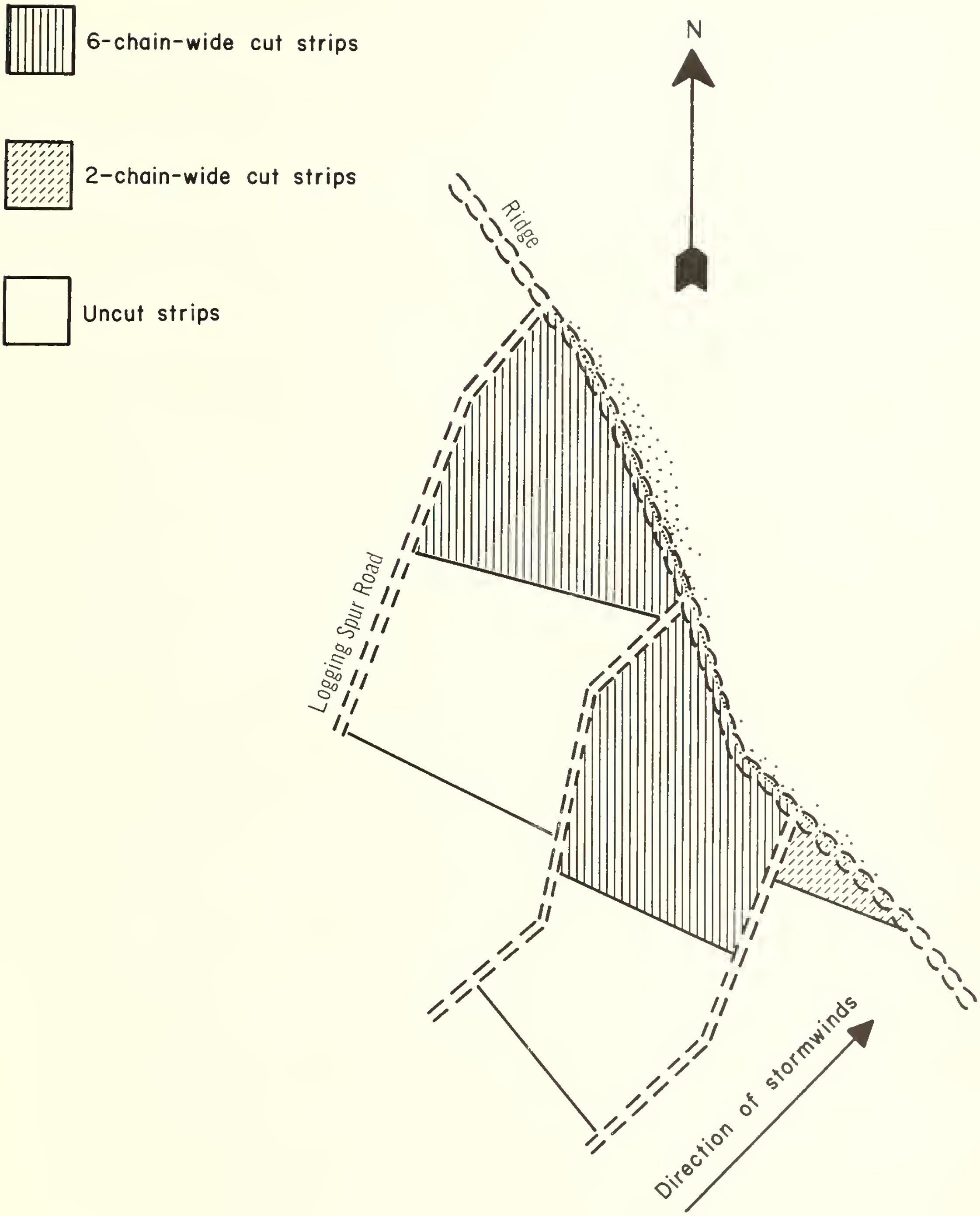


Figure 9.--Stormwinds blowing from the southwest caused heavy damage to leeward boundaries of two 6-chain-wide units that were located on a ridgetop on the east side of Fool Creek. Location of windthrown trees is shown by dots.

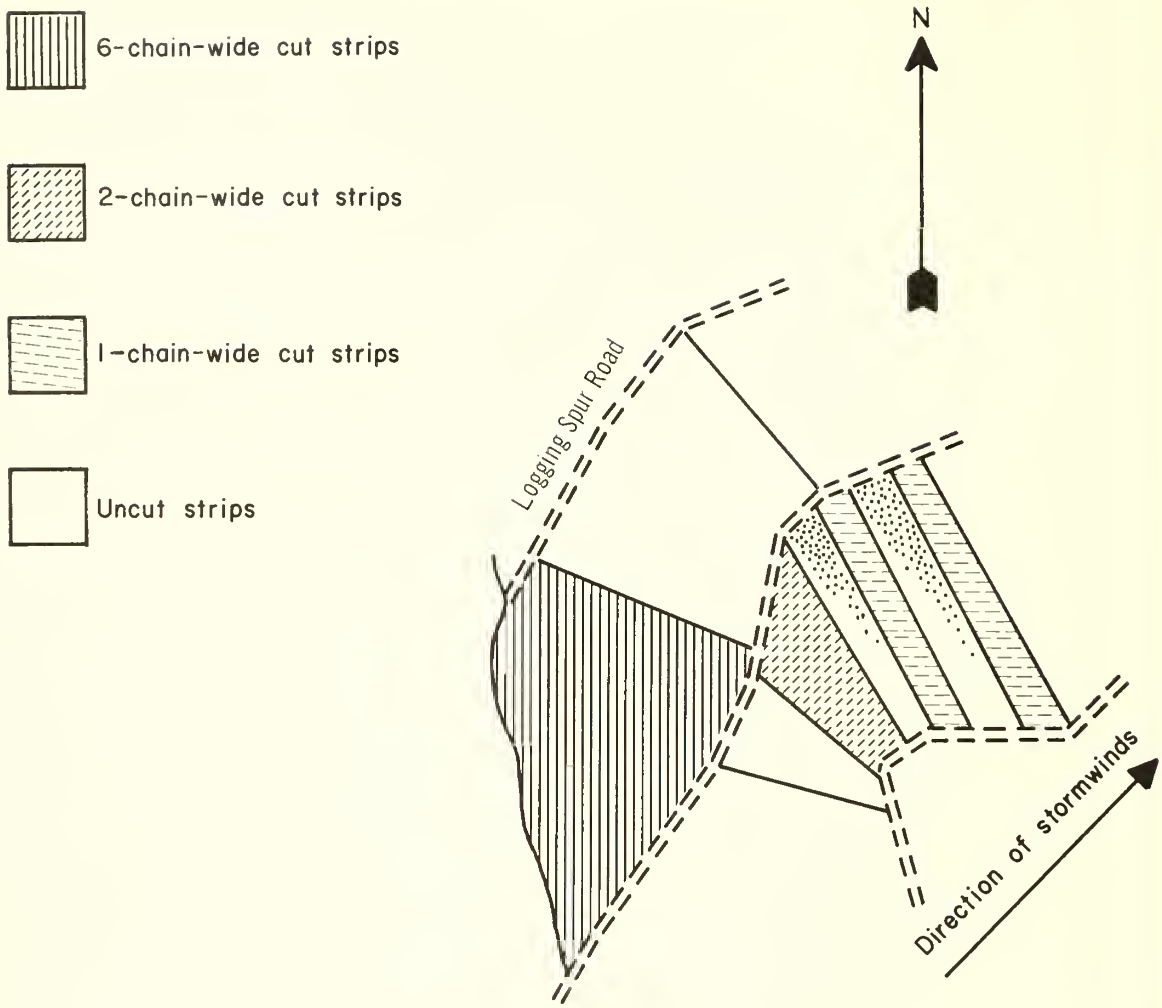


Figure 10.--Stormwinds blowing from the southwest caused heavy damage to the lower one-third of two 1-chain-wide units on a northwest-facing slope that were left on an exposed point by a change in slope gradient. Location of windthrown trees is shown by dots.

using 1-chain-wide units to cut the area of one 6-chain-wide unit. Windfall losses per unit of area cut were less, therefore, on the 6-chain-wide units than on the other widths of clearing tested.

Studies and observations of wind damage in the central Rocky Mountains have indicated that most of the vulnerable trees are blown down by the first severe windstorms after harvesting. Windthrow on Fool Creek was heaviest the first 2 years after cutting. Since that time cutting boundaries have tended to stabilize.

Additional Recommendations

Guidelines to minimize windfall when locating cutting unit boundaries have been previously developed from a study of blowdown in clearcut spruce-fir stands. Since those recommendations are largely in agreement with the results of this study, and they cover situations and conditions likely to occur in the central Rocky Mountains but not present on Fool Creek, they are summarized below:

1. Do not locate cutting-unit boundary lines where they will be exposed to stormwinds funneling through saddles in ridges to the west or south of the sale area, especially if the ridges are at higher elevations.

2. Avoid locating cutting boundaries on ridgetops and other topographically exposed situations, on shallow or poorly drained soils, or in stands with a high proportion of defective trees.

3. Make cutting units as large as regeneration requirements, topography, soil, and stand conditions permit. In addition to less perimeter for unit of area cut, larger units permit more flexibility in locating boundary lines.

4. Be particularly careful to locate the highly vulnerable leeward boundaries on topography, soil, or in stands of sound trees where windfall hazards are low.

5. Try to avoid laying out cutting units with dangerous wind-catching indentations or long straight lines and square corners in the leeward cutting boundary or in boundaries parallel to the direction of stormwinds.

U.S. FOREST SERVICE
RESEARCH NOTE RM - 93

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

Snow Accumulation and Disappearance by Aspect and Vegetation Type in the Santa Fe Basin, New Mexico

Howard L. Gary and George B. Coltharp[1]

Plots on north and south aspects under Douglas-fir, aspen, spruce-fir, and grass cover had maximum snow water equivalents ranging from 7.6 inches on the south-aspect Douglas-fir to 14.5 inches on the south-aspect grass plot. Greatest snow accumulations were observed in the high-elevation spruce-fir and grass types. In this elevation zone there was little difference in accumulation and melt between north and south aspects. Snow melting continued 4 to 5 weeks longer under spruce-fir than under other cover types.

Data collected in other parts of the country have shown that different forest cover types have important effects on snow accumulation and water yield, but information is meager for the snow zones of northern New Mexico. This paper reports a survey of the influence of prevailing forest types on snow accumulation and disappearance on a high-altitude watershed in the Sangre de Cristo Mountains during the winter and spring of 1959-60.

Description

The area selected for observation was 16 miles northeast of Santa Fe, New Mexico, on the west side of the Sangre de Cristo mountain range. Eight study plots were located within 2.7 miles of each other (fig. 1), on slopes with gradients between 25 and 45 percent.

Two 1/10-acre plots (table 1) were established in each of four vegetation types—Douglas-fir, aspen, spruce-fir, and grass—with one north-aspect and one south-aspect plot in each type. Most plots did not face exactly north or south, but for brevity, aspects are called north and south. Plots within a type were not replicated.

The Douglas-fir and aspen plots were at 9,900 feet elevation ("Low") on the Big Tesuque Creek drainage; spruce-fir and grass plots were at 11,150 feet ("High") on the Rio en Medio drainage.

Data were collected from November 1959 through June 1960. Snow measurements within each cover type were taken at about the same elevations; streamflow data were not available.

Douglas-fir Type

Both the north-slope (ND) and south-slope (SD) plots were surrounded by many acres with similar vegetation,

[1] *Associate Range Scientist and Research Forester, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins, in cooperation with Colorado State University. Research reported here was conducted at Albuquerque in cooperation with the University of New Mexico. Coltharp now is Assistant Professor, Department of Range Science, Utah State University, Logan.*

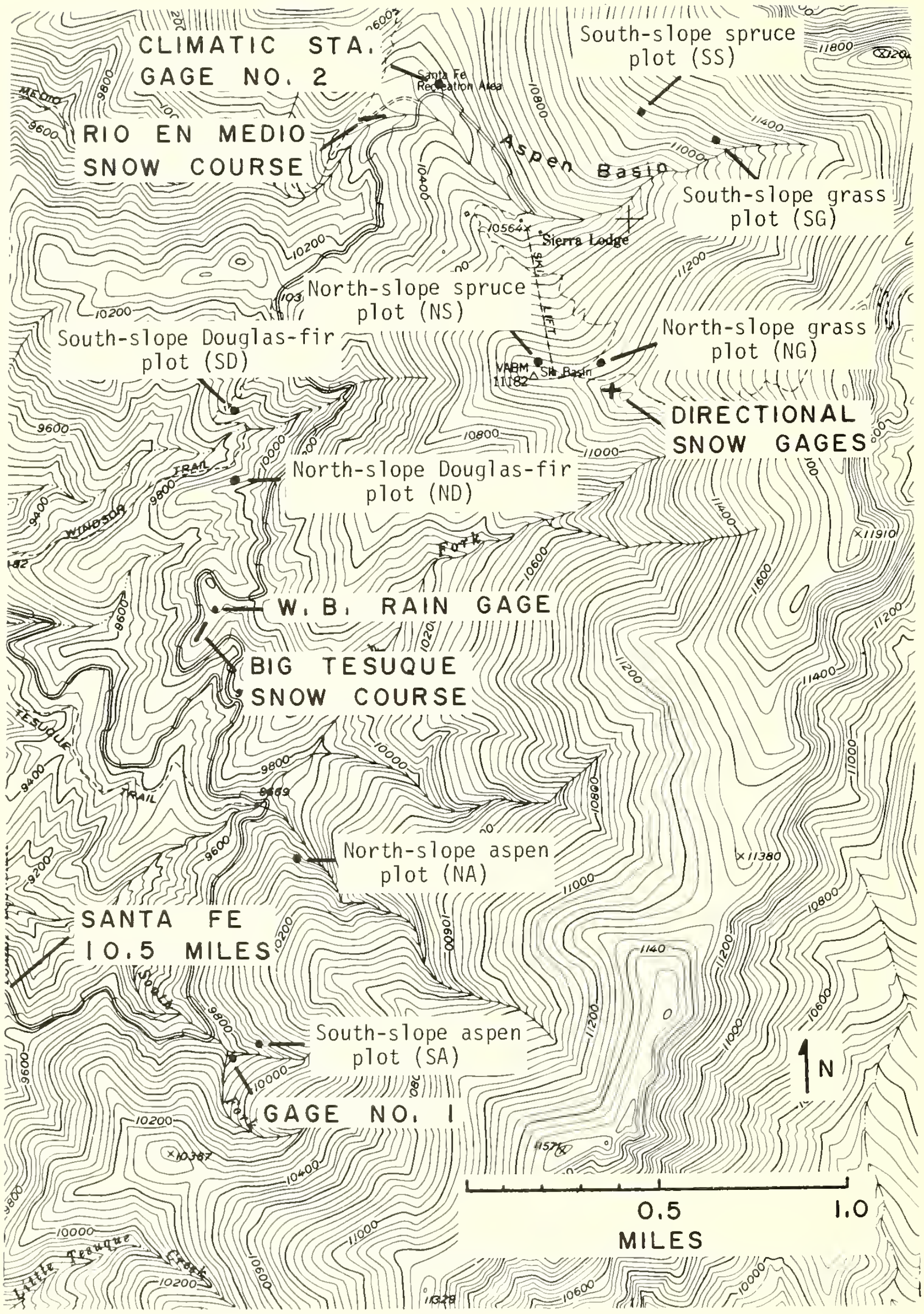


Figure 1.--Topographic map of the study area.

Table 1.--Stand conditions on north and south aspects in Douglas-fir, aspen, and spruce-fir types (per acre basis)[1]

Elevation, vegetation type, aspect, and species	Trees by d.b.h. classes (inches)							Total trees	Basal area	Volume[2]
	1-2	2-4	4-8	8-12	12-16	16-20	20-24			
	Number								Sq. ft.	Bd. ft.
LOW (9,900 feet):										
DOUGLAS-FIR TYPE--(*Pseudotsuga menziesii* (Mirb.) Franco)										
North slope (ND)										
Douglas-fir	260	90	10	0	30	70	10	470	188.5	
Spruce	30	50	20	0	0	0	0	100	7.0	
White fir	10	30	20	0	0	0	0	60	6.2	
Total								630	201.7	13,968
South slope (SD)										
Douglas-fir	50	0	20	20	30	50	10	180	167.3	
White fir	10	10	10	0	0	0	0	30	2.6	
Aspen	10	10	0	0	0	0	0	20	.6	
Total								230	170.5	14,535
ASPEN TYPE--(*Populus tremuloides* Michx.)										
North slope (NA)										
Aspen	650	550	290	20	0	0	0	1,510	107.1	[3] 12.93
South slope (SA)										
Aspen	860	180	470	50	0	0	0	1,560	131.3	[3] 19.98
HIGH (11,150 feet):										
SPRUCE-FIR TYPE--(*Picea engelmannii* Parry-*Abies lasiocarpa* var. *arizonica* (Merriam) Lemm.)										
North slope (NS)										
Spruce	110	170	230	50	10	10	10	590	161.8	
Corkbark fir	470	330	200	20	10	0	0	1,030	91.5	
Total								1,620	253.3	10,170
South slope (SS)										
Spruce	50	70	140	170	30	30	0	490	223.2	
Corkbark fir	20	10	60	40	0	0	0	130	33.3	
Total								620	256.5	12,825

[1] All timber data based on measurements obtained from three to five 1/10-acre plots adjacent to each study plot
[2] Scribner Decimal C (10 percent cull)
[3] Gross cords

slope direction, and gradient (fig. 2). Neither plot had understory shrubs. The ND plot, with almost three times as many trees per acre as SD, differed mainly in the number of trees in the 1-to 4-inch diameter classes (table 1). Basal area was 15 percent greater on ND; SD was more open, had less understory, and higher tree canopies. On ND, dominant trees were 70-80 feet high; on SD, 60-70 feet. Litter was about 2 inches deep on ND, but was thin to absent on SD. ND was on a 45-percent slope facing N. 6°W., at 9,940 feet elevation; SD was on a 38-percent slope facing due south, at 9,930 feet.

Aspen Type

The extensive, nearly pure aspen type in the general study area is the result of fires during the late 1880's. No other tree or shrub species were present on the two aspen plots (fig. 2), although Douglas-fir and white fir probably were climax in the lower elevation of the type, and Engelmann spruce and corkbark fir at higher elevations. Both plots were at 9,800 feet elevation, and were surrounded by many acres of aspen intermixed with a few widely scattered, 30-foot-tall Douglas-fir and spruce trees. Downed aspen logs were on each plot; herbaceous ground cover on each was mainly grasses (*Poa*, *Festuca*, and *Bromus* spp.) and vetches (*Vicia* spp.). Blowing snow events occurred in the vicinity of the plots, since aspen stands present little barrier effect on wind movement during winter.

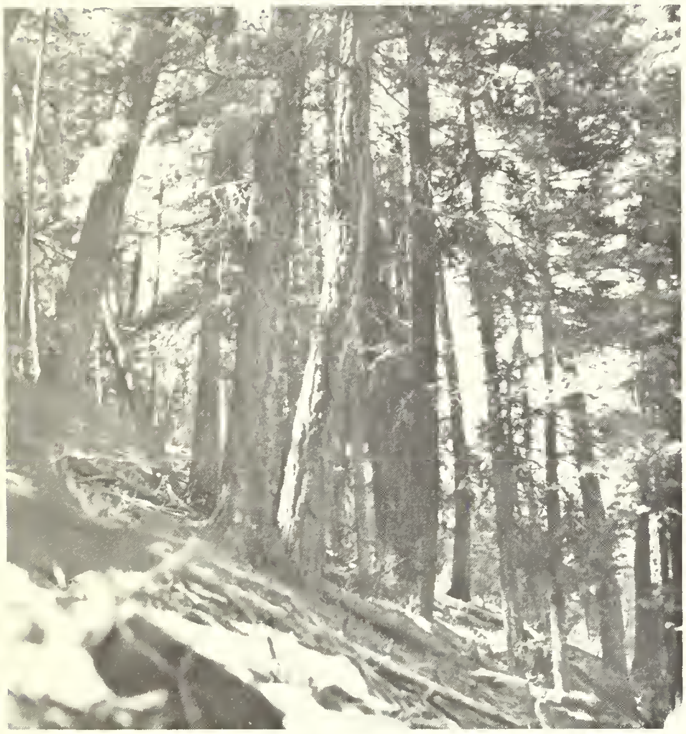
The south-aspect aspen plot (SA) had larger trees and 18 percent more basal area than the north (NA). Five percent of all trees in SA were in the 1- to 2-inch diameter

Figure 2.--Two aspects of four cover types at two elevations, from near the center of each study plot.

LOW ELEVATION (9,900 feet)

DOUGLAS-FIR | ASPEN

North slope



South slope

Figure 2.--Two aspects of four cover types at two elevations, from near the center of each study plot.

HIGH ELEVATION (11,150 feet)

SPRUCE-FIR | GRASS

North slope

South slope

class; on NA, 43 percent (table 1). Dominant trees on NA were 40 to 45 feet tall; on SA, 45 to 50 feet. Slope of NA was 40 percent, facing N. 22° E.; SA was 41 percent, facing S. 20° W. The NA plot was 175 feet below a ridge top, in a well-protected cove. During midwinter, little direct sunlight reached NA because of orientation and shading from a ridge to the south.

Spruce-fir Type

Both study plots (fig. 2) were at 11,145 feet elevation, on 30-percent slopes, and had similar basal areas (table 1). Neither plot supported shrubs. Litter depth was less than 1 inch on the south-aspect plot (SS), and about 2 inches on the north aspect (NS). NS averaged 1,620 trees per acre, 67 percent of which were in the 1- to 4-inch diameter class. SS had 620 trees per acre, with 24 percent in the 1- to 4-inch class. Dominant trees were 70 to 80 feet high on NS; 80 to 90 feet on SS. Larger trees, higher canopies, and less understory were associated with SS. Orientation of NS was due north; SS was S. 19° W.

NS was 100 feet west of a 60-foot right-of-way for a ski lift. Spruce-fir forest was continuous to the north and west, and extended 250 feet south of the plot to a bare ridgetop. SS was 250 feet west of an open area, and was surrounded by a spruce-fir forest.

Grass Type

Plots were adjacent to the spruce-fir plots, at 11,150 feet elevation, on an area that was burned over in the 1880's. Scattered spruce 20 to 30 feet tall occurred nearby, but none were on the plots (fig. 2). Climax species were Engelmann spruce and corkbark fir. Shrubs near the study plots were dwarf juniper (Juniperus communis L.) and Vaccinium spp. Herbaceous ground cover was mainly grasses (Poa, Festuca, and Bromus spp.). Blowing snow events were common in the vicinity of both plots.

The north-slope (NG) plot was on a 25-percent slope facing N. 10° W., about 300 feet north of a ridgetop, and 500 feet south of a continuous spruce-fir forest. The south-slope (SG) plot was on a 35-percent slope facing S. 14° W., 700 feet east of a continuous spruce-fir forest.

Climate

Precipitation catch in a U.S. Weather Bureau storage gage near the center of the study area was 17.22 inches, October 1959 through June 1960. The gage, located at 9,970 feet elevation in an aspen glade (see fig. 1), averaged 14.08 inches for the October-through-June periods, 1949-64. Precipitation received from November through April usually is snow. No other long-term precipitation records are available for the immediate study area.

During the 1959-60 observation period, precipitation was measured in two additional locations (see fig. 1). Gage 1 was near the SA plot, at 9,760 feet elevation. Gage 2 was nearest the SS plot, in a two-tree-height opening of the southwest-facing spruce-fir type, at 10,380 feet elevation. At gage 2, temperature was recorded also (table 2). Precipitation received during the snow-accumulation period (November-April) was 13.6 inches at gage 1; 16.1 inches at gage 2. Maximum temperatures during the midwinter period were generally below freezing.

Four directional snow gages about 3 feet aboveground on a ridgetop near NG (fig. 3) gave information on the direction of incoming and blowing snow. Percent snow catch in each directional gage was highly variable for different time periods (table 3). Storms generally move

Table 2.--Monthly precipitation catch in standard gages 1 and 2, and temperatures recorded at gage 2 during the study period, November 1959-June 1960

Month	Precipitation		Mean temperature, gage 2		
	Gage 1	Gage 2	Maximum	Minimum	Average
	Inches		- - - - °F. - - - -		
November	--	0.40	38.6	19.2	28.9
December	4.15	4.50	29.4	10.7	20.0
January	1.71	1.59	23.3	2.5	12.9
February	2.65	2.70	19.0	-.3	9.4
March	3.30	5.75	33.1	10.0	21.5
April	1.80	1.15	41.2	19.4	30.3
May	.50	1.40	48.2	26.8	37.5
June	2.90	2.45	62.5	37.4	49.9
Total	17.01	19.94			

Figure 3.--Directional snow gages on an open ridgetop. Diameter of gage orifice is 4 inches.

in from the northwest; prevailing wind direction is southwest. Movement of snow by wind action was common in exposed areas.

Data for comparing the observation period with other years of record (table 4) were provided from two U.S. Soil Conservation Service snow courses in the study area. The Big Tesuque snow course is adjacent to the U.S. Weather Bureau storage gage; the Rio en Medio course is in a meadow near gage 2 (see fig. 1). Although precipitation during the present study was higher than average, the snow-accumulation relationships between forest types and aspects would probably be about the same from year to year.

Methods

Snow depth and water-equivalent measurements were started in late November following the season's first permanent snow cover, and continued at 1-week intervals until the snowpack was gone. A circular, 100-foot snow course was established around the center of each study plot. Snow samples were taken at 10-foot intervals along each course with a Mount Rose snow tube. The average value of 10 samples was used to provide a measure of snow depth and water equivalent over each plot. Successive samples were taken in approximately the same location; snow disturbance was mainly confined to the periphery.

Table 3.--Snow catch in directional gages facing north, south, east, and west (February-April 1960)

Time interval	Total catch, all gages	Orientation of gage orifice			
		North	South	East	West
	Inches of water	Percent of total catch			
Feb. 12-19	2.05	63.4	14.6	12.2	9.8
Feb. 19-25	3.90	29.5	29.5	28.2	12.8
Feb. 25-Mar. 4	3.25	30.7	47.7	6.2	15.4
Mar. 4-17	3.35	46.3	4.5	3.0	46.2
Mar. 17-Apr. 1	1.80	77.8	0	8.3	13.9
Average		45	22	12	21

Table 4.--1960 average snowpack water equivalent compared with longtime records from two U. S. Soil Conservation Service snow courses

Snow course	Elevation	Years of record	1960			Longtime records		
			Feb. 1	Mar. 1	Apr. 1	Feb. 1	Mar. 1	Apr. 1
	Feet		- - - - Inches of water equivalent - - - -					
Big Tesuque (Small aspen, scattered spruce and fir)	10,000	1942-65	7.1	7.0	6.9	4.2	5.1	5.0
Rio en Medio (Open, widely scattered spruce)	10,400	1950-65	9.4	11.4	9.9	5.9	7.6	7.1

Results

Snow Accumulation

Of the four types studied, snow accumulated most rapidly and deeply under the spruce-fir type, but maximum snow water equivalent was highest on the grass plots (fig. 4, table 5). Rates and amounts of snow accumulation were nearly identical on north and south aspects of spruce-fir type, but varied greatly between aspects on the Douglas-fir and aspen types.

From February 19-25, total snow catch by the four directional gages (see table 3) was 3.9 inches; at gages 1 and 2, about 0.5 inch. The highest daytime temperature for the same period was 21°F., recorded at gage 2. But during that week, NA and SA plots lost 1.5 inches of snow water, apparently by wind scour, while losses or gains under the other three vegetation types were nil.

Maximum accumulation of snow water equivalent, although about the same on SA and SD, was considerably less than on the other study plots. NA plot had 3.7 inches more stored snow than ND, and NA remained near maximum from March 3 to April 1. That maximum was 94 percent of the maximum stored on NS, which was 1,265 feet higher. Observations the following year in the same vicinity but on different plots show that maximum snow water equivalent on north-aspect aspen was again high—87 percent of that on north-aspect spruce-fir. Maximum snowpack water equivalent occurred on March 3 on SS, SD, ND, and SA. On NS, the maximum occurred on April 1, and again on April 29, following the last major winter storm.

Snow cover on ND and SD plots was not persistent until mid-December, but after that, snow accumulations were deeper on ND than on SD. Rate of accumulation was about the same, however, for both aspects. The difference in snow water equivalent—1.5 inches more on ND—remained the same from mid-January until peak snow accumulation on March 3 (fig. 4).

During all measurement periods, snow accumulation began sooner and snow water equivalents were significantly higher on NA than on SA. On several occasions, there was evidence of considerable snow movement by wind action from the ridge south and west of NA—snow blown from the windward side of the ridge was deposited over the more protected NA plot. At other times, wind scour was evident on NA.

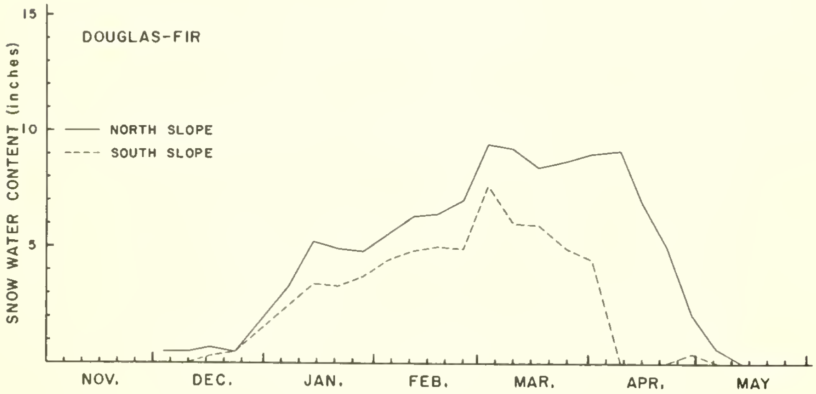
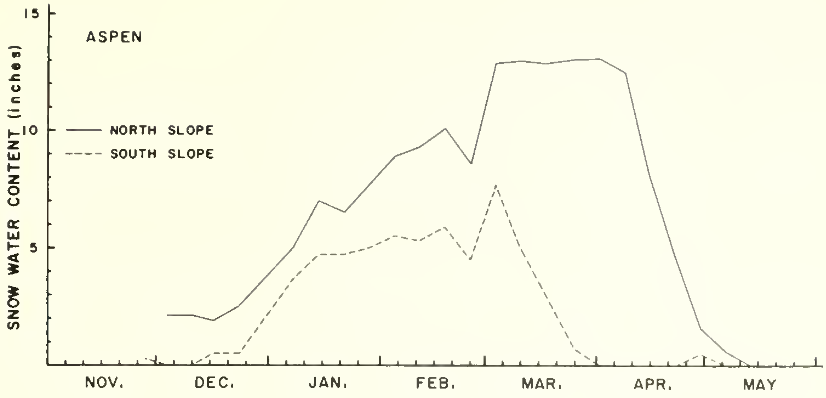


Figure 4.--Snow water equivalent under the four forest cover types.


ASPEN
NORTH SLOPE
SOUTH SLOPE
SNOW WATER CONTENT (inches)
15
10
5
NOV.
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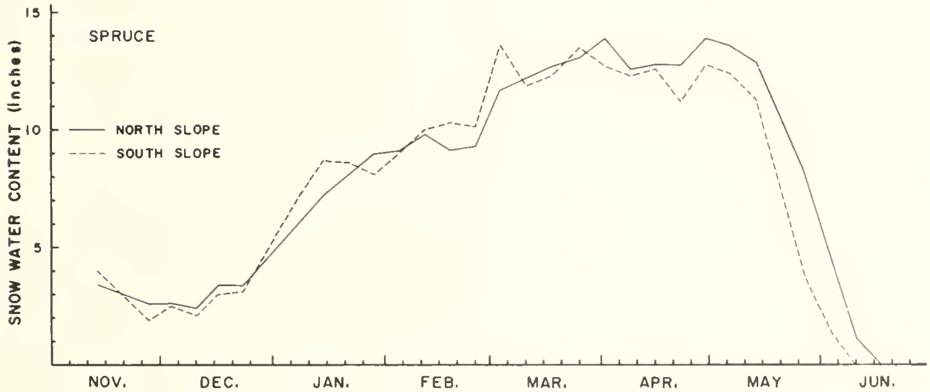
SPRUCE
NORTH SLOPE
SOUTH SLOPE
SNOW WATER CONTENT (inches)
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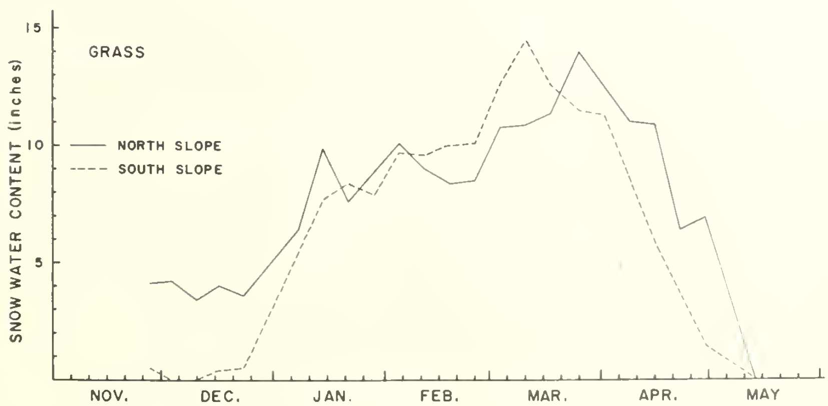
GRASS
NORTH SLOPE
SOUTH SLOPE
SNOW WATER CONTENT (inches)
15
10
5
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY

Table 5.--Maximum depth, water content, and density of snowpack on eight study plots, with date of complete snow disappearance, March-June 1960

Vegetation type, aspect, and elevation (feet)	Maximum snow depth		Maximum water content		Snowpack density: Maximum at time of maximum accumulation		Snowpack density: Maximum		Snow disappearance
	Date	Inches	Date	Inches	Date	gm./cm.³	Date	gm./cm.³	Date
LOW (9,900 feet):									
Douglas-fir									
North	Mar. 3	45	Mar. 3	9.4	Mar. 3	0.21	Apr. 15	0.37	May 13
South	Mar. 3	33	Mar. 3	7.6	Mar. 3	.23	Apr. 1	.37	Apr. 8
Aspen									
North	Mar. 25	55	Mar. 25	13.1	Mar. 25	.23	Apr. 15	.39	May 13
South	Mar. 3	35	Mar. 3	7.7	Mar. 3	.22	Mar. 25	.35	Apr. 1
HIGH (11,150 feet):									
Spruce-fir									
North	Apr.1,29	48	Apr.1,29	13.9	Apr. 1	.32	May 13	.41	Mid-June
South	Mar. 3	53	Mar. 3	13.6	Mar. 3	.26	May 20	.47	June 10
Grass									
North	Mar. 25	44	Mar. 25	14.0	Mar. 25	.33	Apr. 15	.36	May 13
South	Mar. 3	54	Mar. 10	14.5	Mar. 10	.33	Apr. 15	.40	May 13

Snow accumulation was negligible during November and December on SG, ND, SD, and SA, but 4 inches accumulated on NG (fig 4). After initial establishment of a snow cover on NG and SG, blowing snow helped to shape erratic snow-accumulation patterns. For example, on January 21, snow water equivalent was 8.4 inches on SG compared to 7.6 on NG. Again, from February 18 to March 17, SG ranged from 1.2 to 3.6 inches more stored water than NG. Slightly higher snow densities usually were associated with SG.

Snowpack Depletion

During the spring period, snowpack depletion was slower over north aspects, but it was more evident on the 9,900-foot Douglas-fir and aspen types than on the 11,150-foot spruce-fir and grass types (fig. 4). Spring depletion was about the same on NS and SS, with NS lagging 4 to 8 days.

Weekly snow measurements provide data to compare the effects of vegetation differences on snow depletion on north and south aspects (table 6). Comparison of data for percent snow retention on Douglas-fir and aspen types shows that depletion was nearly complete over the south aspects April 1-8, while water equivalents on the north aspects of both types were 96 to 100 percent of maximum.

Depletion rates on north aspects were lower under Douglas-fir than under aspen. Much of the difference is apparently related to favorable effects on the Douglas-fir canopy in reducing wind movement and insolation. At the time of maximum water equivalents, nearly 4 inches more water was stored over the NA plot, but from April 22 until the snow disappeared, snow water storage remained the same over ND and NA.

Peak water equivalent was reached March 10 on SG. By March 25, when NG had reached the peak, water equivalent on SG had decreased to 80 percent of maximum. From March 25 to April 22, however, before last increment to snowpacks between April 22 and 29, water losses from the two snowpacks were about the same—7.5 inches on NG, 7.8 on SG.

By May 13, snow had completely disappeared on both grass plots. At the same elevation, however, the spruce-fir plots retained snow cover until mid-June—4 weeks longer than the grass types—and both spruce-fir plots had about the same retention patterns. When snow depletion was complete in all other cover types, snow water equivalent was still 83 percent of maximum on SS, and 88 percent of maximum on combined NS and SS.

Summary and Conclusions

Snow accumulation and depletion were recorded at weekly intervals on north and south aspects under Douglas-fir, aspen, spruce-fir, and grass types. The Douglas-fir and aspen study plots were at 9,900 feet elevation (low); spruce-fir and grass plots were at 11,150 feet (high). Maximum accumulation of snow water equivalent was as follows:

	Inches
Low:	
Douglas-fir, south aspect	7.6
Aspen, south aspect	7.7
Douglas-fir, north aspect	9.4
Aspen, north aspect	13.1
High:	
Spruce-fir, south aspect	13.6
Spruce-fir, north aspect	13.9
Grass, north aspect	14.0
Grass, south aspect	14.5

At the lower elevation, in the Douglas-fir and aspen types, snow disappeared initially on south aspects 4 to 5 weeks earlier than on the north. In the spruce-fir and

Table 6.--Weekly snowpack water retention expressed as percent of maximum water equivalent, March-June 1960

Vegetation type, aspect, and elevation(ft.)	Maximum water content	Weekly water equivalent of snowpack															
		March				April					May				June	
		3	10	17	25	1	8	15	22	29	6	13	20	27	3	10
	Inches	Percent of maximum															
LOW (9,900 feet):																	
Douglas-fir																	
North	9.4	100.0	97.9	89.4	92.6	95.7	96.8	73.4	53.2	22.3	6.4	0	0	0	0	0
South	7.6	100.0	78.9	77.6	64.5	57.9	0	0	0	7.9	0	0	0	0	0	0
Aspen																	
North	13.1	98.5	99.2	98.5	100.0	100.0	95.4	61.1	35.1	12.2	4.6	0	0	0	0	0
South	7.7	100.0	64.9	39.0	9.1	0	0	0	0	6.5	0	0	0	0	0	0
HIGH (11,150 feet):																	
Spruce-fir																	
North	13.9	84.2	87.8	91.4	94.2	100.0	90.6	92.1	92.1	100.0	97.8	92.8	74.8	56.8	33.1	7.9
South	13.6	100.0	87.5	90.4	99.3	93.4	90.4	92.6	82.4	94.1	91.2	83.1	55.1	27.2	10.3	0
Grass																	
North	14.0	77.1	77.9	81.4	100.0	89.3	78.6	77.9	45.7	49.3	25.0	0	0	0	0	0
South	14.5	87.6	100.0	86.9	79.3	77.9	59.3	40.7	25.5	10.3	4.8	0	0	0	0	0

grass types at the higher elevation, depletion patterns on north and south aspects were about the same. Snow disappearance on both aspects in the grass type was complete by May 13, which coincided with time of disappearance on the north aspects of Douglas-fir and aspen. In the spruce-fir type, snowpack water equivalent was about 88 percent of maximum when snow disappearance was complete over all other study types. Snow disappeared completely on the spruce-fir type 4 to 5 weeks later than on other types.

The survey of snowpack conditions reported in this study was not designed for statistical treatment. Results of the 1-season study suggest, however, tentative recommendations for vegetation management to affect time of runoff. If management is for delayed snow depletion at lower elevations, favoring Douglas-fir in the aspen zone may be desirable. At higher elevations, the similarity in total accumulated snow water between spruce-fir and grass types, and the delay in snowpack depletion under spruce-fir, indicate at least two management possibilities: (1) Management for delayed snow depletion and runoff would favor spruce-fir cover and limited cutting in old-growth stands, particularly on south slopes; (2) management for maximum melt rate of snow and peak runoff would indicate clearcutting.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 94

REST SERVICE
. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Conversion of Tree Heights in Logs to Heights in Feet:

Black Hills Ponderosa Pine

James L. Van Deusen[1]

Gives conversion factors for converting heights in 16-foot logs to heights in feet so trees can be sold by the cord as roundwood.

The market for saw logs in National Forest timber sales varies from time to time in the Black Hills. It may be desirable at times, for timber management reasons, to sell the trees by the cord as roundwood.

Board-foot volumes can be converted readily to cubic-foot volumes with existing volume tables,[2] when cruise data are collected in terms of d.b.h. and total tree height. However, many of the past sawtimber sales were cruised by d.b.h. and the number of 16-foot logs that could be cut from the sample trees. These raw data were used with a net board-foot volume table[3] to obtain estimates of saw-timber volume. Some sales are still cruised by d.b.h. and log height. Data collected in terms of log height cannot be satisfactorily converted from board-foot to cubic-foot volumes without knowing the relationship between log height and total height.

[1] *Associate Silviculturist located at Rapid City in cooperation with South Dakota School of Mines and Technology; central headquarters are maintained at Fort Collins in cooperation with Colorado State University.*

[2] *Myers, Clifford A. Volume tables and point sampling factors for ponderosa pine in the Black Hills. U. S. Forest Serv. Res. Pap. RM-18, 16 pp. 1964.*

[3] *Ballard, J. Net ponderosa pine volume table, Black Hills National Forest. R-2 Suppl., Forest Serv. Handb. 2431.23. 1959.*

The purpose of this Note is to supply the information needed to convert tree heights, expressed as the number of 16-foot logs, to total heights in feet. Conversion values are given in the following tabulation:

Height in 16-foot logs (number)	Estimated total tree height (feet)
0.5	44
1.0	50
1.5	55
2.0	61
2.5	66
3.0	72
3.5	78
4.0	83
4.5	89
5.0	95
5.5	100
6.0	106

Tree heights in feet were estimated by the equation:

$$y = 38.2 + 11.3X$$

where

Y = total tree height, in feet,

X = number of 16-foot logs to a top diameter of 8.0 inches, inside bark.

The correlation coefficient (r) was 0.89 and the standard error of estimate (s) was 6.6 feet at the average height of 74.6 feet.

The conversion equation is based on data from 706 sample trees scattered throughout the Black Hills; 208 of the trees were graphed on forms FS 558-a under the direction of E.M. Hornibrook during the 1930's, and 498 trees were measured in 1962 during the field phase of a cooperative lumber recovery study. Ranges of data were: number of 16-foot logs, 0.5 to 6.0; d.b.h., 10.0 to 33.6 inches; total height, 38 to 116 feet.

A second equation that included d.b.h. along with number of 16-foot logs was computed from data of the 208-tree sample. Both variables were highly significant statistically, but addition of diameter reduced the error of estimate by only 0.3 foot. Only the number of logs-height equation from the combined sample is reported because it can be more easily applied.

The first step is to convert number of 16-foot logs recorded on field tally sheets to the appropriate total tree heights shown in the tabulation. Volumes for each combination of diameter and height class can then be obtained by interpolating between 10-foot height classes in tables prepared by Myers,[2] or in other local tables that use total tree height as one of the variables. For rougher estimates which do not involve interpolation, total heights from the conversion table can be rounded to even 10-foot height values, and volumes can be read directly from the table.

Volumes in merchantable cubic feet may be divided by 77 to produce estimates of cord volume of unpeeled wood.

Agriculture --- CSU, Ft. Collins

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 95

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

Summer Deferred Grazing
Can Improve Deteriorated Semidesert Ranges[1]

Earl F. Aldon and George Garcia[2]

Research in west-central New Mexico showed alkali sacaton on flood plains offers management its best chance for increasing productivity of semidesert lands. It is highly palatable, and can produce much herbage on a relatively small area. Under summer-deferred grazing, production of alkali sacaton has been gradually increasing in spite of variable precipitation.

A management system is needed that will help restore the productivity of deteriorated semidesert ranges. With this in mind, in 1952, the Bureau of Land Management and the Rocky Mountain Forest and Range Experiment Station began a cooperative study in the Rio Puerco basin in west-central New Mexico. The San Luis experimental watersheds, as they are called, are located approximately 58 miles northwest of Albuquerque, New Mexico, in the transition zone between woodland and semidesert grassland. The area consists of three adjacent watersheds with a total of 1,364 acres, comprised of mesas or uplands, steep rocky breaks, and alluvial grasslands.

[1] *Research reported here was conducted in cooperation with the Bureau of Land Management, U. S. Department of the Interior.*

[2] *Hydrologist and Forestry Research Technician, with central headquarters maintained at Fort Collins in cooperation with Colorado State University; authors are located at Albuquerque in cooperation with the University of New Mexico.*

The principal perennial grass species are alkali sacaton (Sporobolus airoides Torr.), galleta (Hilaria jamesii (Torr.) Benth.), and blue grama (Bouteloua gracilis (H.B.K.) Lag.).

Stock water is produced by summer runoff and collected in earthen dams at the southern end of each watershed. Average annual precipitation for the period of study was 10 inches. The average growing-season precipitation (May 1 to November 1) was 6 inches.

Methods

In an effort to improve range conditions, we began a system of deferred grazing and controlled utilization. To evaluate any changes measurements of herbage production, stocking rates, and percent utilization by weight were recorded seasonally. Production and stocking rates were determined each fall. Utilization was determined in the spring immediately after overwinter grazing had been terminated.

Herbage production of the principal grass species was determined by a weight-estimate[3] and double-sampling technique.[4]

Stocking rates were adjusted annually in an effort to obtain 55 percent herbage use of alkaki sacaton. Utilization was determined periodically during the grazing season and at the close of the grazing season, and, when necessary, grazing was discontinued prior to the anticipated date to prevent overuse. Utilization was determined by the ocular estimate-by-plot method [5] on the same plots used for determining production. Hereford cattle were grazed throughout the study. In June of 1957, with fencing complete, the cattle were confined to individual watersheds and grazed overwinter only (November 1 to April 30).

Growing-season precipitation was measured weekly from May 1 to November 1. The overwinter measurement period was from November 1 to April 30.

Results

Average utilization of alkali sacaton varied less than 5 percent between watersheds for all years; therefore, results are given as averages for the whole 1,364 acres rather than by individual watersheds. Stocking rates over the area averaged 16 animal units per section for the 6-month winter grazing season:

	Total livestock	Animal units
Yearling heifers:		
1957-58	41	19
Cows with calves:		
1958-59	41	19
1959-60	32	15
1960-61	24	11
1961-62	32	15
1962-63	35	16

Air-dry herbage in pounds per acre for the three principal grass species is listed in table 1. Alkali sacaton generally contributed about a third of the total yield, while galleta usually contributed more than half. Though widely distributed over the watersheds, blue grama generally contributed less than 20 percent of the total herbage production.

There was no apparent relationship between precipitation and herbage production (table 1). Seasonal and annual precipitation and combinations of monthly totals were analyzed, but none could be correlated with herbage production.

Utilization percentages (table 1) revealed cattle had a definite species preference for alkali sacaton, followed by galleta and blue grama. The order of preference reflects differences in palatability of the dry herbage. Leaves and culms of the three species were dry and partially leached throughout most of the winter grazing period. Alkali sacaton apparently remains palatable even when dry, whereas galleta may become palatable only after wetting by rain or snow. The blue grama in this area is mostly very low growing; consequently cattle are able to remove only a small percentage of the herbage.

Discussion

Galleta consistently contributed over 50 percent of the total herbage produced (table 1). This is primarily due to the number and distribution of plants. Galleta is found throughout the area, while blue grama is found primarily on the dry, upland sites. Alkali sacaton is abundant on the alluvial

[3] *Pechanec, J. F., and Pickford, G. D. A weight estimate method for determination of range or pasture production. Amer. Soc. Agron. J. 29: 894-904. 1937.*

[4] *Wilm, H. G.,Costello, D. F.,and Klipple, G. E. Estimating forage yield by the double-sampling method. Amer. Soc. Agron. J. 36: 194-203. 1944.*

[5] *Pechanec, J. F., and Pickford, G. D. A comparison of some methods used in determining percentage utilization of range grasses. J. Agr. Res. 54: 753-765. 1937.*

Table 1.--Precipitation, and average air-dry herbage production and percent utilization of the principal perennial grass species on the San Luis watersheds

Year	Precipitation		Average air-dry herbage production				Average utilization[3]		
	Total annual[1]	Growing season[2]	Alkali sacaton	Galleta	Blue grama	Total of principal species	Alkali sacaton	Galleta	Blue grama
	- - Inches - -		- - - - Pounds per acre - - - -				- - - Percent - - -		
1957	12.23	8.35	37.0	55.3	9.3	101.6	--	--	--
1958	12.00	6.53	89.7	96.6	33.4	219.7	32.2	20.7	11.0
1959	10.66	6.81	70.8	104.8	24.1	199.7	54.0	28.8	10.0
1960	10.28	5.33	52.7	102.0	24.7	179.4	70.4	26.8	9.1
1961	10.32	9.31	89.3	122.7	31.3	243.3	48.5	17.2	5.6
1962	6.47	2.70	119.3	161.3	38.0	318.6	38.1	6.9	1.0
1963	--	--	--	--	--	--	54.4	15.0	2.2

[1] Water year is November 1 - October 31; e.g., 1958 is November 1, 1957 - October 31, 1958
[2] May 1 - November 1.
[3] Measured in the spring of year listed for previous growing season.

lood plains, although it is also found on the drier upland sites. Alkali sacaton produces large quantities of herbage on relatively small areas; individual plants yield several times as much herbage as those of galleta.

Since cows and calves tend to graze near water, it would be expected that plants on the alluvial flood plains would be used more than those on the uplands. Alkali sacaton grew in such areas, and was used more than the other species (table 1).

In 1959 and 1963, when production of alkali sacaton was about 100 pounds per acre, overwinter stocking at 18 head per section resulted in the desired 55 percent utilization of alkali sacaton. In 1961, when production of alkali sacaton was about 90 pounds per acre, overwinter stocking at only 15 head per section resulted in only 38 percent use of alkali sacaton (table 1).

Under summer-deferred grazing, production of alkali sacaton has been gradually increasing in spite of variable precipitation (table 1). We feel that alkali sacaton on flood plains offers management its best chance for increasing the productivity of these semidesert lands, and that it is important to manage for this vegetation.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 96

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

Effect of Seasonal Stem Moisture Variation and Log Storage on Weight of Black Hills Ponderosa Pine

Vern P. Yerkes [1]

The moisture content of ponderosa pine trees in the Black Hills fluctuated enough from season to season to account for a significant portion of the variability that might be experienced in weight scaling. A difference in moisture content of trees on different growing sites was also noted. Weight loss from logs left in woods storage for up to 108 days was not great and could largely be ignored in weight scaling. Lumber degrade during storage would probably be a more serious problem, and normally would be the main concern in log storage.

Introduction

How to determine accurately and economically the volume of small and generally low-quality logs is a problem facing the Black Hills timber industry. The majority of the lumber produced from these logs is in the lower common grades, which face declining markets and hence narrowing profit margins. A low-cost and accurate method of volume determination is needed to help reduce log production and sale administration costs. Such a system should also tend to reduce misunderstandings between buyer and seller.

Weight scaling has met with considerable success and acceptance in similar situations in other parts of the nation.

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The reliability of weight scaling in Black Hills ponderosa pine has been questioned, however. Individuals in the industry report that ponderosa pine logs weigh substantially more in the winter than in the summer. Also, some operators cut logs and leave them lying in the woods (a method of storage) for considerable lengths of time before hauling them to the sawmill. This practice could result in extensive weight loss through drying of the logs. Both of these problems could have a serious impact on the application and acceptance of weight scaling.

The weight of a living tree can fluctuate seasonally only through changes in stem moisture content. Conflicting reports are available on the extent of this fluctuation in other species and its effect on weight scaling. These reports vary from no appreciable seasonal change, or with no effect on weight scaling (1, 12, 14, 15), to changes ranging up to 40 percent for both hardwoods and softwoods (2, 3, 5, 6). Several authors also report variation of moisture content not only between sites (2, 3, 5, 8, 15), but also vertically and laterally within trees and between trees on the same site.

This pattern of conflicting reports also exists for weight loss in pulpwood and saw logs held in storage. Here, reports range from a slight weight loss to weight losses serious enough to limit weight scaling methods in both softwoods and hardwoods (1, 4, 10, 11, 15).

This study had three major objectives as applied to Black Hills ponderosa pine. They were to determine (1) the size and duration of annual variation in moisture content in tree stems, (2) the amount and rate of weight loss from woods-stored logs in the summer, and (3) the effect, if any, the above have on weight scaling. Aspen trees were included in the study as an additional check on methodology and earlier reported results.

Methods

Seasonal Variation in Stem Moisture

Ten healthy trees on each of five sites were selected for study of seasonal stem moisture variation. Trees were selected to sample as wide a range of diameters as possible on each site. Tree diameters ranged from 10.0 to 23.5 inches d.b.h. Sites were selected for their apparent soil moisture availability and included ridgetop, south slope, north slope, well-drained flat, and beaver pond fill. One-half-inch-diameter increment cores (fig. 1), for moisture content determination, were extracted from each tree in each of five physiological "seasons." The "seasons" sampled were (1) just prior to dormancy in the early fall, (2) after dormancy but before winter freezeup, (3) during winter freezeup, (4) after winter freeze but before dormancy broke in early spring, and (5) during the height of the growing season in late spring. Increment cores were extracted at breast height from equally spaced and randomly assigned positions around each tree. Sampling was extended into the fall of the second year in an effort to be sure that trees returned to the late-growing-season moisture content.

Immediately after they were extracted, the cores were cut into heartwood and sapwood segments and wrapped in heavy-duty aluminum foil. They were weighed as soon as possible to the nearest 0.01 gram, ovendried at 103°C., and reweighed. Moisture contents were then calculated on an ovendry basis.

Ten aspen trees were similarly sampled, except that heartwood and sapwood were not separated.

Weight Loss From Stored Logs

Data to determine the amount and rate of weight loss were collected from 50 woods-stored logs. They were stored in groups of 10 under five different woods storage conditions ranging from an open field to a dog-hair stand of reproduction (fig. 2). The logs were weighed every 3 weeks over a period of between 101-108 days from July to September (fig. 3). Late-summer storage was tested because this season of the year offers the most severe drying and degrade conditions, and therefore should result in the maximum weight and degrade losses.

Figure 1.--
(Above) One-half-inch increment borer, a, used in this study compared to the standard, more commonly used 0.2-inch borer, b.
(Below) Comparison of increment cores extracted by the borers a and b shown above.

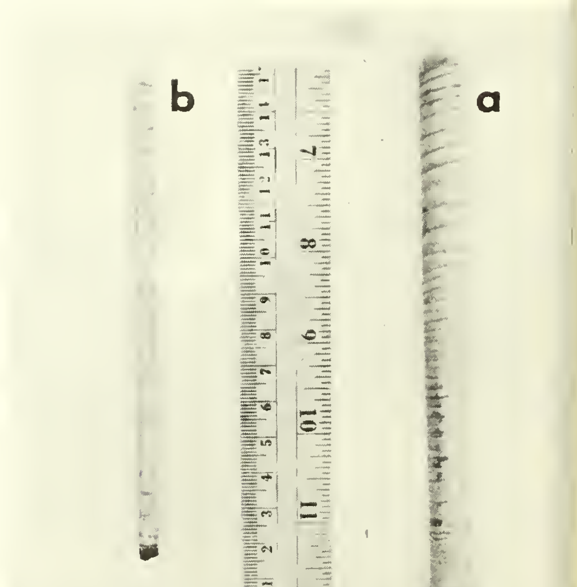

Figure 2.--Sites where ponderosa pine logs were stored ranged from an open pasture (above) to a dense reproduction thicket (below).

Figure 3.--Logs were weighed to the nearest 5 pounds every 3 weeks with this hydraulic load cell, chain hoist, and tripod.

Results and Discussion

Seasonal Variation in Stem Moisture

The moisture content of ponderosa pine sapwood was found to vary significantly [2] with the "seasons" sampled during 1963-64 (fig. 4). The highs of February and April were significantly different from the lows of June, September, and November. Moisture content of the trees in September 1964 was not significantly different from that of the previous September. These results follow reasonably well those reported by Parker (13) for ponderosa pine sapwood, and quite closely those of Gibbs (5) for jack pine in Canada, and Fielding (3) for Monterey pine in Australia.

Trees on the higher quality sites—north slope and well-drained flat—averaged 8 to 14 percent higher sapwood moisture content than those on lower quality sites—ridgetop, south slope, and beaver pond fill—even though the beaver pond fill was selected for its high water table.

[2] *Ninety-five percent level of significance used throughout this report.*

The statistical grouping of the two "better" and the three "poorer" sites indicated that the moisture content of the sapwood may be affected more by the vigor of the tree or total site quality than by available soil moisture alone. This agrees with Fielding's (3) conclusions for Monterey pine in Australia.

Ponderosa pine heartwood moisture content remained surprisingly constant at near 30 percent. The average heartwood moisture content of the 10 trees sampled on each site remained between 28 and 33 percent during the entire year. This is the same as Parker (13) found for Douglas-fir in the Rocky Mountains, but is considerably below and much more constant than he reported for ponderosa pine.

On each site studied, sapwood moisture content varied considerably between trees. The average coefficient of variation for all observations was 16 percent. Fielding (3) and Gibbs (5) have both noted some variation. For this group of trees, however, those with above- or below-average sapwood moisture content for the site were consistently so. Most frequently, the tree with the highest or lowest sapwood moisture content at one "season" was also highest or lowest in at least two other "seasons." If this phenomenon extends to other species and areas, it could explain some of the conflicting results of earlier studies where different trees were compared at different seasons.

The significant variation of aspen moisture content for the year (fig. 4) compares well with that reported earlier by Hall (6), Bendsten and Rees (2), and Gibbs (5). The aspen moisture content was high during winter and early spring—about 22 percent above the fall low.

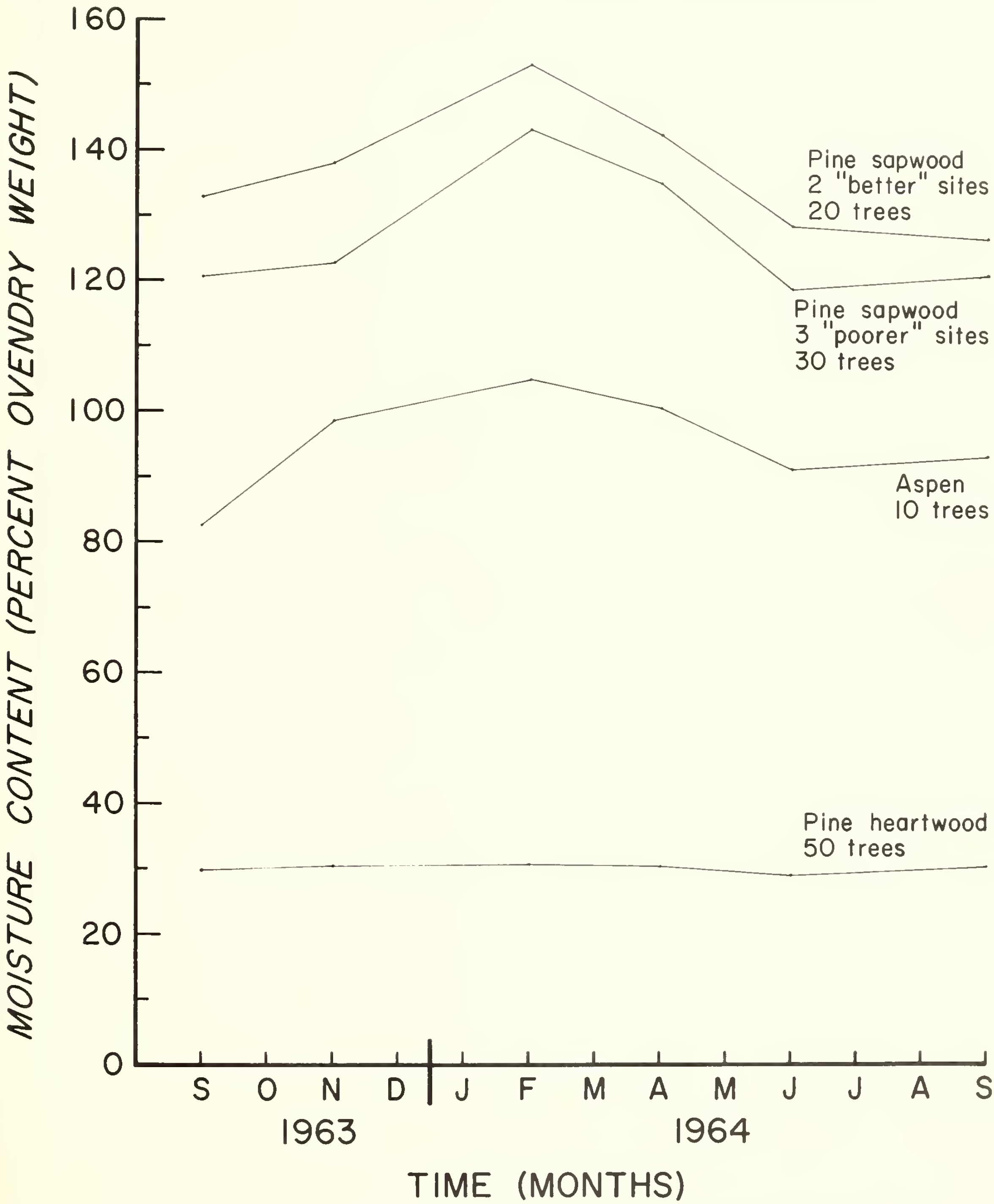

Figure 4.--Annual variation of moisture content at breast height for Black Hills ponderosa pine and aspen sawtimber trees.

The effect of seasonal variation in moisture content on weight:cubic foot ratios of ponderosa pine logs was estimated. Summer and winter weights were calculated[3] for 32 logs used in a previous study. The logs contained 487 cubic feet of wood, and had a volume of sapwood ranging from 5 to 99 percent. Total summer weight of these logs was calculated to be 23,300 pounds. The summer-to-winter increase in sapwood moisture content of 24 percent resulted in an 8.5 percent increase in calculated log weights. The average calculated weight per cubic foot for these logs changed from 47.9 to 52.0 pounds for summer and winter weights, respectively. Use of either one of the above ratios for predicting both summer and winter volumes for these logs would have resulted in a winter volume of about 40 cubic feet greater than the summer volume. This would be about 8.6 percent of the summer volume, the approximate cubic foot volume of a log 16 feet long and 18 inches d.i.b. at the small end.

[3] *Weight was calculated from specific gravity and volumes for heartwood and sapwood from an earlier study (16) and the moisture contents for sapwood and heartwood found in this study.*

Weight Loss From Stored Logs

Fifty ponderosa pine logs were stored in the woods for up to 108 days through the late summer. They lost an average of 41 pounds, or 5.3 percent of their beginning weight. Total weight loss for individual logs ranged from 20 to 100 pounds. Since there was only a relatively small moisture loss during the study, and only a small segment of the total drying curve represented, the rate of weight loss for the average log was expressed as a straight line (fig. 5).

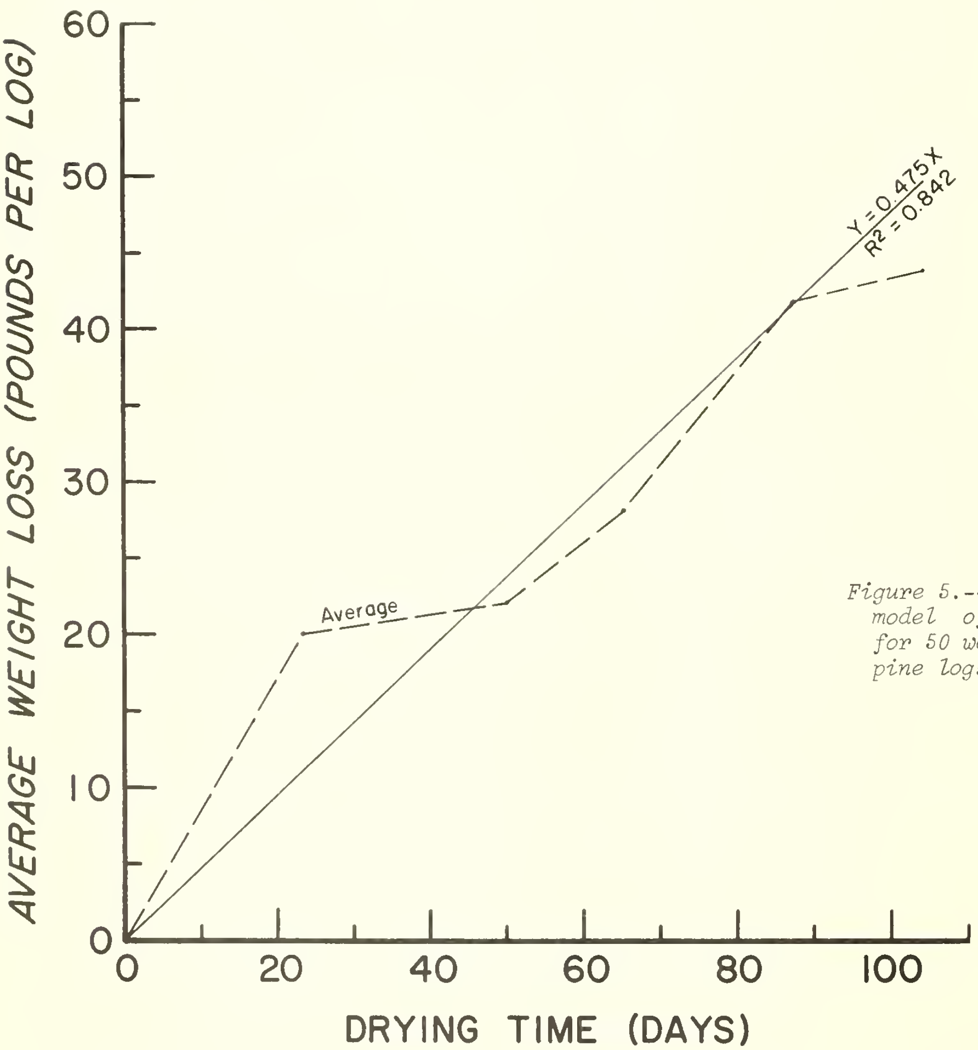

Figure 5.--Average and linear model of weight loss per log for 50 woods-stored ponderosa pine logs in the Black Hills.

A covariance analysis, including 10 logs from three trees on each of five storage sites, did not show a significant effect of site on weight loss, even when variability in beginning log weights was considered. Also, total loss from logs in upper portions of the trees was not significantly different from loss from the butt sections. When weight loss was expressed as a percent of beginning weight, however, there was a significantly higher percentage weight loss for the upper logs (table 1).

Comparison of weight loss data shows that some trees tend to lose more total weight than others in all log positions (table 1).

This brings about the confusing pattern of a small log from one tree losing more total weight than a larger one from a second tree. No explanation of this phenomenon could be found by plotting total weight loss against such variables as beginning percent sapwood moisture content, percent sapwood, diameter, surface area, or bark thickness. It appears that some unmeasured characteristic of the bark or wood of a tree has a direct bearing on the drying rate of freshly felled trees when stored in the woods.

The practical importance of the weight loss, both in total loss and rate of loss, is considerably lessened when one considers other factors. The most important of these

Table 1.--Randomly selected study trees showing pattern of weight loss from logs of the same tree stored for 101 to 108 days

Tree number and position of log	Beginning weight	Average weight loss during storage	
	Pounds	Pounds	Percent
Tree No. 3-2:			
First log	770	30	3.9
Second log	595	25	4.2
Third log	355	25	7.0
Total or average	1,720	27	4.6
Tree No. 5-1:			
First log	1,400	35	2.5
Second log	1,000	25	2.5
Third log	795	40	5.0
Fourth log	310	20	6.4
Total or average	3,505	30	3.4
Tree No. 2-1:			
First log	850	45	5.3
Second log	575	40	7.0
Third log	295	20	6.8
Total or average	1,720	35	6.1
Tree No. 1-1:			
First log	1,550	65	4.2
Second log	1,145	60	5.2
Third log	640	60	9.4
Total or average	3,335	62	5.5
Tree No. 4-3:			
First log	2,000	70	3.5
Second log	1,535	65	4.2
Third log	800	65	8.1
Total or average	4,335	67	4.6

is the degrade of lumber due to blue stain and insect attack. All logs in this study showed heavy blue staining and insect activity after only 9 weeks of storage. If the average log from this study had been converted to lumber, blue stain alone could have reduced the 1, 2, and 3 common lumber normally recovered from it to 3, 4, and 5 common grades (9). Such degrade could reduce this log's value a maximum of about 48 cents. During this time, the average log would lose about 28 pounds or about 3.6 percent of its beginning weight. This would represent only 2 or 3 cents per log "gain" in scale if the stumpage rate was $10 per thousand board feet and weight per board foot was 10 pounds.

Conclusions

Seasonal variation of the moisture content of ponderosa pine logs in the Black Hills appears large enough to be accounted for in a weight scaling program. This can be accomplished in either of two ways—by using the generally accepted technique of sampling and using a varying weight: volume ratio, or by using a fixed weight:volume ratio with seasonal adjustments to compensate for seasonal weight fluctuations. In the first method, a given number or percent of the loads of logs to be weight scaled would be weighed and stick scaled, and the conversion factor adjusted after each load sampled. It would be necessary, however, to select sample loads throughout the year in the same proportion as the total volume hauled during each season. The second method would require the establishment of an acceptable conversion factor and experience data on the weight fluctuation detected in a commercial operation.

On the other hand, weight loss from logs stored in the woods can largely be ignored. Weight loss is small in relation to possible degrade loss, so contract operators will tend to weigh logs as soon as possible after felling to maximize log scale and keep degrade to a minimum.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 97

OREST SERVICE
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OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Survival and Early Growth of Ponderosa Pine Planting Stock in the Black Hills

Charles E. Boldt[1]

"Average" 1-0, 2-0, 1-1, and 2-1 seedlings were handplanted in contour furrows on a marginal and a favorable planting site in 2 consecutive years. Favorable moisture limited severity of tests in both years. On the basis of third-year survival and fifth-year average heights, it was concluded that 2-0 stock should be planted operationally for enough years to verify or discount its economic advantage over 2-1 stock.

For many years, National Forest planting guides recommended 2-1 or 1-2 ponderosa pine stock for Black Hills plantings. Steadily rising production costs, however, have made 3-year-old transplants prohibitively expensive. The question naturally arose: Could some younger, cheaper class of stock be used without jeopardizing planting success?

Research was called upon to supply an answer. This Note tells briefly what we did and what we learned.

What We Did

We made four separate tests of four different classes of planting stock. One complete test was installed at each of two locations, in each of 2 consecutive years—1962 and 1963. We included the same set of stock classes in all four tests: 1-0, 2-0, 1-1, and 2-1. To improve the likelihood of a good information yield, we selected the two locations for as much contrast as possible in the suitability for planting.

One test location was a 30-year-old burn on the southeast edge of the Black Hills. This area appeared to be marginal for planting. Situated just above the forest-grassland transition zone, it receives approximately 18 inches of precipitation per year, or only slightly more than the minimum necessary to support well-stocked, commercial stands of ponderosa pine. Site index within the test area was estimated to be 50 to 55 feet.

For the contrasting test location, we selected a 15-year-old burn in the northeastern portion of the Hills. Average annual precipitation of about 24 inches places it among the most abundantly watered areas in the entire Black Hills. It has a high potential for timber production, and is unusually favorable for planting. Site index was estimated to be 65 to 70 feet. Soils at both locations are friable loams derived from Mississippian limestone.

Site preparation was the same at both locations: contour furrows were made at about 8-foot intervals with a single-disc plow, drawn by a track-laying tractor. This treatment has been used extensively on the Black Hills

[1] *Silviculturist, located at Rapid City in cooperation with the South Dakota School of Mines and Technology; central headquarters are maintained at Fort Collins in cooperation with Colorado State University.*

National Forest to break up heavy sod and brush cover on planting sites in old burns.

Each test was a set of eight randomized blocks; each block contained four plots. A plot was a segment of a contour furrow long enough to accommodate 20 trees of a single class, planted about 2 feet apart. A block was an unbroken string of four plots. Blocks were arranged one per furrow in eight successive furrows. Stock classes were assigned at random to the plots in each block.

Test stock came from the Forest Service's Bessey Nursery, at Halsey, Nebraska. All test stock was grown from Black Hills seed, and trees of all classes except the 1-0 had been root pruned. All of the stock for a given year's tests was lifted at the same time, 2 to 3 weeks before spring planting.

We planted only trees that appeared to represent the norm for each class in terms of overall size, balance, and general physical condition. This eliminated some of the within-class variability of bed-run stock.

The selected stock was protectively packaged according to standard practice, hauled promptly to the Black Hills, and held in dark, moist, cold storage until the day of planting.

All trees were handplanted in the bottoms of the plowed furrows. To minimize within-block variation due to differences in planting skill and care, all trees in a given block were planted by the same individual.

We made the initial survival count in each planting at the end of the first growing season, and continued the counts on a spring-and-fall schedule through the end of the third growing season. We also measured the total heights of surviving trees in each of the 1962 plantings, at the end of the fifth height-growth period.

What We Learned

Transplant stock is more costly to produce and use than seedling stock. At the Bessey Nursery in 1966, total production costs for lifted 1-1 and 2-1 ponderosa pine transplants were about \$19 and \$24 per thousand, respectively. Comparable costs for 1-0 and 2-0 seedlings were about \$10 and \$13. Since there is an even larger spread between selling prices, it is clear that a switch from 2-1 stock to any of the younger classes—especially to seedlings—could result in substantial savings in a large reforestation program.

How would such a switch affect planting success, as measured by tree survival and growth? Unfortunately, the tests were not severe. Growing-season precipitation was above normal in both years of planting, and it deviated only slightly from the normal during the balance of the test period.

All four classes of stock survived well at both locations following both years of planting (fig. 1). Rated by usual standards, the best

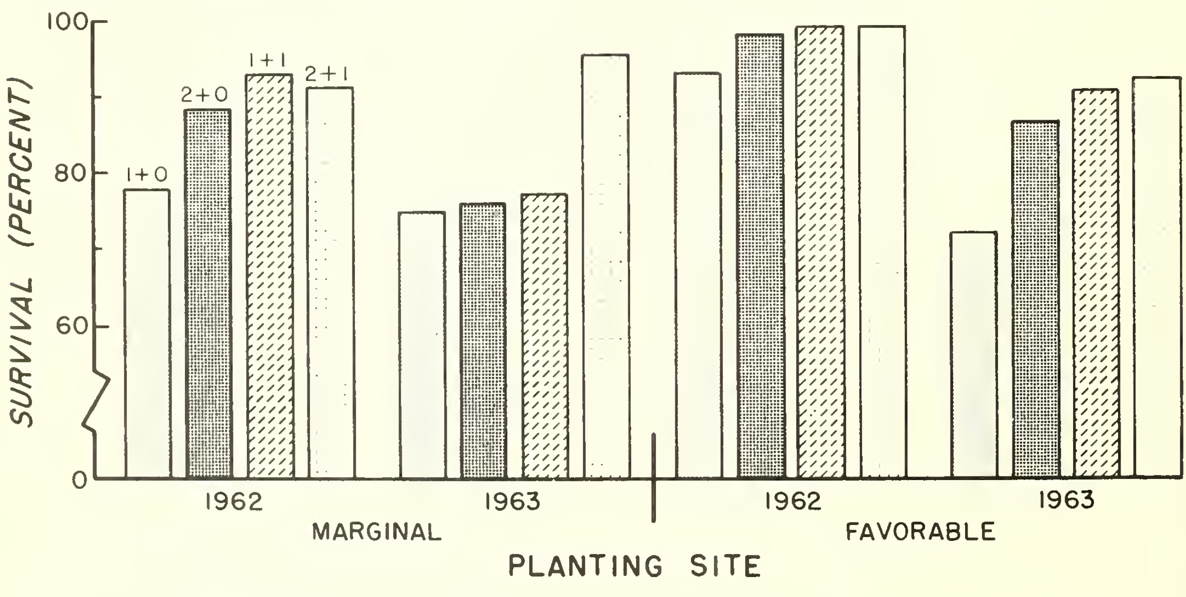

Figure 1.--Average rates of third-year survival for four classes of ponderosa pine planting stock planted on two Black Hills sites in two different years.

survival was excellent and the poorest was good—few tree planters would be dissatisfied with third-year survival rates above 70 percent.

Without some explanation, the relatively poor survival of the three youngest classes on the marginal site in 1963 could be misleading. Nearly 40 percent of all trees lost in that particular test were killed by cattle trampling or goat browsing, neither of which was an important cause of mortality in the other tests. Impact of the damage was greatest among 1- and 2-year-old trees. When average survival values were adjusted upward by the amount of these obviously controllable losses, survival rates in the 1963 test compare favorably with those of the 1962 test at the same location.

Plantation success, however, requires more than just getting some minimum number or percentage of planted trees to survive on each planted acre. Rapid, early development of trees is also important, particularly on areas where competing vegetation rebounds quickly following site preparation (fig. 2). Planted trees that fail to dominate competition within the

Figure 2.--Trees planted in 1962 at a marginal location:

Two months after planting

Four years later, trees were competing with the vigorous regrowth of ground cover between furrows.

first few years after planting may never do so, or be long delayed.

The test trees showed substantial differences in average height at the end of the fifth growing season after planting:

	Average height by site class	
	Marginal	Favorable
	(Inches)	
Age class:		
1-0	10.9	14.7
2-0	15.4	17.7
1-1	18.8	20.1
2-1	17.1	23.0

Differences among means in excess of 6 inches were very unlikely to have been the results of chance. Trees of the 1-0 class appeared less likely to outgrow competition than any of the older classes, especially on the harsher site.

The 1-year-old seedlings have two other practical disadvantages: First, their small size makes them difficult to handle and plant properly, either by hand or machine; second, when planted in the bottoms of furrows, they are vulnerable to burying by waterborne silt and debris. Few 1-0 trees survived after being buried to the base of the uppermost whorl of needles. Such burying was a major cause of loss among trees of this class, but caused only negligible losses among the older trees.

Conclusions and Recommendations

All four classes of stock can be expected to survive satisfactorily on the general run of Black Hills planting sites in years of favorable moisture. Success on the marginal site suggests that the four classes would perform similarly on most central and northern Hills sites in years of subnormal growing season precipitation.

1-0 seedling stock is the most economical, but it has some important shortcomings: It is difficult to plant, is subject to burying, and its early growth is slow.

1-1 stock survived and grew as well as the 2-1 stock but, because of the cost of transplanting, 1-1 trees are almost as expensive as 2-1.

The 2-0 stock appears to provide the best combination of economy and performance. It costs only about half as much as 2-1 stock, yet it survived and grew nearly as well at both test locations.

On the basis of this evidence, we recommend that 2-0 stock be adopted as the standard class for Black Hills plantings. It should be used operationally for enough years to thoroughly test its behavior in periods of moisture shortage. If it survives and grows satisfactorily in dry years as well as wet, its use should continue. On the other hand, if there is a marked increase in 2-0 plantation failures during dry years—relative to rates of failure of 2-1 plantations in the past—then the apparent economic advantage of the 2-0 stock should be reassessed.

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U.S. FOREST SERVICE
RESEARCH NOTE RM -98

FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Changes in Grass Production on Ungrazed Converted Chaparral

Floyd W. Pond[1]

Ungrazed stands of weeping lovegrass in cleared chaparral begin to deteriorate a few years after treatment. The decline does not appear to be related to brush cover or precipitation.

Production of seeded grass on chaparral lands in central Arizona generally depends on degree of brush control (Pond 1961). After burning, a temporary brush control at best, production of seeded grass is usually high for a few years but rapidly declines as the sprouting bushes approach prefire size (Pond and Cable 1962). This loss of grass production has been attributed to competition between the classes of vegetation. Recent observations, however, show that ungrazed grass stands, initially high in cover and production, may also deteriorate on areas essentially cleared of competing shrubs. This Note reports changes in grass basal cover and production on areas of differing brush kill (0 to 100 percent) over a period of 8 years.

[1] *Range Scientist, located at Flagstaff, in cooperation with Northern Arizona University; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

Methods

The experimental area was the same one used in an earlier study of grass production and density under varying amounts of shrub live oak cover (Pond 1961).

In 1957, 22 areas 50 by 87 feet were located within a 7-acre exclosure built after the 1951 Pinal Mountain fire. All shrubs except shrub live oak (Quercus turbinella Greene) were killed with a basal application of a mixture of 2,4-D and 2,4,5-T in diesel oil. The shrub live oak plants were then treated with chemicals to create 2 areas each of 11 crown cover classes: 0, 10, 20. . .90 and 100 percent reduction of original shrub live oak cover. Subsequent sprouting was controlled by reapplication of chemicals in 1958, 1960, and 1962. Weeping lovegrass (Eragrostis curvula (Schrad.) Nees) was sown on all 22 areas (fig. 1).

Grass basal cover on each area was measured along 10 randomly placed 50-foot line transects (Canfield 1942), the one restriction being that no line was closer than 4 feet to another line or the edge of that area.

Figure 1.--Helicopter view of one small plot seeded to weeping lovegrass after 90 percent of the shrub live oak was killed with a basal spray of 2,4-D combined with 2,4,5-T in diesel oil. Photo taken in 1964, 7 years after initial treatment.

Grass production was measured by the weight-estimate method of Pechanec and Pickford (1937). Ten 9.6-square-foot plots were placed at 5-foot intervals along the right side of each of 2 of the 10 transects. Production was estimated on five of these plots each year of measurement. Of the remaining five plots, one was selected each year on which grass production was first estimated and then clipped to convert the estimated values to actual weight by a double-sampling technique (Wilm et al. 1944). All vegetation measurements were made in 1958, 1959, 1960, 1962, and 1965.

Results

Grass basal cover tended to be inversely proportional to shrub live oak crown cover each year of measurement (fig. 2). In 1958 there was high variation among plots in the 1-year-old grass stand, and grass cover varied from 0.30 percent on plots with no oak kill to almost 1.20 percent on plots with 90 percent oak kill. By 1960, grass cover had reached maximum on most plots, and varied from 0.41 on plots of no oak kill to about 2.75 on plots with complete oak kill. Grass cover changed little between 1960 and 1962, but by 1965 had decreased to less than 0.20 on plots of no oak kill and was only 1.20 on plots with complete oak kill.

Grass production followed trends similar to those for grass basal cover, but began to decline earlier (fig. 3). In 1960, production varied from 200 pounds on plots with no oak kill to over 1,600 pounds on plots with complete oak kill. Production on all plots had decreased by 1962, and in 1965 varied between 180 pounds on plots with no oak kill to about 1,000 pounds on plots with complete oak kill.

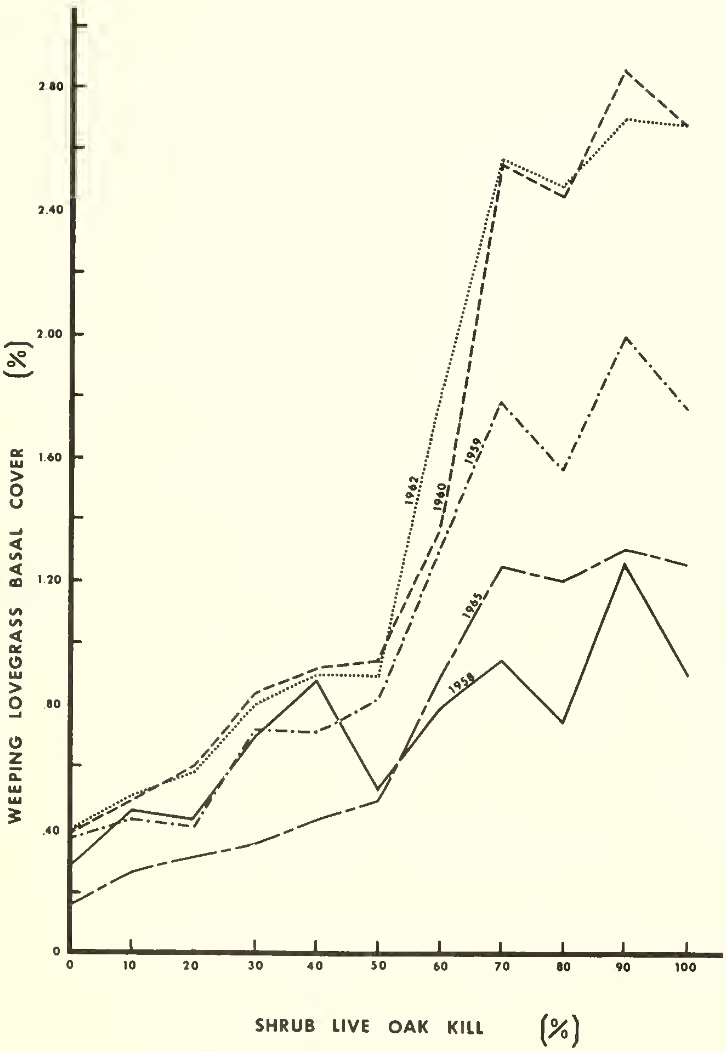

Figure 2.--Basal cover of weeping lovegrass growing under various percentages of shrub live oak crown cover.

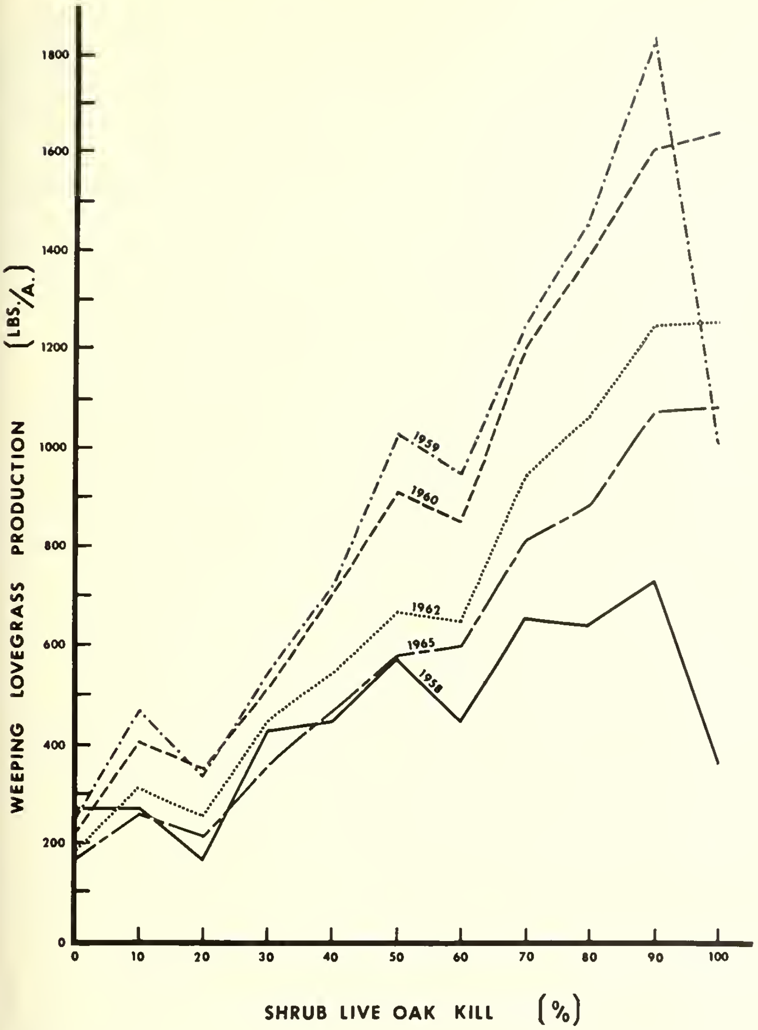

Figure 3.--Production of weeping lovegrass growing under various percentages of shrub live oak crown cover.

Analysis of variance showed that, when the relationship between shrub kill and grass production or cover for each year's data was expressed as a straight line, there were significant differences in the slopes of the lines. This indicates that both cover and production changes were real.

Discussion

During any 1 year, production and basal cover of seeded grasses on cleared and partially cleared chaparral lands depended on degree of chaparral kill. After 8 years, grass production on completely cleared lands was still eight times that on plots where no oak was killed. The fact that grasses rapidly reach peak cover and production on these areas and then tend to decline has little to do with degree of brush kill since this occurred on all plots, even those with complete shrub kill.

Production on all plots neared its highest point during the second year after treatment and remained high through the following year, but was beginning to decline by the fifth year and continued to decline into the eighth year. Basal cover reached its highest point during the third growing season and was still high during the fifth growing season, but had declined by the eighth growing season.

In the second year, plants were vigorous and healthy. Production was high even though basal cover had not reached a peak. By 1962 production had dropped but basal cover was at its highest point, which indicates that some plants were beginning to deteriorate. Both basal cover and production had declined by 1965. At this last measurement, many plants had no green leaves. Although these plants appeared to be firmly rooted, the slightest pull separated the crowns from the already decayed roots. In addition, many other plants were in poor condition, with only one to a few green leaves where many had been produced in previous years.

Amount of shrub live oak crown cover and size of the individual had little to do with the ability of a grass plant to survive. Large plants, 6 or more inches in diameter, as well as single-stem plants were found dead on all plots in 1965.

Causes for this die-off are unknown, but the problem could have serious implications from both watershed and range management viewpoints. In 1962, the loss in production was first thought to be a reflection of an extremely dry spring and summer in 1961. After adequate and well-distributed rainfall in 1962, 1963, and 1964, however, both production and basal cover of grasses were still significantly lower in 1965 than in 1961.

There is a possibility that moderate grazing could be beneficial. Nelson (1934), Kelting (1954), and several others have shown that grass cover and production are frequently higher on moderately grazed areas than on areas completely closed to grazing.

Grazing may be impractical or detrimental on steep mountain watersheds. Ehrenreich (1959) and others have shown that light burning is also an effective way to eliminate old residue. A winter burn, when plant bases are damp, could be beneficial on the steep, ungrazable areas.

Future studies should be oriented toward finding ways to halt deterioration of lovegrass stands on treated chaparral range. How helpful grazing may be is already being investigated. Other studies should be initiated to study treatments such as burning and fertilization.

Summary

Stands of weeping lovegrass on areas cleared of chaparral show signs of deterioration after a few years. Production and cover are high for 1 to 2 years after seeding, but gradually decrease each year thereafter. The decline does not appear to be related to either brush cover or precipitation. This deterioration could possibly be halted by moderate grazing. On steep mountain watersheds where grazing is unacceptable, burning in the dormant season and fertilization should be investigated as possible alternative treatments.

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U.S. FOREST SERVICE
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OREST SERVICE
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Soil-Moisture Trends After Thinning and Clearcutting in a Second-Growth Ponderosa Pine Stand in the Black Hills

Howard K. Orr[1]

Thinning from 190 square feet basal area and nearly 2,000 trees per acre to 80 square feet and 435 trees apparently did not induce free water seepage to ground water in dry years when the unthinned stand did not yield seepage. Thinning reduced the soil moisture depletion potential, however, thus increasing the seepage potential. Actual increase in seepage depends on enough incoming moisture to overcome soil moisture deficits, which were greater at the end of each of 5 years of study in the unthinned than in the thinned portion of the stand. Clearcutting and maintenance in bare condition did apparently induce free water seepage, even in relatively dry years. Subsequent establishment of a weed stand followed by Kentucky bluegrass reduced seepage yield potential, but it remained higher than in thinned and unthinned portions of the stand due to less capacity for moisture depletion from the entire soil mantle.

The Forest and Water Situation

Black Hills forests have undergone striking changes since the start of settlement in the mid-1870's. Exploitive cutting, fires, and insect epidemics nearly denuded extensive forest areas in the first 30 or so years, and virtually all harvestable stands in the remainder of the area were at least partially cut over. Pine reproduction established quickly on most cutover areas. As these replacement stands developed under management and protection since about 1905, the degree of stocking started back on an upward swing and the number of acres fully occupied by forest cover gradually increased. Water yield per unit of precipitation seemingly declined during the same period.[2] Whether this apparent decline was due to the increasing forest stocking and degree of site occupancy remains debatable. Nevertheless, the extent to which pine forest in the Black Hills can or will be managed to bolster water supply may well hinge on obtaining answers to the following questions: Can thinning significantly increase amount of water available for streamflow? If so, how heavily must stands be thinned, how extensive must areas of thinning be, and how must they be managed to produce tangible and practicable water benefits?

Here reported are some results of a preliminary study designed to explore soil-moisture patterns and trends after thinning and patch clearcutting in a dense 70-year-old, second-growth pine stand.

[1] *Hydrologist, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University; the author is located at Rapid City in cooperation with South Dakota School of Mines and Technology.*

[2] *Orr, Howard K. Precipitation and streamflow in the Black Hills. U. S. Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Sta. Pap. 44, 25 pp., illus., 1959.*

Figure 1.--Looking from north to south over the forest area in which the experimental plots were located. The clearcut plot is just to left of center. The thinned and unthinned plots lie adjacent to the clearcut plot on the right.

The Study Area and Treatment

Three contiguous 120- x 150-foot plots were laid out in the summer of 1957. One was thinned to 80 square feet basal area per acre, one was clearcut, and one was left unthinned. Pretreatment stand characteristics are summarized in table 1. The posttreatment stand on the thinned plot consisted of 435 trees per acre, averaging 36 feet tall and 5.8 inches d.b.h., spaced roughly 10 feet apart.

The plots, on the lower and more gently sloping portion of a steep north to northeast facing slope (fig. 1) had an average gradient of 9 to 10 percent. Soils appeared to have developed in place from limestone parent material. Soil horizons were well developed and clearly defined. Relatively little rock was present to a depth of about 48 inches. Physical characteristics of the soil are summarized in table 2.

Combined slope position and soil characteristics indicate a tree height site index of 70 to 75 feet at 100 years—near the upper limit of the 36 to 75 range of site indices sampled by Myers and Van Deusen in their analyses of 107 Black Hills sites.[3]

Little understory vegetation was present on any of the three plots at the time of treatment in August 1957, a common condition in such dense stands. After treatment, the clearcut plot was kept free of invading vegetation by periodic application of herbicide through 1958 and 1959. It was then seeded to Kentucky bluegrass in the spring of 1960 and again in 1961.

Measurements

Gross precipitation and soil moisture are the prime factors involved in determination of the moisture relations and trends reported here. Gross precipitation was measured weekly in standard gages, one located on the clearcut

[3] *Myers, C. A., and Van Deusen, James L. Site index of ponderosa pine in the Black Hills from soil and topography. J. Forest. 58: 548-555, illus., 1960.*

Table 1.--Pretreatment stand characteristics

Treatment	Trees/acre	Average height	Diameter at breast height		Basal area
			Range	Average	
	Number	Feet	- - - - Inches	- - - -	Sq.ft./acre
Clearcut	1,462	39	1.8 - 13.1	5.0	199
Thinned 1/	1,972	32	1.7 - 9.9	4.2	190
Unthinned	2,885	29	1.0 - 8.8	3.5	193
Average	2,106	33		4.2	194

1/ One old-growth sawtimber tree, 19 inches d.b.h., was not included in the tally. This tree was cut during treatment.

Table 2.--Physical characteristics of soil

Depth interval (inches)	Sand	Silt	Clay	Texture class	Bulk density	Pore space[1]			Wilting point moisture content[2]
						Total	Detention	Retention	
	- - Percent - -				Grams/cc.	- - - - - - - - Percent of soil volume - - - - - - - -			
0- 6	29	53	18	SL	1.22	49.3	11.0	38.3	12.1
6-18	23	47	30	L-CL	1.48	41.9	7.0	34.9	20.7
18-30	22	48	30	CL	1.60	38.4	3.6	34.8	21.4
30-42	25	48	27	CL- L	1.53	40.3	4.7	35.6	17.4
42-54	31	47	22	L	1.48	41.4	6.2	35.2	14.0
54-66	35	42	23	L	1.53	42.0	6.1	35.9	12.6

1/ Determined by draining saturated soil cores to equilibrium moisture content under 60 cm. tension.

2/ Determined by draining saturated samples to equilibrium moisture content under 15 atmospheres tension.

plot and one in a nearby natural opening. A continuous record was obtained from one recording gage.

Throughfall and stemflow were also measured weekly on the thinned and unthinned plots—stemflow from the fall of 1957 through the growing season of 1959, and throughfall from the fall of 1957 through 1960. These important facets of the hydrologic cycle are to be reported separately.

Soil moisture was measured gravimetrically in late September or early October each year, 1958 through 1962. Samples were taken at 0-6 inches, and then by 12-inch depth intervals with a King tube. It was possible to sample to 42 inches depth at nearly all points, to 54 inches at about 60 percent of the points, and to 96 inches at a few points. Samples were collected at a minimum of 12 random points in the center 60- by 90-foot portion of each 120- by 150-foot treatment plot at each sampling interval.

Gravimetric determination of soil moisture was supplemented with weekly measurements from a stack of Colman units installed at one selected location in each treatment plot. These units, placed at 3, 12, 24, 36, 48, 60, and 72 inches depth, were calibrated against random gravimetric samples within treatments.

Soil bulk density was sampled by 2-inch increments in each of six pits systematically spaced to sample the entire study area. Average bulk densities measured from the six pits were used to convert percent by weight moisture contents to percent by volume and inches depth for all three treatments.

Surface runoff was measured from two 1-milacre plots in each of the three treatments.

Results

Soil moisture content was relatively high at the time of treatment in August 1957 due to above-average precipitation in the earlier summer and spring months—9.5 inches of rain in May and 5.0 inches in June. Precipitation continued slightly above average in 1958 (table 3). Three years of increasingly severe drought followed. Precipitation then rose to about 180 percent of long-time average in 1962.

At the time of general thaw in late March and early April of 1958, moisture content of the 0- to 6- and 6- to 18-inch levels was high, and probably near retention capacity in all three treatments. By the end of April, moisture had penetrated and fully recharged the 42- to 54-inch level in the clearcut plot, and free water seepage below 54 inches started. But moisture did not penetrate the 42- to 54-inch level in the thinned plot until early June, and in the unthinned plot until early July. In the thinned plot, the 42- to 54-inch level recharged to near retention capacity and some moisture

Table 3.--Gross precipitation by months and water years

Month	1958	1959	1960	1961	1962
	- - - - - - - - - - -	- - -	Inches	- - -	- - - - - - - - - - -
October	1.24	0.28	0.35	0.04	2.10
November	.71	.87	1.50	.57	.43
December	.25	.50	.27	1.20	.43
January	.39	.41	.14	.06	.54
February	.58	.64	.96	.43	.87
March	1.52	.93	.48	.91	1.00
April	4.19	2.40	2.41	2.16	1.06
May	3.43	3.46	3.02	1.98	10.65
June	4.37	3.57	2.97	2.40	8.60
July	4.46	1.61	.51	2.90	7.07
August	1.34	.22	1.95	.62	1.63
September	.09	2.71	1.17	1.44	1.42
Total annual 1/	22.57	17.62	15.73	14.71	35.80

1/ Annual amounts listed here do not in some cases coincide exactly with amounts later listed in calculations of moisture use because of slight adjustment to coincide with exact dates of soil moisture measurement.

penetrated deeper, but apparently not as free water seepage. In the unthinned plot, full recharge was reached only to the 18- to 30-inch level (fig. 2). Little moisture penetrated the 42- to 54-inch level, and there was no indication of moisture penetration below 54 inches.

In the clearcut plot, the only apparent moisture loss during the 1958 season was to evaporation from above about 18 inches depth. Seepage below 54 inches, which had started in April, evidently continued to some time in August. At the end of the season the entire 54-inch soil mantle except for the 0- to 6- and 6- to 18-inch levels remained near retention capacity; the deficit in the combined 0- to 6- and 6- to 18-inch levels was only about 0.6 inch of water. In the thinned and unthinned plots, however, combined transpiration and evaporation extracted moisture from the entire 54-inch profile and also some slight amount from below 54 inches. Persistent depletion started in both treatments in July. By the end of the season, the entire mantle in the unthinned plot had been reduced to or below wilting point moisture content. Though evapotranspiration had also extracted moisture from the entire mantle in the thinned plot, some available moisture remained throughout the mantle at the end of the season. The amount available increased with depth.

Though 1959 was a drier year than 1958, the clearcut plot again fully recharged, and seepage below 54 inches began in April and continued into August. And at the end of the

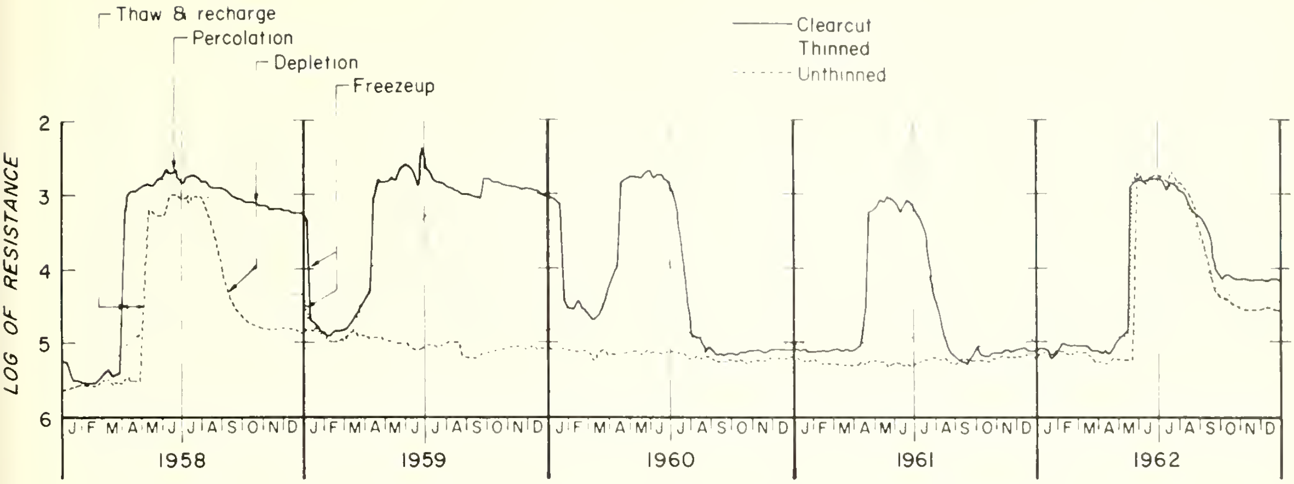

Figure 2.--Moisture trends in the 18- to 30-inch level as indicated by log resistance readings of fiberglas units.

Data are presented in terms of log of resistance rather than moisture content because calibrations were not equally precise for a given level in all three treatments. For example, the 18- to 30-inch level in the unthinned plot remained too dry throughout most of the study period for satisfactory calibration over the entire moisture range. But calibrations for this level in the thinned and clearcut plots and for high levels in the unthinned plot provided satisfactory indices of average moisture conditions within treatments. Hence log of resistance readings provide a better basis for comparison of treatment trends than moisture contents based on questionable calibrations. Retention capacity is about log resistance 3, and wilting point is about log resistance 5.

season, the mantle again remained near full retention capacity.

The 1959 moisture patterns in both the thinned and unthinned plots were characterized by lesser depths of moisture penetration and full recharge than in 1958. In the thinned plot, the 30- to 42-inch level partially recharged, but little if any moisture penetrated deeper. Little moisture, if any, penetrated below the 6- to 18-inch level in the unthinned plot, and moisture content of the mantle below 18 inches remained at wilting point or below throughout the year. Evapotranspiration accounted for the equivalent of total precipitation during the year, and for further depleted mantle storage in the thinned plot despite September rains that recharged the 0- to 6-inch level. In the unthinned plot, the moisture content of levels below the approximate 18-inch depth of moisture penetration was so low, and moisture was held at such high tensions, that further depletion by evapotranspiration was practically impossible. September rain was sufficient to more than offset what little further depletion did occur, and at the end of the season the mantle held slightly more moisture in storage than at the end of the 1958 season. Nevertheless, the entire mantle except for the 0- to 6-inch level remained at or below wilting point moisture content.

The 1960 moisture patterns in both the thinned and unthinned plots were characterized by still lesser depths of moisture penetration, full utilization of current season moisture in evapotranspiration, and further depletion of moisture storage in all levels of the profile.

Moisture pattern in the clearcut plot changed drastically in 1960, due primarily to the establishment of a vegetative cover. Bluegrass was sown in April. Along with the little bluegrass that germinated, a dense stand of weeds (mainly lambsquarter) unexpectedly developed from seed apparently lying dormant in the soil. The weed stand developed rapidly in May and June and became exceedingly rank—some growing over 6 feet tall. As in 1958 and 1959, the mantle fully recharged and free water seepage below 54 inches depth started by late April. Rapid moisture depletion by transpiration from the weed stand became apparent in the 6- to 18-inch level by late June and quickly progressed downward, cutting off free water seepage below 54 inches in July—approximately 1 month earlier than seepage had stopped in 1958 and 1959. During the season, moisture content was depleted to wilting point or below to at least 18 inches depth. By the end of the season, total mantle storage had been reduced about 7.3 inches below the amount of storage in October 1959.

The years 1958 through 1960 had been ones of increasing moisture stress for the tree plots as precipitation declined and mantle storage was depleted. The trend continued and further intensified in 1961. In the clearcut plot, which was again seeded to bluegrass (few weeds appeared), moisture penetrated only to the 30- to 42-inch level, and built up to retention capacity only to some point in the 18- to 30-inch level. Moisture penetrated no deeper than the 6- to 18-inch level in the thinned plot and the 0- to 6-inch level in the unthinned plot. Evapotranspiration apparently accounted for total precipitation during the year plus further soil-moisture depletion in all three treatments. However, the net depletions were less than in the previous 2 years due to the already severe moisture stress conditions.

The trend reversed in 1962. A season of unusually heavy precipitation started with more than 2 inches of rain falling on May 14 and 15, and a total of 10.65 inches accumulating by the end of the month. Totals of 8.60 and 7.07 inches fell in June and July. The entire 54-inch mantle fully recharged on all three treatment plots. Moisture penetrated below 54 inches earliest in the clearcut plot, latest in the unthinned plot. Apparent free water seepage below 54 inches started May 21-28 in the clearcut plot and about mid-June in the thinned and unthinned plots, and evidently continued to near September 1 in all three treatments. Persistent depletion of all mantle levels in all three treatments started in July, but rates of depletion and amounts withdrawn decreased with depth. At the end of the season, moisture was available throughout the profiles in all three treatments, the amounts remaining available increasing with depth. Measured increases in total 54-inch mantle storage over 1961 were 4.3, 4.7, and 4.7 inches respectively for the clearcut, thinned, and unthinned plots.

The descriptions of moisture trends in the foregoing paragraphs are based on the pertinent water balance equation: evapotranspiration (ET), is equal to gross precipitation (P), minus surface runoff (SRO), minus seepage below depth of measurement (X), plus (or minus) any reduction (or increase) in measured mantle storage (S).

$$ET = P - SRO - X \pm S$$

Total moisture dispostion by years can be approximated with this equation. Primary sources of moisture for disposition are gross precipitation and soil storage. If there was reduction of soil storage from the end of 1 year to the next, disposed moisture is gross precipitation plus the reduction. If there was an increase in soil storage from the end of 1 year to the next, total disposed moisture is gross precipitation minus the increase. Calculations of disposed moisture on this basis ($P \pm S$) are shown in table 4.

The above equation regrouped to place disposed moisture ($P \pm S$) on one side becomes:

$$P \pm S = ET + SRO + X$$

Surface runoff was negligible during the study and hence can be eliminated, leaving only evapotranspiration and seepage as functions of disposed moisture. By comparing periodic field measurements of soil moisture with moisture retention capacities, seepage below the 54-inch depth of measurement can be detected. In 1959, 1960, and 1961 there was no apparent moisture penetration below 54 inches in the thinned or unthinned plots, or in the clearcut plot in 1961. In these cases, total disposed moisture must have been accounted for by evapotranspiration alone, as indicated in table 4. In the remaining cases—the clearcut plot in 1959 and 1960, and all three treatment plots in 1962—disposed moisture is made up of unknown relative amounts of evapotranspiration and seepage below 54 inches.

Considering the magnitude of total mantle moisture contents in table 4 together with sampling variance, there is little doubt that fall differences between treatment plots were real and significant, especially in the fall of 1958 and again in 1959. From these apparently real initial soil moisture differences, and subsequent trends supported by the trend of annual precipitation, it is reasonable to infer also that there were real differences in evapotranspiration among all three treatment plots in 1959, and between the thinned and unthinned plots in 1960, though these contentions cannot be supported statistically due to design of the study. Then in 1961, at peak severity of the 3-year period of drought, there was apparently little if any real difference in evapotranspiration among the three treatment plots.

It could not be claimed that total disposed moisture for the thinned and unthinned plots in 1959, 1960, and 1961 represents total evapo-

Table 4.--Total disposed moisture, precipitation plus or minus change in 54-inch mantle storage, by treatments and water years[1/]

Moisture factor	Clearcut		Thinned		Unthinned	
	- - - - -	- - - - -	- - - - -	Inches	- - - - -	- - - - -
1959						
Gross precipitation		17.57		17.57		17.57
Soil moisture 9/58	17.39		12.62		8.47	
Soil moisture 10/59	18.28		11.55		9.21	
Moisture change	+ 0.89	- 0.89	- 1.07	+ 1.07	+ 0.74	- 0.74
Disposed moisture		16.68		18.64		16.83
1960						
Gross precipitation		15.79		15.79		15.79
Soil moisture 10/59	18.28		11.55		9.21	
Soil moisture 10/60	11.01		8.92		8.21	
Moisture change	- 7.27	+ 7.27	- 2.63	+ 2.63	- 1.00	+ 1.00
Disposed moisture		23.06		18.42		16.79
1961						
Gross precipitation		14.71		14.71		14.71
Soil moisture 10/60	11.01		8.92		8.21	
Soil moisture 10/61	10.73		8.43		7.93	
Moisture change	- 0.28	+ 0.28	- 0.49	+ 0.49	- 0.28	+ 0.28
Disposed moisture		14.99		15.20		14.99
1962						
Gross precipitation		35.80		35.80		35.80
Soil moisture 10/61	10.73		8.43		7.93	
Soil moisture 10/62	15.04		13.14		12.65	
Moisture change	+ 4.31	- 4.31	+ 4.71	- 4.71	+ 4.72	- 4.72
Disposed moisture		31.49		31.09		31.08

1/ Amounts of disposed moisture underlined are fully accounted for as evapotranspiration. The others include unknown amounts of seepage.

transpiration. Though no moisture apparently penetrated below 54 inches on either treatment plot in any of the 3 years, there was some moisture depletion from below 54 inches as indicated by both gravimetric sampling and electrical resistance readings. Moisture tension remained so great, however, that the amount of depletion must have been extremely small. Quantitative accounting, were it possible, would add to evapotranspiration totals and almost certainly result in even greater differences between treatments than are evident in table 4.

Summary and Discussion

Results of this preliminary study suggest several points of potential significance to design of forest management practices for conservation of water. Thinning dense second-growth pine on a high-quality site from 190 square feet basal area and nearly 2,000 trees per acre to 80 square feet basal area and 435 trees per acre immediately reduced evapotranspiration. Consequently, more moisture was held in soil storage on a thinned than on an unthinned plot entering a period of 3 successively drier years. Under these conditions, evapotranspiration was apparently greater from the thinned than from the unthinned plot because more soil moisture was available. At the same time, however, the seepage potential remained higher on the thinned than on the unthinned plot because of a smaller soil moisture deficit.

In 1962, when precipitation rose to nearly 36 inches, more than twice the amount received the previous year, the soil mantle fully recharged on both the thinned and unthinned plots. Free water seepage below 54 inches depth apparently started a short time earlier from the thinned plot than from the unthinned plot, however, which suggests a greater total seepage for the season from the thinned.

Clearcutting and maintenance in bare condition definitely induced free water seepage when it evidently would not have occurred otherwise, judging from the unthinned plot. Later establishment of a weed stand and then bluegrass reduced soil moisture storage and hence the seepage yield potential, but the seepage yield potential remained higher than in the thinned or unthinned plots because of shallower depth of soil moisture depletion.

These results strictly apply only to the one set of three experimental plots on a high-quality site and under the recorded sequence of precipitation year events. Also, results were no doubt influenced by protection of the surrounding uncut forest. Hence results could be considered pertinent only to cut areas of similar size similarly protected. The size of the clearcut plot and the degree of protection by surrounding forest might be fairly typical of patch clearcutting for water yield improvement. Routine thinning, however, ordinarily involves larger areas. More comprehensive study is needed to determine the potential, particularly of thinning, for water yield improvement on a wider variety of sites and on larger areas. Such studies are urgently needed for guidance in making management decisions aimed at better integrated production and utilization of water, timber, and forage in the Black Hills.

Agriculture --- CSU, Ft. Collins

1968

U.S. FOREST SERVICE
RESEARCH NOTE RM - 100

FOREST SERVICE
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Effect of a Watershed Treatment with Picloram on Water Quality

E. A. Davis, P. A. Ingebo, and C. P. Pase [1]

A watershed treatment of soil-applied picloram pellets for the control of chaparral brush resulted in the movement of detectable amounts of picloram into the stream water. The highest concentration found was 0.37 p.p.m. After 16 months and 40 inches of accumulated rainfall, picloram was no longer detectable in the stream water.

The potential danger of contaminating stream water with chemicals applied to watersheds for the control of brush or other undesirable vegetation cannot be overlooked. Watershed chemical treatments for widespread use should not adversely affect the products of the streams, lakes, and reservoirs, or subsequently irrigated crops. They should also be harmless to wildlife, livestock, and humans.

Picloram is a potent herbicide, effective against a broad spectrum of forbs and woody plants.[2] The effectiveness of picloram on shrub live oak (Quercus turbinella Greene)[3] in greenhouse studies suggested its use for the control of chaparral shrubs on experimental watersheds in Arizona (Davis 1964). This report concerns the picloram content of stream water from a chaparral watershed partially treated with picloram.

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[2] *Bovey 1965, Gantz and Laning 1963, Goodin et al. 1966, Green et al. 1966, Nation 1965, Watson and Wiltse 1963, Wiltse 1964.*

[3] *Nomenclature according to Kearney and Peebles. Arizona flora with supplements. Ed. 2. 1085 pp. 1960.*

Experimental Design

Three-Bar watershed B is located at 3,300 feet elevation in the Mazatzal Mountains of central Arizona. The 46.5-acre watershed is situated about 8 miles northwest of Lake Roosevelt. The brush is predominantly shrub live oak mixed with a variety of other sclerophyllous species such as birchleaf mountainmahogany (Cercocarpus betuloides Nutt.), sugar sumac (Rhus ovata S. Wats.), yellow leaf silktassel (Garrya flavescens S. Wats.), and Palmer oak (Quercus dunni Kellogg). Emory oak (Quercus emoryi Torr.) occurs along the wetter stream bottom sites. The soil is of granitic origin, coarse textured, and highly permeable to water.

The treatment was designed to determine the effect of partial elimination of brush on water yield and sediment production, and consisted of chemically treating all shrubs, with the exception of the most desirable browse species, on northeast-facing slopes and in the channel bottoms (fig. 1). The total treated area contained 18.5 acres (39.8 percent of the watershed). The major portion of the treated area (16.4 acres) received a soil application of fenuron (3-phenyl-1,1-dimethylurea). The northeast-facing slope (2.1 acres) of a small distinct drainage was treated with a soil application of the potassium salt of picloram (4-amino-3,5,6-

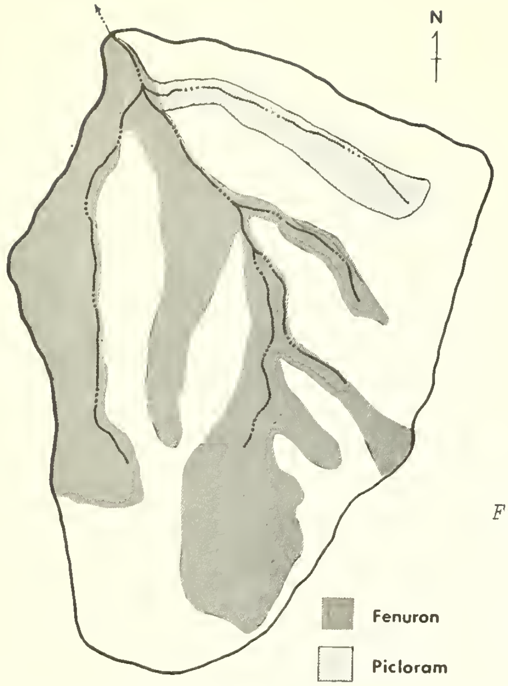

Figure 1.--Diagram of watershed B. Only northeast-facing slopes and channel bottoms were treated. Lightly shaded area was treated with soil-applied picloram. Darkly shaded areas were treated with soil-applied fenuron.

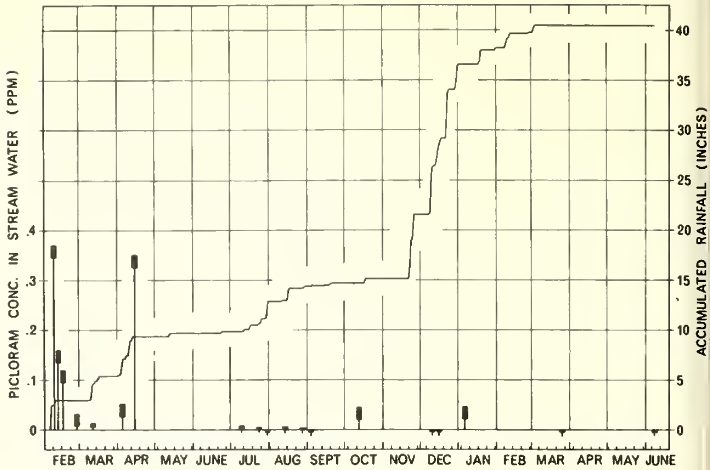

Figure 2.--Picloram concentration in the stream water from watershed B, and accumulated rainfall, measured at base of watershed, during a 16-month period after treatment. Picloram was applied on February 1, 1965.

trichloropicolinic acid).[4] Only ground occupied by shrubs was treated. Picloram pellets (10 percent acid equivalent) were applied by hand February 1, 1965, at an intended rate of 8 pounds (acid equivalent) per acre to the ground actually treated. Upon completion of the treatment the overall rate on the 2.1-acre slope was found to be 9.3 pounds (acid equivalent) per acre. Although this rate was probably higher than necessary to eradicate several of the shrub species, it was marginal for shrub live oak.

Because the picloram-treated drainage was small, surface flows seldom occurred in its channel, and it was not generally possible to obtain water samples directly from it. On three occasions about a year after treatment, however, such samples were possible. All other samples were collected at the weir at the base of the watershed, where picloram was diluted by water yield from the entire watershed.

Water samples were collected at irregular intervals over a period of 16 months, from February 8, 1965, through June 7, 1966. The samples were stored in 1-pint brown polyethylene bottles at 35°-38° F. prior to analysis. Samples were analyzed by a sand culture bioassay method (Leasure 1964).[4] Safflower was used as the indicator plant. Because the bioassay method can detect minute amounts of picloram at levels below those at which fenuron is inhibitory, it was possible to analyze the samples by this method even though fenuron may have been present.

[4] *Appreciation is extended to The Dow Chemical Company for providing the picloram used in this study, and for performing the picloram analyses.*

Results

Movement of picloram into and through the soil and into the stream water depends upon rainfall. The relationship between rainfall, measured at the base of the watershed, and picloram concentration in the stream water as a function of time is given in figure 2.

On the fifth and sixth days after treatment there was a 2.53-inch rain. On the seventh day, the picloram concentration in the stream water at the weir was 0.37 p.p.m. During the next 30 days there was only 0.73 inch of rain, and the concentration of picloram steadily declined through the period to 0.014 p.p.m. on March 11. From March 11 through April 14 it rained on 14 days, with a total of 6.02 inches for the period. On April 14 the picloram concentration had increased to 0.35 p.p.m. In the next 6 months, rainfall totaled 5.38 inches, and picloram was present either in trace amounts (0.003 to 0.008 p.p.m.) or was not detectable; on October 12 the concentration was 0.045 p.p.m.

Rainfall from October 14 through December 15 was 13.59 inches, with heavy rains after November 21. A water sample was collected from the picloram-treated drainage alone for the first time on December 10, and again on December 15; both samples were free of picloram. By January 5, 1966, an additional 8.23 inches of rain had fallen, and the concentration of picloram at the weir was 0.046 p.p.m. From January (

through March 25, rainfall totaled 3.95 inches. On March 25, another water sample was obtained from the picloram-treated drainage alone, and was found to be free of picloram. The last water sample was collected at the weir on June 7, 1966, after 3 months without rain, and did not contain picloram in detectable amounts.

Discussion

The extent of movement of picloram into the stream was related to rainfall duration and amount. For example, a series of 10 rains totaling 4.05 inches over a period of 26 days (March 10 - April 4) produced only 0.052 p.p.m. in the stream water. A series of 19 showers totaling 5.03 inches over 130 days (April 27 - September 3) produced zero to 0.008 p.p.m. However, after 2.53 inches of rain over a 2-day period (February 6-7) the stream water contained 0.37 p.p.m. picloram. Also, after 5 storms which gave 2.22 inches in 6 days (April 7-12) the picloram concentration was 0.35 p.p.m. The high concentrations of picloram occurred after periods of heavy rainfall. Equal or greater total amounts of rain received in small showers over an extended period of time produced only trace amounts of picloram. The high concentration of picloram after the initial heavy rain could have resulted from surface and subsurface movement of chemical. It is possible there was a brief flow of water in the channel during and immediately following the storm, and that some picloram was moved rapidly over the soil surface. Then at the point where surface flow ceased subsurface movement could have occurred. Rapid subsurface movment of picloram was also possible since the loose rocky soil would be expected to offer minimal resistance to leaching. The extent of leaching of picloram is inversely related to the extent that it is sorbed by the soil, and to the water-holding capacity of the soil. It is most readily leached through sandy montmorillonitic soils low in organic matter, and leached with the greatest difficulty through lateritic clay soils and muck soils (Dow Chemical Company 1963) The susceptibility of picloram to leaching (Hamaker et al. 1963; Merkle et al. 1966) is one reason that soil applications are effective on deep-rooted plants.

That the movement of soil water is a layered process, in which new rainfall on the surface of the soil pushes the old water downward, is nicely demonstrated with tritiated water (Zimmermann et al. 1966). Seepage water is old capillary water freed by the wave of water from above. Movement of picloram through the soil and into the stream water can be viewed in much the same way, with the sorption process interposed. The fact that picloram was not detected in the stream water after nearly 26 inches of winter rain indicates that most, if not all, of the free picloram had been removed. After a total of 40.43 inches of rain in the 16-month period after treatment, picloram was not detected in stream water from the picloram-treated drainage alone, or in the stream water from the entire watershed.

Picloram not lost through leaching is highly persistent; it is only slowly decomposed by soil microorganisms (Hamaker et al. 1963). Analyses of treated soils from four States indicated losses of picloram ranging from 58 to 96 percent within 1 year after application, in areas receiving 5 to 22 inches of rain (Goring et al. 1965).

It is clear that some contamination of stream water occurred as a result of the soil application of picloram. The highest concentrations, 0.37 p.p.m. and 0.35 p.p.m., were in samples collected at the weir at the base of the watershed. Since the picloram-treated slope represented only 4.5 percent of the total area of the watershed, there was a possible 22-fold dilution in the concentration of picloram in the water from the picloram-treated drainage.

Toxicological studies have shown that picloram is low in toxicity to a variety of test animals, including avian, mammalian, and aquatic species, and that it does not represent a hazard to livestock or wildlife when used as recommended (Lynn 1965). The maximum concentration tested that caused no observable ill effects on a variety of fish species after 96 hours' exposure was 100 to 320 p.p.m. In an aquatic food chain study, water containing 1 p.p.m. picloram had no adverse effects on the growth of algae, Daphnia, or guppies (Hardy 1966). Data on the acute oral toxicities (single doses) of 2,4-D and picloram indicate that 2,4-D is 5 to 20 times more toxic than picloram to rats, mice, and guinea pigs (Lynn 1965, Rowe and Hymas 1954).

Although there is no apparent hazard to wildlife, stock, or aquatic organisms from a watershed treatment such as that applied on watershed B, the use of picloram-contaminated water for irrigation purposes could cause crop damage. Crops such as alfalfa, sugar beets, safflower, and soybeans are very sensitive to picloram. H. F. Arle[5] found that 2 ounces (0.125 lb.) of picloram per acre applied in 3.5 acre-inches of water (0.158 p.p.m.) at the first postemergence irrigation, reduced the yield of cotton on the first picking but not on the second picking; total yield was normal. Stream water from watershed B contained a peak concentration of 0.37 p.p.m. picloram, which, if used directly to irrigate sensitive crops, could represent a hazard. Water from treated areas generally would be vastly diluted with water from other regions, however, as in the case of the watershed B treatment. The potential danger of widespread watershed treatments with picloram would depend on the extent of contamination of the reservoir and canal systems. In turn, the level of contamination of these systems would depend upon the percentage of the total watershed area treated within the region feeding the reservoir, and the distance between treated areas and irrigated croplands. Some loss of picloram in the water could be expected due to its degradation by ultraviolet light (Dow Chemical Company 1963).

The results of this study can only serve as a guide to the possible effects on stream water quality when watersheds are treated with picloram. The extent of contamination caused by picloram treatments can be expected to vary with location, and will depend upon size of area treated, amount of chemical applied, type of application (soil or foliage), soil type and properties, topography, and precipitation.

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1968

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RESEARCH NOTE RM - 101

OREST SERVICE
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Natural Reproduction of Spruce-Fir After Clearcutting in Strips, Fraser Experimental Forest

Robert R. Alexander[1]

Numbers and stocking of seedlings and saplings on 1-, 2-, 3-, and 6-chain-wide clearcut strips were determined after logging in 1956, and in 1966. Reproduction in 1966 will provide a satisfactory replacement stand on all strip widths tested, but it is largely advanced growth that survived logging. Both advanced and subsequent reproduction is predominantly subalpine fir, but there is enough Engelmann spruce to provide an adequate representation of this more valuable species in the replacement stand on all strip widths.

In the central Rocky Mountains, some pattern of clearcutting has generally been the initial step in converting old-growth stands of Engelmann spruce (Picea engelmannii Parry)-subalpine fir (Abies lasiocarpa (Hook.) Nutt.) into manageable stands of young growing stock. Low stumpage values coupled with the difficulty of establishing artificial regeneration have made restocking clearcut areas with natural regeneration a fundamental objective in spruce-fir management.

Past research on the Fraser Experimental Forest has shown that spruce reproduces slowly but ultimately well after clearcutting small openings.[2] Elsewhere in Colorado, the establishment of natural reproduction of spruce after clearcutting has been variable, with stocking generally better on small than large openings.[3] Although advanced growth was predominately subalpine fir, it contributed substantially to total stocking on both large and small clearcut openings. Furthermore, those trees helped maintain an environment favorable to the establishment of new reproduction.[4]

The Study

This paper reports the 10-year results of a study to test the effect of clearcutting on (1) the establishment of new reproduction, and (2) the development of residual advanced growth left after logging in 1956 in the spruce-fir type on the Fool Creek drainage of the Fraser Experimental Forest.

Description of Area

The study area was located on north- and northwest-facing slopes at 10,500 to 11,000 feet

[1] *Principal Silviculturist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Alexander, Robert R. Harvest cutting old-growth mountain spruce-fir in Colorado. J. Forest. 61: 115-119, illus. 1963.*

[3] *Alexander, Robert R. Stocking of reproduction on spruce-fir clearcuttings in Colorado. U. S. Forest Serv. Res. Note RM-72, 8 pp., illus. 1966. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

[4] *Ronco, Frank. Lessons from artificial regeneration studies in a cutover beetle-killed spruce stand in western Colorado. U. S. Forest Serv. Res. Note RM-90, 8 pp., illus. 1967. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

elevation. Slope gradients ranged from 10 percent on the north slope to 30 percent on the northwest slope. Soils are gravelly, sandy loams of the Darling series, developed in place from gneisses and schists, interspersed with bogs and wet places.[5]

The original forest overstory was a mature to overmature stand of 250- to 350-year-old Engelmann spruce and subalpine fir, intermixed with various amounts of old-growth lodgepole pine (Pinus contorta Dougl.). The understory was composed of spruce and fir seedlings, saplings, and poles.

Ground vegetation on the Darling soils—predominately grouse whortleberry (Vaccinium scoparium Leiberg)—did not increase after cutting. Ground vegetation in the bogs and wet places—principally grasses, sedges (Carex spp.), mountain bluebell (Mertensia ciliata G. Don), arrowleaf groundsel (Senecio triangularis Hook.), bittercress (Cardamine cardifolia A. Grey), brook saxifrage (Saxifraga arugta D. Don), cranesbill (Geranium richardsonii Frisch and Trautv.), Rocky Mountain parmissia (Parmissia fimbrata Koenig), fleabane (Erigeron speciosus (Lindl.) DC), and alpine pyrola (Pyrola asorifolia Michx.),—increased considerably after cutting.

Cutting Pattern

Timber was removed in alternate clearcut strips located at right angles to the contour. Four different widths of clearing were used: 1, 2, 3, and 6 chains. The four strip widths were repeated on each aspect. Average length of the clearings was about 600 feet, the slope distance between logging spur roads (fig. 1). All trees 4.0 inches in diameter and larger were removed from the cleared strips by horse skidding. No special precautions were taken to avoid damaging advanced growth. Cutting began in 1954 and was completed in 1956.

Measurements

Reproduction was surveyed after logging was completed in 1956, and in 1966. Measurements were made to the same standards each time. A stratified random sample of 360 milacres—10 milacres on each of 36 transect lines, 10 links wide and 100 links long—was taken in each width of clearing on each aspect. Distribution of the transects on each aspect were: six transect lines in each of six 1-chain-wide strips, 12 transect lines in each of three 2-chain-wide strips, 18 transect lines in each of two 3-chain-wide strips, and all 36 transect lines in one 6-chain-wide strip.

Numbers and stocking of seedlings and saplings from 2 years old to 4.0 inches in diameter were recorded by species for each milacre sampled. Only reproduction of good form and vigor was included. An attempt was made to record reproduction as either advanced or subsequent in the 1966 survey but that was not possible. Subsequent reproduction in this paper is therefore expressed as the increase in numbers and stocking of seedlings between 1956 and 1966.

Analysis of Data

Relationships between density and stocking of seedlings and saplings by species in 1966, and strip width and aspect were tested by covariance analyses. The 1956 data were used as a covariate in the analyses to represent initial conditions. There were no significant differences in either adjusted density or stocking of spruce and fir reproduction due to aspect, but differences between strip widths were significant for both variables of spruce reproduction. The width x aspect interaction was also significant for both species and both variables—primarily because the 1-chain-wide strips did not behave in the same manner on each aspect. However, since the differences between 1-chain-wide strips on the two slopes were associated with factors other than size of opening and aspect, the data from the two slopes were combined to show the average increase in reproduction on the different strip widths between 1956 and 1966.

Results

Numbers of Seedlings and Saplings

On Fool Creek, where stands contained abundant advanced reproduction, enough trees survived logging to restock all strip widths

[5] *Retzer, J. L. Soil survey of Fraser alpine area, Colorado. U. S. Forest Serv. and Soil Conserv. Serv., in cooperation with Colo. Agr. Exp. Sta., Series 1956, No. 20, 47 pp., illus. 1962.*

tested; numbers ranged from 4,183 per acre on the 2-chain-wide strips to 5,957 per acre on the 6-chain-wide strips (table 1). Composition of surviving advanced growth was predominately subalpine fir. Firs outnumbered the more valuable spruces by about four to one on the 2- and 6-chain-wide strips, two and one-half to one on the 1-chain-wide strips, and three to two on the 3-chain-wide strips. There were no lodgepole pines in the advanced reproduction.

Advanced reproduction, although desirable stocking in spruce-fir forests, may not be abundant in all old-growth stands. Furthermore, results from similar studies on the Fraser Experimental Forest indicated that only about one-half of the advanced growth survives logging.[7, 6] Where advanced reproduction is scarce, the effectiveness of any cutting pattern for regenerating a stand must be measured in terms of new reproduction established after cutting.

Subsequent reproduction was not abundant on any of the strips 10 years after cutting. The best recovery was made on the 3-chain-wide strips where 1,365 new seedlings per acre were established. New seedlings on the 3-chain-wide strips outnumbered the increase on the 1- and 6-chain-wide strips by more than two times, and were four times greater than the increase on the 2-chain-wide strips (table 1).

Species composition was not improved by new reproduction. More new firs than new spruces were established on all strips except the 2-chain-wide, where new lodgepole pines outnumbered both spruces and firs. Lodgepole pines also established in greater numbers than spruces on the 6-chain-wide strips. Establishment of subsequent lodgepole pines was related to the amount of pine in the original overstory, however, and not to strip width.

The failure of species composition to improve after cutting is in disagreement with past work on the Fraser Experimental Forest and elsewhere in Colorado.[2 7] In those studies, new spruces greatly outnumbered the increase in new first on both narrow and wide clearcut strips.

[6] *Alexander, Robert R. Damage to advanced reproduction in clearcutting spruce-fir. U. S. Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Res. Note 27, 3 pp., 1957. Fort Collins, Colo.*

[7] *Alexander, Robert R. Unpublished data on file, Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

Figure 1.--Aerial view of Fool Creek, showing pattern of cleared strips and road network.

Stocking

All strips were well stocked after logging; stocking ranged from 76 percent on the milacres sampled on the 1-chain-wide strips to 83 percent on the 6-chain-wide strips. Although advanced reproduction that survived logging was predominately subalpine fir, Engelmann spruce was adequately distributed on all strips; 54 percent of the milacres sampled were stocked to spruce on the 3-chain-wide strips, 48 percent on the 1- and 6-chain-wide strips, and 37 percent on the 2-chain-wide strips (table 1).

Total stocking increased at about the same rate as new reproduction established after logging, but the increase in stocking was propor-

Table 1.--Numbers and stocking of seedlings and saplings, Fool Creek, Fraser Experimental Forest, Colorado -- 1956, 1966

Width of openings and species	Trees			Stocking		
	1956	1966	Increase	1956	1966	Increase
	- - Number per acre - -			- - Percent per acre - -		
1-chain-wide openings:						
Engelmann spruce	1,360	1,453	93	47	52	5
Subalpine fir	3,036	3,557	521	68	70	2
Lodgepole pine	0	26	26	0	1	1
All	4,396	5,036	640	76	78	2
2-chain-wide openings:						
Engelmann spruce	894	988	94	37	46	9
Subalpine fir	3,289	3,378	89	75	77	4
Lodgepole pine	0	162	162	0	10	10
All	4,183	4,521	345	78	86	8
3-chain-wide openings:						
Engelmann spruce	2,017	2,386	369	54	68	14
Subalpine fir	3,186	4,176	990	70	80	10
Lodgepole pine	0	6	6	0	1	1
All	5,204	6,568	1,365	78	86	8
6-chain-wide openings:						
Engelmann spruce	1,182	1,208	26	48	52	4
Subalpine fir	4,775	5,306	531	79	82	3
Lodgepole pine	0	132	132	0	6	6
All	5,957	6,646	689	83	88	5

tionally greater for spruces and pines than for firs. By 1966, from 78 to 88 percent of the milacres sampled were stocked, and spruce was present on 46 to 64 percent of the milacres (table 1).

Conclusions

Reproduction on Fool Creek in 1966 will provide a satisfactory replacement stand on all strip widths tested, but it is largely advanced growth that survived logging. Both advanced and subsequent reproduction is predominately subalpine fir, but there is enough spruce on all strip widths to provide a good representation of the more valuable species in the replacement stands. Although the increase in both numbers and stocking of new seedlings differed between strip widths, there was no apparent relationship between size of opening and new reproduction established after logging.

The scarcity of subsequent reproduction can be attributed in part to seed supply, and competition from ground vegetation. Seedfall studies on Fool Creek show that seed crops of both spruce and fir during the period 1956-65 were fair to moderate in 3 years, poor in 3 years, and nearly complete failures in the other 4 years.[7] On those strips located wholly or in part in wet places, grasses and other ground vegetation increased so rapidly after cutting that they created an effective barrier to the establishment of new reproduction, especially of spruces, which have more exacting seedbed requirements than first. On some individual strips, the density of herbaceous vegetation was so great that competition reduced the numbers of seedlings and saplings surviving in 1966 to less than the number alive in 1956.

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Engineering Techniques and Principles Applied to Soil Erosion Control[1]

Burchard H. Heede[2]

Two basic approaches to erosion control are (1) resisting natural forces, and (2) utilizing them. Examples of (1) are check dams and grassed waterways; of (2), Italian hydraulic reclamation where erosive forces are used to stabilize watersheds. Objective of both is to establish a vegetation cover.

Engineering approaches to soil erosion control can be classified into two broad groups if viewed in terms of energy. The first and possibly much older group embraces all those measures that check the erosive forces of the water. Two classical approaches—treatments by check dams and by grassed waterways—illustrate this group, and are discussed on the basis of research findings at the Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service.

The second approach utilizes, rather than combats, the erosive forces to stabilize a watershed. Italian hydraulic reclamation is an example.

The intent of all these erosion control measures is to establish a vegetation cover. Check dams and grassed waterways both modify the regimen of the flow by decreasing the erosive forces of the waterflow to a level that permits vegetation to grow. The vegetation cover, in turn, must enhance the stabilization processes to make the treatments fully successful and durable.

[1] *Paper presented at Panamer. Soil Conserv. Congr., 1st Congr. (Sao Paulo, Brazil, Apr. 12-29, 1966) v. 1, sect. 1, pap. 6, 16 pp.*

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In Italian hydraulic reclamation, the erosive action of the water is concentrated at selected locations on the watershed until a more erosion-resistant topography has been developed.

Principles

Check dams transform the original turbulent gully flow to more tranquil flow by slowing the water velocities at the upstream face of the structure, and by dissipating the water energies on the structural aprons. Thus, in a system of check dams, water turbulence and accompanying erosion energies decrease downstream. Decreases are therefore greatest where the largest number of dams are installed, assuming identical conditions of flow and channel. Yet, stabilization can generally be attained without constructing excessive numbers because gullies tend to stabilize as a result of structural influences.

In the United States, early check dams were spaced to keep the crest of spillway of a structure at the same elevation as the toe of the next upper structure. This spacing did not allow for the fact that the deposition above check dams has a positive slope and that closely spaced dams will therefore, interfere with the deposition processes. We found accumulations of sediment between check dams that buried the upper structure to half of its effective height. It was estimated that nearly 25 percent of the sediment-catching capacity of the dams had not been utilized due to close spacing.

Unfortunately, information on the deposition slope above gully control structures has been derived empirically and then only for some areas. Several studies showed that a relationship exists between the slope of deposition above dams and that of the original channel (Ferrell 1959, Heede 1960).[3]

More recent research (Woolhizer and Lenz 1965) demonstrated that not only the original channel gradient influences the deposition slope, but also the width of the channel at the structure and the height of crest of spillway above the original channel thalweg. The mechanical composition of the sediment was not statistically significant. Within the range of slope values encountered, a prediction equation was developed, valid for the physiographic region of the study area.

The deposition of sediment above check dams influences flow and channel. Since the slope gradient of the deposition will be smaller than that of the original thalweg, flow velocities will decrease as compared with those before treatment. In V-shaped gullies, the sediment deposits will also provide a wider channel bottom on which the flows will have larger width and shallower depth. This also decreases velocities by increasing the wetted perimeter and the roughness. Furthermore, depositions decrease gully depth and the length of the gully side slopes. Since a shorter side slope adjusts faster to its natural angle of repose, and a vegetation cover can grow on stable slopes only, depositions are important in gully stabilization.

In contrast to gully control by check dams, treatments by waterways change the topography immediately and strive to establish a vegetation cover when land reshaping is finished. The replacement of raw gullies by smoothed waterways not only facilitates the growth of vegetation but also modifies the regimen of future flows. These modifications result in decreased flow velocities and load-carrying capacity of the water and its erosive energy. Then cover crops combined with intensive agricultural management will maintain stabilization.

Gully control structures differ from conventional water storage structures in two important aspects that influence design criteria. First, the failure of water storage dams often entails some jeopardy to life and high-cost property. Second, the stability of such structures generally remains static or deteriorates with age. Thus the initial design of water storage dams must be adequate to withstand the full stresses of anticipated events indefinitely or over some specified life with full allowance for the expected deterioration with time.

In contrast, failures of gully control dams do not usually jeopardize life or valuable property because they are commonly located on wild lands where human habitation is sparse and cultural features are few. Also, and very significantly, their design stability is augmented in time by the very nature of their function—that of trapping sediment to the point where the structure crest becomes a new level of the upstream gully floor. Thus, an effectively designed and placed check dam should be exposed to the full magnitude of design stresses only during an initial period of time, and one so limited that there should be very low probability of an event with destructive potential.

The costs of structures are mainly related to stability aspects and factors of safety. Thus, if designs are based on somewhat higher risks, considerable savings may be possible.

Design of Check Dams

Check dams may be classed in two categories: (1) porous dams built of logs or loose rocks and (2) solid dams built of concrete or masonry.

Porous dams, although made of low-cost materials, are, to some extent, more difficult to design than are solid dams. For any given flow, the dynamic and hydrostatic pressures on a porous structure are smaller than on a solid dam. Other forces may be greater, however, such as the buoyancy on individual structural components, and may lead to the dam's destruction. On the other hand, loose rock gives a check dam the flexibility to fil

[3] *Kaetz, A. George, and Rich, Lowell R. Report of surveys made to determine grade of deposition above silt and gravel barriers. (Unpublished office report of U. S. Soil Conserv. Serv., Albuquerque, N. Mex., Dec. 5, 1939; on file in SCS library, Albuquerque.)*

cavities and other washouts at the structural site and thus stop erosion processes otherwise leading to destruction. Yet, basic information is missing on the magnitudes of pressure releases and the relationships between buoyancy, gravity, and displacement of rocks of different shapes, sizes, and weights within a check dam and in its keys located in the gully side slopes. Therefore, the design of this type of dam cannot be based on energy calculations.

In spite of the fact that porous dams cannot be scientifically designed, such structures, intuitively built, have often proved successful in the course of land management history (Evenari et al. 1961). To learn why these devices are successful, studies were initiated to evaluate the effectiveness of early check dam systems built of logs and loose rocks in gullies of the Colorado Rocky Mountain Front Range in the 1930's (Heede 1960). The elevation of the study areas ranged from 7,000 feet to 9,000 feet. Average yearly precipitation was about 16 inches. The soils comprised two complexes derived from granite and shale, respectively. The study showed that, for effective control by check dams, the critical locations in gullies should be recognized and that a successful design of the individual dams must fulfill the hydraulic requirements.

Another study was initiated with the objectives to design and construct different types of rock check dams in gullies, embedded in marine shales and sandstones of the Colorado Rocky Mountains at an altitude varying from 7,500 feet to 8,500 feet. Yearly precipitation averaged 17.4 inches. Preliminary results indicate that simply built check dams should maintain their place in modern gully control (Heede 1966). Double-fence rock check dams with effective heights between 2 and 6.5 feet proved most economical. Within this range of heights, and on slope gradients between 0.05 and 0.15, a check dam system with higher dams was less expensive than a system based on lower dams.

Solid dams also have a place in gully control. Design problems are more clearly understood and more easily solved. They have not been used extensively, however, because construction costs are often excessive in remote watershed areas. In an attempt to overcome this limitation, the author designed a low-cost, prefabricated and partially prestressed concrete check dam (Heede 1965b). A prototype was built and tested in the same watershed where our rock check dams were installed(fig. 1). The check dam consists of 9 major units, is 45 feet long, 4 feet high, as measured from

Figure 1.--After one year, sediment has collected to the crest of a prefabricated concrete check dam. Rock riprap below the dam protects gully bottom and side slopes from impact of falling water and the eddies near the banks.

original gully bottom to crest of spillway, and was installed in 3 hours in a gully at the mouth of a 1-square-mile watershed. Installation time did not include excavation and backfilling.

The larger units of the dam were built from lightweight concrete, which permit airlift by helicopter. Mass production on the basis of the prototype is feasible and would decrease the cost of the dam considerably. It is estimated that the manufacture of the parts for 15 or more prototype dams would cost $1,000 each. With slight modifications, the design is also applicable to weirs.

During the first spring snowmelt after installation, the dam accumulated 4,000 cubic feet or 140 tons of sediment to the crest of its spillway. Continuous flows lasted 5 weeks and saturated the deposits and the gully side slopes. Thus, the hydrostatic pressure of the water and the saturated soil pressure of the deposits acted simultaneously on the dam. The structure passed through the most severe test it will probably ever experience. During its existence to date of 2½ years, neither the dam nor the gully site has required maintenance.

Design of Waterways

In our study,[4] the design criteria applied to the installation of grassed waterways differed in some regards from those used in agriculture. The main criteria were:

1. Place waterway away from the gully fill on undisturbed soils;
2. Increase the length of waterway over that of the original gully and thus decrease the gradient of the thalweg;
3. Design gently rounded cross sections that allow waterflows to spread;
4. Keep earth cuts as shallow as possible to avoid exposure of underlying, low-fertility soil or rock;
5. Save topsoil during construction and spread over surface of waterway and all disturbed areas to help establish vegetation; and
6. Establish as quickly as possible grass or other low-growing vegetation on waterway and all other disturbed areas.

[4] *Heede, Burchard H. Conversion of gullies to vegetation-lined waterways on mountain slopes. 1968. (In preparation for publication, Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.)*

We inspected formulas and design procedures established empirically by older research (Chow 1959, Ree and Palmer 1949) and found that they were not applicable to the design of our waterways. In this older research, grass species differed from ours and slope gradients were gentler. Plants and gradients both influence the roughness of flow, a parameter most important in flow and channel stability calculations and very difficult to estimate with some degree of reliability. Since small differences in the value of the roughness cause large differences in the results, the usefulness of calculations not supported by established values becomes highly questionable. We found, as others have (Miller 1965), that a strong need exists for more research on the roughness coefficient at different conditions of flow, channel, and vegetation.

Not all gullies of our study watershed could be treated by waterways. Some gullies were located on valley bottoms or smaller topographic depressions that did not provide sufficient space for a waterway or would have required the new watercourse to be too straight and short. Other gullies were so large that deep cuts into the land surrounding the channel would have been required to furnish the gully fill material. The watersheds of still other gullies had such shallow topsoil that the supply would have been inadequate for spreading over all disturbed areas after construction. Thus, the decision of where to apply waterways was based on gully and valley characteristics.

Individual waterway design was largely determined by the topographic conditions of the site. For example, the width of a valley bottom generally limits the length of the waterway and with this, the flatness of the gradient. Our data showed that we could increase the length of the waterways over that of the original gullies by 8 to 17 percent, and at the same time decrease the gradients by 9 to 17 percent. These figures indicate a considerable decrease of the erosive energies during future flows.

When the construction of the waterways by a tractor with blade and a sheepfoot roller was finished, vegetation was planted on the waterways and all disturbed areas. For quick cover, yellow sweetclover and ryegrass, and for a permanent cover, smooth brome and intermediate wheatgrass were seeded.

After three or four growing seasons, the waterways were compared with the untreated gullies. Gullies and waterways were resurveyed by means of a net of reference points that had been established when construction was finished. The resurvey showed that losses by erosion corresponded to an average depth of soil of 0.04 inch on the entire area tributary to the waterways, as compared with an average of 0.34 inch on the tributary area of the gullies. Thus the installation of waterways, although accompanied by extensive surface disturbance during construction, prevented an average soil loss equal to 0.30 inch depth over their tributary area, or reduced soil loss by an average of 88 percent. If, the net erosion per linear foot of watercourse of the waterways was compared with that of the untreated gullies, losses amounted to 2.91 cubic feet and 14.03 cubic feet, respectively. This relationship remained consistent when the individual waterways were contrasted with their respective control gullies.

Comparisons of Waterways and Check Dams

The costs of gully treatments by grassed waterways and by rock check dams were compared. For this comparison, cost figures were used that have been derived from the construction of rock check dams and waterways on the same watershed during the same year of treatment. For the control of one linear foot of gully, $1.26 was expended for the construction and maintenance of grassed waterways and $1.37 for check dams.

The difference in cost of 8 percent between the types of treatment is not significant and does not justify the selection of the type of treatment on this basis alone. Far more important for this selection is the fact that 19 percent of the original cost of installation was expended for the maintenance of waterways, while only 4 percent was required at the check dams. In deciding on the type of gully control, one should consider also that, due to the extensive ground surface disturbance, a grassed waterway remains in an erosion-sensitive stage until an effective ground cover is established. The risk, inherent to nearly all types of erosion control work, is therefore greater for waterways at the beginning of treatment than for check dam systems.

Italian Hydraulic Reclamation

In Italian hydraulic reclamation of eroding hillsides (fig. 2), the erosive forces of the

Figure 2.--In the early stages of hydraulic reclamation downhill trenches (right background) have smoothed sharp-crested ridges like those in foreground. (Photo courtesy of Soil Conservation District, Alta Val D'Era, Valterra, Italy.)

water are not resisted but utilized and intensified. Two distinctly different topographic features, namely, valley bottoms and hillsides, are treated simultaneously. Engineering techniques applied by the method can be summarized as follows:

1. Increase the energies of the water by concentration of surface runoff and the formation of torrential streams;

2. Predetermine locations of erosion and deposition by placement of check dams at the toe of unstable hillsides; and

3. Maintain the stability of the smoothed hillsides by intense land management measures such as cover crops, contour furrows, and concrete-lined downhill trenches.

Hydraulic reclamation is performed in west central Italy where soft clays reach a depth of 1,000 feet (Heede 1965a). In the upper part of a watershed selected for treatment, water-collecting ditches are dug in a herring-bone pattern. These collector systems discharge the water into trenches that are excavated on the backs of ridges running downslope on unstable hillsides. The water attains torrential energies in the downhill trenches. On the valley floor, located at the foot of the hillsides, check dams are installed that cause deposition of the stream sediments. These deposits stabilize the toes of the hills, and erosion occurs mainly at the upper part of the slopes. As a result, the slope gradient decreases. After three or four years, the hillsides are usually sufficiently smoothed to allow plowing. The objective of this plowing is to fill the collector ditches and to smooth the downhill trenches and other parts of the hillside not smoothed by the water. Tillage and heavy application of fertilizer follow. The relatively high costs inherent in this system of intense land restoration are offset because high-value crops such as table olives, grapes, vegetables, corn and wheat can be grown on the restored land.

Conclusion

This paper covers some of the engineering principles and techniques that are applicable to the treatment of gullies and unstable hillsides—grassed waterways, solid and porous check dams, and hydraulic reclamation. It is concluded that, ideally, engineering designs applied to soil erosion control should be based on the energy relations of the acting and resisting forces at the structure. Yet in most cases, the lack of basic information on precipitation and runoff in mountains, as well as insufficient knowledge on the behavior of structures, force the designer to use rough estimates of the energies involved. It follows that erosion control engineering relies heavily on empirical and, to a much smaller extent, on theoretical approaches. In this sense, the control of soil erosion is still an art. Because of this shortcoming, installations are often overdesigned, resulting in unnecessary expense. Further research on the energy relations at erosion control structures should give a more scientific basis to projects in soil conservation.

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SUMMARY

There are two basic approaches to the control of erosion. In the first, we resist the natural erosive forces, in the second we utilize them. Check dams and grassed waterways are examples of the first approach, Italian hydraulic reclamation of the second. The author proposes that stability aspects and factors of safety for check dams installed in wildlands differ from those of other water-impounding structures. This principle was considered in the design of a new type prefabricated concrete check dam. Because the forces acting on a porous structure are hard to estimate, the design of rock check dams cannot be based on energy calculations. Grassed waterways that replaced gullies on steep mountain hillsides reduced erosion by 88 percent during three years when compared with untreated gullies. In Italian hydraulic reclamation, man-made torrents utilize the available energies of rushing to reshape steep slopes to more stable gradients. The author concludes that available engineering techniques and principles are limited in their applicability to soil erosion control, and that engineering judgment must still assume a considerable role in the design of erosion control structures.

SUMARIO

Existen dos técnicas básicas para controlar la erosión. En la primera, resistimos las fuerzas naturales desgastadores; en la segunda, las utilizamos. Diques controlados y vías de agua cubiertas de pasto son ejemplos de la primera técnica; la segunda consiste en el empleo del sistema de la reclamación hidráulica Italiana.

El autor propone que los aspectos de estabilidad y los factores de seguridad de los diques controlados que se instalan en tierras silvestres difieren de otras estructuras que rebalsan aguas. Este principio fue fomado en cuenta en el diseño de un nuevo tip de dique controlado construído de concreto y fabricado de antemano. Ya que es difícil calcaular las fuerzas corroedoras que influyen en una estructura porosa, el diseño de diques controlados construídos de piedra no puede estar basado en calculaciones de energía. Vías de agua cubiertas de pasto que reemplazaron los arroyos en los flancos empinados de las colinas disminuyeron la erosión con un por ciento de 88 durante un período de tres anõs, al compararse con los arroyos a los cuales no se les hizo nada. En el sistema de la reclamación hidráulica Italiana, se construyen torrentes para que éstos utilizen las fuerzas utilizables de agolpamiento de agua y formen ángulos más estables en las inclinaciones escarpadas. El autor concluye que las técnicas y los principios de ingeniería disponibles están limitados en su aplicabilidad al control de la erosión del terreno y que el juicio ingeniérico debe tomar una gran importancia en el diseño de estructuras para el control de la erosión.

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Composition, Production, and Site Factors of Some Grasslands in the Black Hills of South Dakota

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Two major grassland types were found, bluegrass and mixed prairie. On the prairie type, total herbage and grass production were greater on ungrazed than on grazed range; little difference was apparent on the bluegrass type. Moisture regime appears to be an important single factor in determining which type occurs on a given site--more moist sites are dominated by bluegrasses; the drier sites by prairie vegetation.

Scattered throughout the Black Hills National Forest are about 1 million acres of meadows, parks, and prairies, ranging in size from a few to 20,000 acres. These grasslands represent about 30 percent of the total area, and are an important resource. They are grazed each summer by nearly 32,000 head of livestock, and are used seasonally by a deer herd estimated at 60,000 to 100,000 animals.

Early explorers were impressed with the luxuriant vegetation of the grasslands in the Black Hills. The report of the Custer Expedition (Ludlow 1875) emphasized the rich growth of grasses and forbs in the valleys, and the extent of the grasslands. In the Newton-Jenney report (1880) it was stated that: "The Black Hills are an oasis of verdure among the open and level plains. A luxuriant growth of grass spreads over the whole region;. . ." P. A. Rydberg in his floral survey of the Black Hills (1896) said ". . .the valleys are rich grasslands. In a meadow near French Creek the grass stood one meter high." Black Hills grassland vegetation has also been listed in later papers by Hayward (1928) and McIntosh (1949).

This Note describes the species composition, herbage production, and soils of the grasslands of the Black Hills. It is designed to provide a fuller understanding of this important resource.

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Methods

To describe the grasslands, 15 permanent exclosures located throughout the Black Hills were sampled for species composition and herbage production. The exclosures vary in size from 0.5 to 2.0 acres, and have been protected for varying periods of time (table 1). Grazed areas immediately adjacent to the exclosures were also examined to determine the influence of grazing on these grasslands. Site attributes such as elevation, geology, soils, physiography, and precipitation zone were recorded for each exclosure.

Herbage production was estimated by the method of Pechanec and Pickford (1937) on 20 systematically spaced 9.6-square-foot circular plots in each exclosure. Production on grazed range adjacent to each exclosure was measured by the same method. Floristic composition was calculated as percentage of total air-dry herbage weight.

Table 1.--Major site factors of exclosures on prairie and bluegrass ranges in the Black Hills, South Dakota

Grassland type and exclosures	Year established	Elevation	Aspect	Precipitation zone[1]	Physiography	Parent material[2]	A_1 depth	Depth to C	pH to C
		Feet		Inches/yr.			- - Inches - -		
PRAIRIE TYPE:									
Pass Creek Range	1938	4,600	Northeast	17	Flat	Limestone-R	5	9	8.9
Sand Creek	1954	4,500	West-southwest	20	Flat ridge	Limestone-R	3	9	8.9
Robinson Flats	1938	4,300	Southwest	17	Flat	Limestone-R	3	19	8.7
North Pilger	1953	4,500	Northeast	17	Slope	Sandstone-R (Calcareous)	9	18	7.6
Pass Creek Erosion	1938	4,600	South-southeast	17	Slope	Sandstone-A	5	19	6.5
BLUEGRASS TYPE:									
Nigger Creek	1951	6,000	East-northeast	19	Draw bottom	Metamorphic-A	18	30	7.3
Victoria Creek[3]	1939	4,500	South-southwest	20	Bench on stream	Metamorphic-A	15	31	7.0
D Ranch	1949	6,400	Northeast	22	Draw bottom	Limestone-A	10	36	7.4
Minnesota Ridge	1939	6,100	North-northwest	23	Flat ridge	Metamorphic-R	4	22	5.5
Windy Flats[3]	1948	5,500	Southwest	23	Flat ridge	Metamorphic-R	6	21	5.6
Dutchman Flat[3]	1947	6,200	West-northwest	19	Head of draw	Metamorphic-R	4	23	6.5
Bear Canyon	1950	6,700	East	22	Slope	Limestone-A	2	20	8.2
Castle Forks	1940	6,300	Southeast	22	Bench	Limestone-A	7	15	6.1
Doll Road	1947	6,200	South-southwest	19	Slope	Mica and quartz-R	1	4	6.0
Big Hill[3]	1949	5,300	South-southeast	22	Rolling upland	Sandstone-R	11	18	6.2

[1] As designated by Orr (1959).
[2] R = Residual; A = Alluvial.
[3] Areas burned over by forest fires.

Soil data were obtained from a soil pit in each exclosure. Soils were described in the field according to procedures in the Soil Survey Manual (U. S. Soil Survey Staff 1951, pp. 137-141, 173-188). The Bouyoucos method (Bouyoucos 1951) was used for textural analysis; pH was determined electrometrically (Chapman and Pratt 1961). Geological maps of South Dakota (Darton 1951) and Wyoming (Love et al. 1955) were used to determine parent material formations.

The soils of the Black Hills grasslands have not been correlated, and series names cannot be given to the described profiles. Soils are developed in both residual and transported materials from limestone, sandstone, and metamorphic rock formations. In each grassland type, soils have been grouped on the basis of the rock formations from which they have developed and on the characteristics of the solum.

Results

The vegetation of the exclosures (ungrazed) and adjacent rangelands (grazed) can be classified into two general grassland types—bluegrass and prairie. Site factors are shown in table 1; species composition, herbage production, and soil characteristics are in table 2.

Ungrazed Range

Bluegrass type.—At the sites where it was dominant, Kentucky bluegrass[2] averaged 1,047 pounds per acre[3] and made up 68 percent of the herbage. Canada bluegrass produced 1,928 pounds per acre and comprised 76 percent of the vegetation in the one exclosure where it was dominant. Other important grass and grasslike species in the bluegrass type were wheatgrasses, sedges, timothy, and smooth brome. Seventeen other species of grasses were present. Average production of all grasses and sedges in the bluegrass exclosures was 1,281 pounds per acre, or 81 percent of the total herbage.

Forb and shrub production averaged 19 percent of the total herbage in the 10 exclosures in the bluegrass type. The most common forbs were fleabanes, yarrow, and dandelion. Shrub species made up only a minor part of the vegetation. Fringed sagebrush and western snowberry were the most abundant species.

Prairie type.—Blue grama, needle-and-thread, or big bluestem dominated four of the

[2] *Common and botanical names of all plants mentioned are listed at the end of this Note.*
[3] *All herbage weights referred to in this paper are on an air-dry basis.*

five prairie exclosures; Japanese chess dominated the other. Other important species were little bluestem, western wheatgrass, and sedges. Average production of grasses and sedges was 804 pounds per acre, and together they made up 88 percent of the composition. The most abundant forb species in the prairie type were false-tarragon sagebrush and gayfeather. Other common forbs were medic and globemallow. Average forb production on the five exclosures was 111 pounds per acre. Shrubs were sparse, averaging only 8 pounds per acre and comprising less than 1 percent of the plant composition. Fringed sagebrush was the most common species.

Grazed Range

Bluegrass type.—On grazed range outside the 10 bluegrass exclosures, total grass and sedge species composition averaged 74 percent. Kentucky bluegrass was dominant at eight sites, Canada bluegrass at one site, and timothy at one site. Average production of grasses and sedges was 1,172 pounds per acre.

Forbs comprised 26 percent of the vegetation on the grazed range. The most important forb increaser was white clover. At the Dutchman Flat site it made up 20 percent of the composition (440 pounds per acre). Yarrow was the most abundant forb on grazed range.

Some exclosures in the bluegrass type were markedly different in composition from adjacent grazed range. Inside the Nigger Creek exclosure the vegetation was almost entirely Kentucky bluegrass, with only traces of other species. Total estimated herbage yield was 1,703 pounds per acre. On grazed range adjacent to this exclosure, estimated total production was 1,645 pounds per acre. Of the total, Kentucky bluegrass produced 1,097 pounds or 67 percent, and forbs produced 546 pounds or 33 percent. Yarrow was the principal forb.

Prairie type.—Mean herbage yield on grazed range was 610 pounds per acre compared with 915 pounds on ungrazed range. Grass and sedge species produced an average of 570 pounds per acre on grazed range and 804 pounds per acre on ungrazed range. These plants made up a greater percentage of the total herbage on grazed range: 93 to 88 percent, respectively. Major species on grazed range were blue grama, big and little bluestems, and sedges. Sedges and western wheatgrass were the most abundant species in the grazed area adjacent to the exclosure dominated by Japanese chess. No Japanese chess was found on the grazed area outside the exclosure. Total forb composition was 7 percent on grazed range compared with 12 percent on ungrazed range. Gayfeather was the most important forb species on grazed range of the prairie type.

Discussion

The most apparent environmental differences in the prairie and bluegrass types are elevation, precipitation, solum depth, and soil parent materials (table 1). These differences have been accentuated by the locations of the exclosures used in sampling. Four of the five exclosures where the vegetation was classed as prairie were located in the southern Black Hills where the general elevation is lower, annual precipitation less, and the parent material principally sandstones and limestones. The topography is a rolling upland with only moderately high intervening ridges. The only prairie-type exclosure in the northern Black Hills was located on an exposed west-southwest ridge with a very shallow, rocky soil derived from limestone. This exclosure is at low elevation on the edge of the mountainous uplift that composes the majority of the northern region.

The exclosures where the vegetation was dominated by bluegrass were located throughout the central and northern parts of the Black Hills. This region is generally mountainous and dissected, and has much higher average elevation, greater annual precipitation, and a complex geology with metamorphic rocks predominant. Several of the bluegrass-dominated exclosures are located in old forest burns. These sites might support ponderosa pine forest if the pine seedlings were able to establish in the bluegrass sod.

Moisture regime is probably more important than elevation by itself. Stream bottoms in the southern part of the Black Hills are dominated by prairie species in the northern region. These latter areas are often on steep, southern, or western exposures immediately adjacent to the bluegrass-dominated bottoms, or in extensive "balds."

Apparently, bluegrass is able to withstand grazing pressures better than the prairie-type grass species. Although bluegrass production was not greatly affected by grazing (table 2), several species such as yarrow and fringed sagebrush were more abundant on grazed than on ungrazed bluegrass ranges. Grazing on the prairie-type ranges apparently reduced both total herbage production and grass production

Table 2.--Herbage production,[1] species composition,[2] and soil characteristics of bluegrass- and prairie-type ranges, ungrazed and grazed, in the Black Hills of South Dakota

Range type and plant species	First exclosure				Second exclosure				Third exclosure			
	Ungrazed range		Grazed range		Ungrazed range		Grazed range		Ungrazed range		Grazed range	
	Production[1]	Composition[2]	Production[1]	Composition[2]	Production[1]	Composition[2]	Production[1]	Composition[2]	Production[1]	Composition[2]	Production[1]	Composition[2]
Bluegrass type												
ALLUVIAL BOTTOM LANDS	Nigger Creek				Victoria Creek				D Ranch			
Grasses and sedges:												
Kentucky bluegrass	1,703	100.0	1,098	66.7	1,353	71.3	2,187	89.2	277	26.6	430	35.5
Western wheatgrass	0	0	0	0	30	1.6	7	.3	0	0	0	0
Timothy	0	0	0	0	0	0	0	0	146	14.0	160	13.2
Smooth brome	0	0	0	0	177	9.3	0	0	0	0	0	0
Sedges	(3)	(4)	1	.1	159	8.4	7	.3	26	2.5	33	2.7
Other	0	0	0	0	34	1.8	12	.5	11	1.1	25	2.1
Total	1,703	100.0	1,099	66.8	1,753	92.4	2,213	90.3	460	44.2	648	53.5
Forbs and shrubs:												
Yarrow	0	0	37	2.2	0	0	(3)	(4)	126	12.1	278	23.0
Cinquefoil	0	0	3	.2	0	0	7	.3	6	.6	64	5.3
Fleabane	0	0	1	.1	0	0	0	0	187	18.0	27	2.2
Dandelion	0	0	0	0	0	0	0	0	130	12.5	76	6.3
Fringed sagebrush	0	0	489	29.7	0	0	205	8.4	0	0	0	0
Western snowberry	0	0	0	0	106	5.6	25	1.0	0	0	0	0
Other	0	0	16	1.0	39	2.0	1	(4)	131	12.6	118	9.7
Total	0	0	546	33.2	145	7.6	238	9.7	580	55.8	563	46.5
Total, all species	1,703	100.0	1,645	100.0	1,898	100.0	2,451	100.0	1,040	100.0	1,211	100.0

Soil characteristics (Alluvial bottom lands): Three of the soils in the bluegrass type are developed in relatively recent depositions on alluvial benches along streams, and do not have sequences of genetically related horizons. Two (Nigger Creek and Victoria Creek exclosures) are developed on transported metamorphic material, and the other (D Ranch exclosure) on limestone alluvium. Surface layers have very dark brown (10 YR 2/2 M) and brown (7.5 YR 3/2 M) to dark gray brown (10 YR 2/2 M) colors, medium textures (loams and silt loams), and are slightly acid (pH 6.1 to 6.5). Total soil depth exceeds 36 inches on all three sites. Subsurface layers are also medium textured and show moderate blocky structure. They tend to be more neutral (pH 6.6 to 7.3) or slightly alkaline (pH 7.5). Profiles were moist throughout in late August, and almost free of stones.

Range type and plant species	First exclosure				Second exclosure				Third exclosure			
METAMORPHIC UPLANDS	Minnesota Ridge				Dutchman Flat				Windy Flat			
Grasses and sedges:												
Kentucky bluegrass	1,372	63.2	1,461	72.2	1,909	86.7	1,102	50.5	324	12.7	419	18.1
Bearded wheatgrass	90	4.2	0	0	14	.6	4	.2	0	0	0	0
Sedges	178	8.2	100	4.9	2	.1	17	.8	0	0	0	0
Canada bluegrass	0	0	0	0	0	0	0	0	1,928	75.8	1,560	67.2
Other	77	3.5	61	3.0	0	0	0	0	5	.2	28	1.2
Total	1,717	79.1	1,622	80.1	1,925	87.4	1,123	51.5	2,257	88.7	2,007	86.5
Forbs and shrubs:												
Fleabane	120	5.5	0	0	0	0	25	1.1	4	.2	4	.2
Goldenrod	53	2.4	(3)	(4)	0	0	0	0	40	1.6	15	.6
Rocky Mountain iris	52	2.4	13	.6	0	0	44	2.0	0	0	0	0
Yarrow	39	1.8	176	8.7	167	7.6	145	6.6	5	.2	29	1.2
White clover	0	0	125	6.2	5	.2	440	20.2	8	.3	6	.3
Prairie thermopsis	0	0	0	0	0	0	0	0	161	6.2	80	3.4
Dandelion	0	0	0	0	61	2.8	130	6.0	0	0	0	0
Fringed sagebrush	0	0	0	0	11	.5	98	4.5	2	.1	48	2.1
Western snowberry	17	.8	2	.1	0	0	81	3.7	0	0	0	0
Other	173	7.9	86	4.2	33	1.5	97	4.4	68	2.7	132	5.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.3	314	13.5
Total, all species	2,171	100.0	2,024	100.0	2,202	100.0	2,183	100.0	2,545	100.0	2,321	100.0

Soil characteristics (Metamorphic uplands): Three bluegrass sites -- Minnesota Ridge, Dutchman Flat, and Windy Flat exclosures -- occur on upland soils developed in place from metamorphic parent materials. Two (Windy Flats and Dutchman Flats) are in areas that have been burned in the past by forest fires, and the soils may be degraded forest soils. The A_1 horizons are from 3 to 6 inches in depth and range in color from very dark brown (10 YR 2/2 M) to very dark grayish brown (10 YR 3/2 M), with sandy and silt loam textures. They are slightly acid (pH 6.1 to 6.5), and have moderate crumb structure. Well developed textural B horizons are present in all profiles. These horizons range from a sandy clay loam to a strong clay texture, and have moderate angular or subangular blocky structure. Reactions are slightly acid (pH 6.1 to 6.5). Coarse fragments, +2 mm. in diameter, are distributed throughout the subsurface horizons.

LIMESTONE UPLANDS

	Bear Canyon				Castle Creek Forks			
Grasses and sedges:								
Kentucky bluegrass	569	50.2	701	62.3	425	38.6	84	7.9
Prairie dropseed	64	5.6	0	0	30	2.7	55	5.2
Sedges	52	4.6	46	4.1	16	1.5	72	6.9
Timber oatgrass	19	1.7	2	.2	4	.4	91	8.6
Timothy	8	.7	1	.1	246	22.4	331	31.2
Columbia needlegrass	7	.6	4	.4	25	2.3	29	2.7
Other	22	1.9	47	4.2	13	1.2	21	2.0
Total	741	65.3	801	71.3	759	69.1	683	64.5
Forbs and shrubs:								
Fleabane	96	8.5	127	11.2	76	6.9	20	1.9
Cinquefoil	57	5.0	62	5.5	35	3.3	107	10.1
Milkvetch	34	3.0	2	.2	9	.8	5	.5
Yarrow	29	2.6	31	2.8	75	6.8	82	7.7
Agoseris	27	2.3	11	1.0	10	.9	23	2.2
Louisiana sagebrush	4	.4	0	0	59	5.4	1	.1
New-Mexican groundsel	24	2.1	6	.5	0	0	0	0
Other	122	10.8	84	7.5	75	6.8	138	13.0
Total	393	34.7	323	28.7	339	30.9	376	35.5

Soils at Bear Canyon and Castle Creek Forks exclosures have developed from limestone alluvium. Bear Canyon is in a gently sloping park; Castle Creek Forks lies on an alluvial bench between two dry forks of Castle Creek. This bench is elevated about 50 feet above the surrounding area. Both soils have A_1 horizons 7 inches deep with silty textures. The color is very dark grayish brown (10 YR 3/2 M) at both sites. Surface horizon pH is slightly acid (pH 6.1 to 6.4). Well developed textural B horizons are present in both soils. These have clay textures, angular blocky structure, and dark yellowish brown (10 YR 4/4 M) colors. Soil reaction in the B horizon at the Bear Canyon exclosure is approximately neutral (pH 6.6 to 6.9). The C horizon is moderately alkaline (pH 8.2), and there is strong effervescence with dilute hydrochloric acid, indicating large amounts of free carbonate. At the Castle Creek Forks exclosure, the B horizon is very stony, and has a pH of 6.0; B horizon at Bear Canyon is only moderately stony. There is no effervescence in Castle Creek Forks soil.

MICACEOUS-SCHIST UPLAND / SANDSTONE UPLAND

	Doll Road				Big Hill			
Grasses and sedges:								
Kentucky bluegrass	457	70.0	622	79.6	824	64.5	809	71.4
Western wheatgrass	26	4.0	9	1.2	51	4.0	0	0
Sedges	24	3.7	32	4.1	25	2.0	3	.3
Canada bluegrass	17	2.6	3	.4	0	0	0	0
Other	33	5.1	32	4.1	34	2.7	12	1.1
Total	557	85.4	698	89.4	934	73.2	824	72.8
Forbs and shrubs:								
Yarrow	14	2.1	6	.8	66	5.1	46	4.1
Fleabane	11	1.7	0	0	18	1.4	0	0
Goldenrod	0	0	0	0	96	7.5	0	0
White clover	0	0	6	.8	52	4.1	245	21.6
Thistle	0	0	0	0	43	3.4	8	.7
Fringed sagebrush	54	8.3	65	8.2	0	0	0	0
Creeping mahonia	0	0	0	0	24	1.9	0	0
Western snowberry	0	0	0	0	20	1.6	0	0
Bearberry	13	2.0	6	.8	19	1.5	0	0
Other	3	.5	0	0	4	.3	9	.8
Total	95	14.6	83	10.6	342	26.8	308	27.2
Total, all species	652	100.0	781	100.0	1,276	100.0	1,132	100.0

[1] Pounds per acre, air-dry weight.
[2] Percent of composition as percent of total air-dry weight.
[3] Less than 1 pound per acre, air-dry weight.
[4] Less than 0.1 percent.

The Doll Road exclosure in the bluegrass type has a soil developed from micaceous material interspersed with whitish quartz. This soil is very shallow, and unweathered platy micaceous schists extend to the surface. There is a thin A_{11}, 3/4 inch thick, and an A_{12}, 2-1/2 inches thick. The former horizon is very dark grayish brown (10 YR 3/2 M), and has a silt loam texture; pH is 5.7. The A_{12} is a very dark brown (10 YR 2/2 M), silt loam. Both A horizons have granular structure. The pH of the A_{12} is 6.0. From 3-1/2 to 14 inches is a loamy, dark brown (7.5 YR 3/2 M) AC horizon with a weak blocky structure and almost neutral reaction (pH 6.8). The C horizon has fine platy structure and is very high in mica. It is dark yellowish brown (10 YR 3/4 M), and has a pH of 7.1.

Soil at Big Hill exclosure is developed on Minnelusa sandstone, and has an A-AC-C horizon sequence. An A_{11} horizon, 5 inches deep, very dark grayish brown (10 YR 3/2 M) in color with a fine sandy loam texture is present. The A_{12} is 6 inches thick, browner (10 YR 5/3 M), and has a very fine sand texture. It is more acid (pH 6.0) than either the A_{11} above it (pH 6.5) or the AC below it (pH 6.6). The AC horizon is light gray (10 YR 7/2 M), very fine sand, 8 inches thick. Below the AC is a sandy, light yellowish brown (10 YR 6/4 M) C horizon with clay lenses distributed through it.

(Table 2 continued on page 6)

Table 2.--Herbage production,[1] species composition,[2] and soil characteristics of bluegrass- and prairie-type ranges, ungrazed and grazed in the Black Hills of South Dakota (continued)

Range type and plant species	First exclosure: Ungrazed range Pro-duction	First exclosure: Ungrazed range Compo-sition	First exclosure: Grazed range Pro-duction	First exclosure: Grazed range Compo-sition	Second exclosure: Ungrazed range Pro-duction	Second exclosure: Ungrazed range Compo-sition	Second exclosure: Grazed range Pro-duction	Second exclosure: Grazed range Compo-sition	Third exclosure: Ungrazed range Pro-duction	Third exclosure: Ungrazed range Compo-sition	Third exclosure: Grazed range Pro-duction	Third exclosure: Grazed range Compo-sition
Prairie type:												
LIMESTONE UPLANDS												
	Pass Creek Range				Sand Creek				Robinson Flat			
Grasses and sedges:												
Needle-and-thread	202	28.6	66	10.1	3	0.3	3	0.5	25	1.7	0	0
Sedges	132	18.7	12	1.8	13	1.5	8	1.4	144	10.0	261	59.1
Blue grama	101	14.3	506	77.1	15	1.7	8	1.4	133	9.3	0	0
Little bluestem	47	6.6	0	0	36	4.1	0	0	0	0	0	0
Sideoats grama	28	4.0	0	0	23	2.6	19	3.4	0	0	0	0
Prairie Junegrass	17	2.4	5	.8	33	3.7	14	2.5	0	0	0	0
Western wheatgrass	10	1.4	27	4.1	19	2.1	30	5.3	364	25.4	74	16.7
Big bluestem	0	0	0	0	392	44.1	248	43.8	0	0	0	0
Japanese chess	0	0	0	0	0	0	0	0	652	45.4	0	0
Other	11	1.6	33	5.0	196	22.1	117	20.7	29	2.0	104	23.5
Total	548	77.6	649	98.9	730	82.2	447	79.0	1,347	93.8	439	99.3
Forbs and shrubs:												
Medic	0	0	0	0	29	3.3	8	1.4	0	0	0	0
Prairieclover	0	0	0	0	17	1.9	0	0	0	0	0	0
False-tarragon sagebrush	0	0	0	0	0	0	0	0	66	4.6	0	0
Broom snakeweed	9	1.3	2	.3	27	3.0	26	4.6	0	0	0	0
Fringed sagebrush	39	5.5	(3)	(4)	16	1.8	3	.5	8	.6	0	0
Other	111	15.6	5	.8	69	7.8	82	14.5	15	1.0	3	.7
Total	159	22.4	7	1.1	158	17.8	119	21.0	89	6.2	3	.7
Total, all species	707	100.0	656	100.0	888	100.0	566	100.0	1,436	100.0	442	100.0

Soil characteristics (Limestone uplands):

The soils underlying the prairie-type exclosures are developed from limestone and sandstone, and are generally shallower than the soils in the bluegrass type. Soils on three of the five exclosures, Robinson Flat, Sand Creek, and Pass Creek Range, are developed from Minnekahta limestone. Two of these (Sand Creek and Pass Creek Range exclosures) have an A-AC-Cca horizon sequence. These two soils are more than 50 miles apart--the Sand Creek exclosure is at the extreme northern end of the Black Hills, while the Pass Creek Range exclosure is in the southern Black Hills.

Both soils are shallow (8 to 9 inches to the Cca horizon) and stony throughout the solum. The A_1 horizons range from 3 to 5 inches thick, with medium textures and mildly to moderately alkaline soil reactions (pH 7.4 and pH 8.1). The soil at the Sand Creek exclosure does not effervesce in the A_1, but the Pass Creek Range exclosure A_1 effervesces strongly. The AC horizon at Sand Creek is 6 inches thick, silt loam in texture, and has very dark brown (10 YR 2/2 M) color. There is strong effervescence, and the pH is 8.1. At Pass Creek, the AC is only 4 inches thick but, except for a slightly higher pH (8.4), it is similar to the AC at Sand Creek.

At the Robinson Flats exclosure, the soil is also derived from limestone, but has a clay B horizon. This is the only prairie-type exclosure where the soil is well developed. The clay loam surface horizon is divided into a light brownish gray (10 YR 6/2 D) granular, slightly acid (pH 6.5) A_{11} horizon, 3 inches thick, and a darker grayish brown (10 YR 5/2 D) A_{12}. This latter horizon is 4 inches thick, with angular blocky structure and a pH of 6.3. The B2t horizon has prismatic structure, dark brown (7.5 YR 4/4 M) colors, and a neutral reaction (pH 7.3). The C horizon is clayey, grayish brown (2.5 Y 5/2 M), and strongly alkaline (pH 8.7). There is strong effervescence in the C horizon.

Range type and plant species	First exclosure: Ungrazed range Pro-duction	First exclosure: Ungrazed range Compo-sition	First exclosure: Grazed range Pro-duction	First exclosure: Grazed range Compo-sition	Second exclosure: Ungrazed range Pro-duction	Second exclosure: Ungrazed range Compo-sition	Second exclosure: Grazed range Pro-duction	Second exclosure: Grazed range Compo-sition
SANDSTONE UPLANDS								
	North Pilger				Pass Creek Erosion			
Grasses and sedges:								
Blue grama	456	43.1	439	59.6	131	26.9	101	15.5
Western wheatgrass	239	22.6	56	7.6	19	3.9	14	2.2
Needle-and-thread	81	7.7	63	8.5	130	26.7	23	3.5
Prairie Junegrass	60	5.7	11	1.5	0	0	0	0
Sedges	50	4.7	49	6.6	54	11.1	21	3.2
Sand dropseed	37	3.5	39	5.3	0	0	2	.3
Red three-awn	18	1.7	5	.7	17	3.5	1	.2
Little bluestem	0	0	2	.3	54	11.1	449	69.0
Other	12	1.1	22	3.0	38	7.8	19	2.9
Total	953	90.1	686	93.1	443	91.0	630	96.8
Forbs and shrubs:								
False-tarragon sagebrush	83	7.8	0	0	1	.2	3	.5
Globemallow	14	1.3	27	3.6	(3)	(4)	(3)	(4)
Pussytoes	3	.3	11	1.5	0	0	0	0
Bugleweed	0	0	0	0	5	1.0	4	.6
Gayfeather	0	0	0	0	32	6.6	(3)	(4)
Other	5	.5	13	1.8	6	1.2	14	2.1
Total	105	9.9	51	6.9	44	9.0	21	3.2
Total, all species	1,058	100.0	737	100.0	487	100.0	651	100.0

Soil characteristics (Sandstone uplands):

The soil at the North Pilger exclosure is derived from a calcareous sandstone. The A_{11} horizon is 4 inches thick and very dark grayish brown (10 YR 3/2 M) with a silty clay loam texture and granular structure. It has a medium acid reaction (pH 5.9). Below this is an A_{12} horizon 5 inches thick. This horizon has fine subangular blocky structure and is dark yellowish brown in color (10 YR 3/4 M). Soil reaction tends to be almost neutral (pH 6.7). From 9 to 18 inches there is a stony, angular blocky, brown colored (7.5 YR 4/4 M) AC horizon. This has silt loam texture and mildly alkaline reaction (pH 7.4). Below 18 inches the soil material becomes hard and dry, and there is little root penetration. This C horizon is stony, and has clay loam texture and dark brown color (10 YR 4/3 M). The soil reaction is mildly alkaline (pH 7.6).

The soil at the Pass Creek Erosion exclosure is derived from a noncalcareous sandstone. The soil is deep, but not strongly developed. A thin (1/2 inch), dark yellowish brown (10 YR 3/4 M), platy, surface horizon (A_{11}) appears to be a crust caused by raindrops. The A_{12} is 4-1/2 inches thick, granular, dark yellowish brown (10 YR 3/4 M), and fine sand in texture. Both surface horizons are slightly acid (pH 6.4 and pH 6.6). From 5 to 11 inches there is a dark brown (10 YR 3/3 M) massive, AC horizon with a neutral soil reaction (pH 7.0). Below this, a dark brown (10 YR 3/3 M), sandy C_1 horizon extends to 18 inches below the surface. This horizon has mildly alkaline reaction (pH 7.5) but does not effervesce. A brown (7.5 YR 4/4 M) C_2 horizon is found below the C_1 and extends to a depth of more than 36 inches. This horizon has a slightly acid reaction (pH 6.5). The light textures found throughout this soil indicate it is probably excessively drained.

[1] Pounds per acre, air-dry weight.
[2] Percent of composition as percent of total air-dry weight.
[3] Less than 1 pound per acre, air-dry weight.
[4] Less than 0.1 percent.

(table 2). Forbs were more abundant on ungrazed prairie-type range than on grazed range. Livestock may be seeking out the desirable prairie forb species.

Summary

Vegetation within 15 permanent range exclosures, located throughout the Black Hills National Forest, were examined for species composition and herbage production. Vegetation on grazed range adjacent to each of the exclosures was examined also.

Two major grassland types were found—bluegrass and mixed prairie. Kentucky bluegrass, sedges, timothy, fleabanes, and yarrow were the most abundant plant species in the bluegrass type. Dominant vegetation at one site was Canada bluegrass. Blue grama, needle-and-thread, and bluestem dominated the mixed prairie type.

Forbs were more abundant on the grazed bluegrass ranges than in exclosures. On prairie-type ranges, forbs were more numerous inside the exclosures. There was no appreciable difference in either total herbage or grass production were considerably greater on ungrazed duction between grazed and ungrazed blue grass ranges. On the prairie type, however, both total herbage and grass production were considerably greater on ungrazed than on grazed range.

The variation in soils and physical environment makes it difficult to determine definite relationships between the grassland types and particular site factors, but moisture regime appears to be an important single factor in determining the grassland type that will occur on a given site. The more moist sites are dominated by bluegrasses; the drier sites by prairie vegetation.

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COMMON AND BOTANICAL NAMES OF PLANTS MENTIONED

Agoseris	*Agoseris* spp.
Bearberry	*Arctostaphylos uva-ursi* (L.) Spreng.
Bluegrass, Canada	*Poa compressa* L.
Bluegrass, Kentucky	*Poa pratensis* L.
Bluestem, big	*Andropogon gerardii* Vitman
Bluestem, little	*Andropogon scoparius* Michx.
Brome, smooth	*Bromus inermis* Leyss.
Bugleweed	*Lycopus* spp.
Chess, Japanese	*Bromus japonicus* Thunb.
Cinquefoil	*Potentilla* spp.
Clover, white	*Trifolium repens* L.
Dandelion, common	*Taraxacum officinale* Wiggars
Dropseed, prairie	*Sporobolus heterolepis* (A. Gray) A. Gray
Dropseed, sand	*Sporobolus cryptandrus* (Torr.) A. Gray
Fleabanes	*Erigeron* spp.
Gayfeather	*Liatris* spp.
Grama, blue	*Bouteloua gracilis* (H.B.K.) Lag.
Grama, sideoats	*Bouteloua curtipendula* (Michx.) Torr.
Globemallow	*Sphaeralcea* spp.
Goldenrod	*Solidago* spp.
Groundsel, New-Mexican	*Senecio neomexicanus* A. Gray
Iris, Rocky Mountain	*Iris missouriensis* Nutt.
Junegrass, prairie	*Koeleria cristata* (L.) Pers.
Mahonia, creeping	*Mahonia repens* (Lindl.) G. Don
Medic	*Medicago* spp.
Milkvetch	*Astragalus* spp.
Needle-and-thread	*Stipa comata* Trin. and Rupr.
Needlegrass, Columbia	*Stipa columbiana* Macoun
Oatgrass, timber	*Danthonia intermedia* Vasey
Pine, ponderosa	*Pinus ponderosa* Lawson
Prairieclover	*Petalostemon* spp.
Pussytoes	*Antennaria* spp.
Sagebrush, false-tarragon	*Artemisia dracunculoides* Pursh.
Sagebrush, fringed	*Artemisia frigida* Willd.
Sagebrush, Louisiana	*Artemisia ludoviciana* Nutt.
Sedges	*Carex* spp.
Snakeweed, broom	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Snowberry, western	*Symphoricarpos occidentalis* Hook.
Thermopsis, prairie	*Thermopsis rhombifolia* Nutt. ex. Rich.
Thistle	*Cirsium* spp.
Three-awn, red	*Aristida longiseta* Steud.
Timothy	*Phleum pratense* L.
Wheatgrass, bearded	*Agropyron subsecundum* (Link) Hitchc.
Wheatgrass, western	*Agropyron smithii* Rydb.
Yarrow	*Achillea* spp.

1968

U.S. FOREST SERVICE
RESEARCH NOTE RM -104

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

Insects and Diseases of Siberian Pea Shrub (Caragana) in North Dakota, and Their Control

Patrick C Kennedy[1]

Grasshoppers do most damage. Malathion is recommended to control most insects; Bordeaux mixture for Septoria leaf spot.

The Siberian pea shrub (Caragana arborescens Lamarck), commonly called caragana, is widely planted in farm and ranch windbreaks and shelterbelts in North Dakota. About 800,000 caragana shrubs have been planted annually in North Dakota in recent years.[2] About 5 million additional caragana seedlings are planted each year in the adjacent Canadian provinces. Caragana is an important, long-lived component of shelterbelts, and its relatively short, dense growth makes it an excellent edge-row species.

The bases for this Note include an insect and disease survey of eastern North Dakota shelterbelts in 1960 (Wilson 1962), an insect survey covering shelterbelts over the entire State during the summer of 1964, an intense insect survey of shelterbelts in five eastern North Dakota counties by Haynes and Stein,[3] and observations by the author from May through October 1965.

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[2] *Personal correspondence, Elmer L. Worthington, Woodland Conservationist, U. S. Soil Conservation Service, Bismarck, North Dakota.*

[3] *Haynes, D. L., and Stein, J. D. Establishment, maintenance and effects of shelter belts in North Dakota. (Unpublished report NcS-12-1, North Central Forest Exp. Sta., St. Paul, Minn.)*

Several insects and diseases were found on caragana. The combination of early summer defoliation by blister beetles, late summer defoliation by grasshoppers, premature leaf fall caused by a fungus, and the work of other pests caused considerable injury to caragana, and lessened the protective and esthetic values of many shelterbelts. These damages lessen the desirability of caragana for shelterbelt planting.

Information that will help identify the most damaging insects and diseases found in the surveys, and the damage they cause, is presented below.[4] In addition, currently recommended and practiced suppression measures are listed on page 4.

Grasshoppers

Of all the insects observed during this study, the spur-throated grasshoppers appear to cause the most damage to caragana in North Dakota. The three species of this group collected most prevalently were the two-striped grasshopper (Melanoplus bivittatus (Say)), the differential grasshopper (M. differentialis (Thomas)), and the red-legged grasshopper (M. femur rubrum (DeGeer)).

The major identifying characteristics of the adult two-striped species are two light tan

[4] *Insects reported in this paper were identified by personnel from the U.S. National Museum and the University of Michigan, T. J. Spilman (blister beetles), I. J. Cantrall (grasshoppers), R. W. Hodges (leaf roller), and W. D. Field (variegated fritillary).*

stripes on the upper side which extend from the head to the wing tips. It is about 1-1/4 inches long. The differential grasshopper has the outer sides of the broad part of the hind legs marked with distinctive black bars arranged like chevrons; it is about 1-1/2 inches long. The red-legged grasshopper has bright red hind legs, and is only 3/4 inch long.

Plains grasshoppers usually feed on cereal grains and grasses, but they will feed on many species of trees and shrubs when their regular food is in short supply. Wilson (1961, 1962) noted that shelterbelt trees were fed upon and injured heavily only after field crops adjacent to the shelterbelts had been harvested. Since caragana commonly occupied the edge row, it was fed upon first and usually injured the most by defoliation and debarking (fig. 1).

Blister Beetles

Three common and destructive blister beetles attack caragana in North Dakota: the ash-gray blister beetle (Epicauta fabricii (LeConte)), the caragana blister beetle (E. subglabra (Fall)), and the Nuttall blister beetle (Lytta nuttallii Say). The adult ash-gray blister beetle is 3/4 to 1 inch long and light gray (fig. 2); the caragana blister beetle is similar but black. The larger Nuttall blister beetle is 3/4 to 1 inch long and colored metallic purple blue with a green sheen.

The adults of all three species feed on caragana during late May and early June. Large numbers may cause severe defoliation, especially if the shrubs are small. The insects may either partially or completely consume the leaves and seed pods (fig. 2). The larvae of most blister beetles feed on grasshopper eggs, and for this reason are considered beneficial.

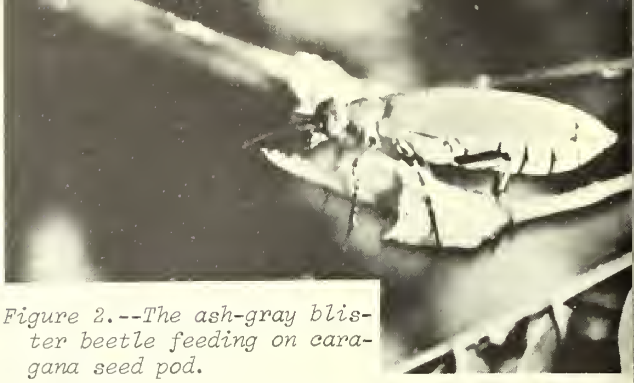

Figure 2.--The ash-gray blister beetle feeding on caragana seed pod.

Weevils

Three small weevils or snout beetles were collected from caragana. All three species are common pests of certain agricultural crops and trees, but are not very destructive to caragana.[3]

The sweetclover weevil (Sitona cylindricollis Fåhraeus) is common throughout the State. The dark gray adult is about 3/16 inch long and usually feeds on the foliage of legumes, principally sweetclover (Melilotus spp.) during the spring and fall. Crescent-shaped notches in the leaves characterize the injury on caragana (Munro et al. 1949).

The lesser alfalfa weevil (Sitona tibialis Herbst =S. scissifrons Say) also occurs throughout North Dakota. It resembles the sweetclover weevil, but is 1/16 to 3/16 inch long, and more steel gray with paler stripes on the back. It is active from May to September (Blatchley and Leng 1916, Loan 1963). The adult normally feeds on several leguminous crop plants, but has been found on caragana miles away from the nearest cultivated legume crop. So far it has done little damage in shelterbelts, but has destroyed entire plots of caragana seedlings in Saskatchewan nurseries (Peterson 1945). The leaves are seldom completely eaten on larger caragana.

The red elm bark weevil (Magdalis armicollis (Say)) was collected from caragana, but I am not certain whether it will injure caragana. The reddish-brown adult, 1/8 to 3/16 inch long, normally feeds in the cambium of dying or recently dead trees, primarily elms.

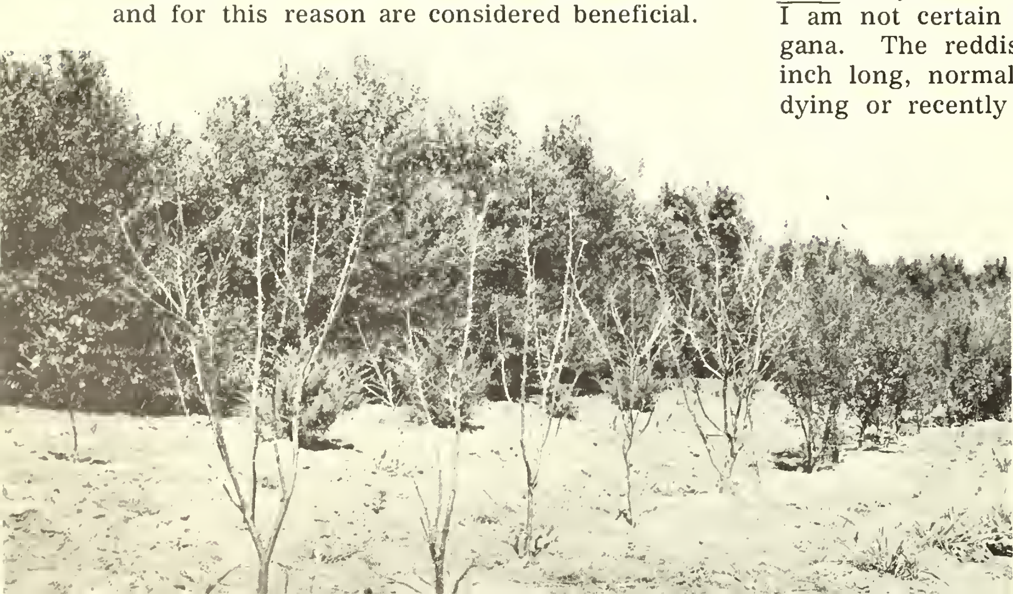

Figure 1.--Grasshopper damage to caragana shrubs in the outside row of a shelterbelt.

Moths and Butterflies

The larvae of the oblique-banded leaf roller (*Choristoneura rosaceana* (Harris)) and the variegated fritillary (*Euptoieta claudia* Cramer) were collected from caragana.

The leaf roller was the more common of the two species. It is about 3/4 inch long when full grown, and pale green to yellow green with a brown head. Most injury occurs in June, when the larva is found singly in a rolled leaf or in a leaf cluster tied with silk where it feeds on surrounding leaves.

The larva of the variegated fritillary is about 1-1/2 inches long when full grown. The body is orange-red with dark brown spines tipped with black. It feeds on the leaves of caragana, but its usual host plants are violets and pansies. Heaviest feeding occurs in August.

Sucking Insects

The caragana aphid (*Acyrthosiphon caraganae* (Cholodkovsky)) and the caragana plant bug (*Lopidea dakota* Knight) are commonly found on caragana. The aphid—small, green, and soft bodied—is usually found in clusters on the leaves, seed pods, and small twigs in mid-June. When populations are heavy the foliage wilts and leaves fall prematurely (Strickland and Hocking 1950).

The plant bug is about 1/4 inch long, and has a black head and legs. The upper thorax and wings are dark brown or black; the abdomen is bright carmine. Populations so far have not been sufficiently high to cause damage.

Septoria Leaf Spot

A leaf spot fungus, probably *Septoria caraganae* (Jacz.) Diedecke, attacks the shrubs during the summer (Walker 1957). Infected leaves become chlorotic (fig. 3A, B) and fall 2 or 3 weeks prior to normal leaf fall (fig. 3C). The fungus infects leaves of declining vigor. Shrubs infected 1 year are likely to be reinfected the next year because diseased leaves collect under them and become the source of reinfection. From my observations, however, certain individuals appear to be less susceptible to the disease. Such shrubs are always more vigorous and taller than susceptible ones (fig. 3D).

Other Organisms

The caragana seed chalcid (*Bruchoptragus caraganae* (Nikolskaja)), though unknown in North Dakota, is common in Manitoba and Saskatchewan. It infests the seed pods and has caused caragana seed losses up to 24 percent (Peterson and Worden 1964).

Figure 3.--Septoria leaf spot on caragana: A. infested leaflets; B. lower surface of leaflet with fruiting bodies; C., D. single-row caragana shelterbelt showing premature leaf fall. Note height and density differences between infected and uninfected shrubs. (Photos A and B courtesy of T. C. Vanterpool, Univ. Saskatchewan.)

A damping-off organism (Rhizoctonia solani Kuhn) and a root rot (Pullicularia filamentosa (Pat.) Rogers) occasionally infect caragana. Little is known about their distribution and injury.

Control Measures

Any one of the aforementioned organisms, with the possible exception of the seed chalcid, whether alone or together may weaken or kill caragana. Grasshoppers, blister beetles, and septoria leaf spot have already caused considerable injury in some localities. Small shrubs, newly planted shrubs, and shrubs weak from limited water or other causes need protection. However, caragana of all ages are susceptible to attack. Currently recommended suppression measures[5] for each organism are listed below:

Destructive organism	Recommended control
GRASSHOPPERS:	Apply malathion (57% emulsifiable concentrate), 1 to 1-1/2 pounds per acre, to a narrow strip of unharvested crop plants adjacent to a shelterbelt with power sprayer. Wait 7 days before harvesting grain. Apply before grasshoppers begin to feed on caragana (N. Dak. Ext. Serv. 1965, Wilson 1961).
BLISTER BEETLES:	Mix 2 tablespoonfuls of malathion (57% emulsifiable concentrate) per gallon of water. Fully cover foliage with mixture, using a knapsack or hydraulic sprayer when beetles become numerous late in May (N. Dak. Ext. Serv. 1965).
WEEVILS, BUTTERFLIES, MOTHS AND CARAGANA PLANT BUG:	Same as for blister beetles, except apply when particular insect is abundant and damaging caragana (see text).
CARAGANA APHID:	Mix 1-1/2 teaspoonfuls of malathion (57% emulsifiable concentrate)per gallon of water. Apply profusely to shrubs with a hydraulic sprayer in mid-June to obtain full coverage.
SEPTORIA LEAF SPOT:	Bury or destroy infected fallen leaves when possible. In August, spray foliage for complete coverage with Bordeaux mixture, using 1 pound of copper sulfate and 1 pound of burnt lime in 12 gallons of water. Follow with second and third applications at 10- to 14-day intervals (Walker 1957).

[5] *For alternative control methods, see U. S. Agr. Res. Serv. and Forest Serv. 1967.*

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U.S. FOREST SERVICE
RESEARCH NOTE RM -105

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

Woodpecker Feeding on Engelmann Spruce Beetle in Windthrown Trees

Paul H Baldwin[1]

Northern three-toed and hairy woodpeckers fed at windthrown Engelmann spruce trees infested with Dendroctonus obesus (Mann.). Sections of the infested boles were covered with screen to prevent woodpecker feeding over the winter and following summer. Estimates at the end of that time showed that woodpeckers caused a relative mortality of 70 to 79 percent of the brood. Predation on the Engelmann spruce beetle in windthrown trees appears to be important in declining infestations.

The Engelmann spruce beetle, Dendroctonus obesus (Mann.) (=D. engelmanni Hopk.), shows a strong tendency to attack windthrown trees and cull logs in preference to green standing trees. The resulting infestations in down logs are often a major source of mature beetles that perpetuate local populations.

Northern three-toed woodpeckers and hairy woodpeckers (Picoides tridactylus and Dendrocopos villosus) are major predators of the spruce beetle; these woodpeckers, together with the less important downy woodpecker (D. pubescens), have been known to reduce the brood of beetles in standing infested trees by 45 to 98 percent. These woodpeckers also work on infested down logs, but resulting mortality of the beetles has not been assessed. Because survival of spruce beetles in fallen trees at severe infestations is often high, Knight[3] has stated that woodpeckers are ineffective predators of beetles in down material. To obtain information on this point, beetle mortality caused by woodpeckers in windthrown trees was studied at a lingering, low-level Engelmann spruce beetle infestation at Beaver and Amethyst Creeks in the Wet Mountains of the San Isabel National Forest, Colorado.

Northern three-toed and hairy woodpeckers were relatively numerous at the study area, having multiplied to a total breeding density of six pairs per square mile since the spruce beetle was first noticed in the area in 1959. In the late summer and autumn of 1966, adult and young woodpeckers were seen feeding in the 3-square-mile study area, and in early June of 1967 numerous woodpeckers showed signs of

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[2] *Knight, F. B. The effects of woodpeckers on populations of the Engelmann spruce beetle. J. Econ. Entomol. 51: 603-607. 1958.*

[3] *Knight, Fred B. Sequential sampling of Engelmann spruce beetle infestations in standing trees. U. S. Forest Serv., Rocky Mountain Forest and Range Exp. Sta. Res. Note 47, 4 pp. 1960.*

nesting activity. It is believed that the northern three-toed woodpeckers, at least, remained in the area through the entire winter on the basis of overwintering behavior observed at small bark beetle infestations elsewhere in Colorado.[4] [5]

Methods

A 3-foot section of the main stem on each of 32 windthrown trees was covered with half-inch-mesh hardware cloth to prevent woodpecker feeding. The hardware cloth was wrapped around the trunk anywhere in the basal half of the infested stem and fixed in position 1¼ inches from the bark by wooden blocks (figs. 1 and 2). The cages were installed in August and September 1966 on windfalls that had been attacked by beetles earlier in the summer. In August 1967, the density of the surviving spruce beetle brood was determined in and under (1) bark protected from woodpeckers, and (2) bark to which woodpeckers had unrestricted access, except as prevented by snow, branches, or lack of space between bark and ground.

[4] *Baldwin, P. H. Overwintering of woodpeckers in bark beetle-infested spruce-fir forests of Colorado. XII Int. Ornithol. Congr. (Helsinki) Proc. 1958: 71-84, 1960.*

[5] *Koplin, J. R. Predatory and energetic relations of woodpeckers to the Engelmann spruce beetle. 187 pp. 1967. (Doctoral thesis on file at Colo. State Univ., Fort Collins.)*

The sampling consisted of counting beetles from a strip of bark 6 inches wide extending around the circumference of the main stem. One strip was counted from the caged area, where the mean diameter was 9.6 inches, and another strip from the uncaged area, usually from 4 to 8 feet farther along the stem, where the mean diameter was 8.6 inches. In most stems Ips pilifrons Sw., a smaller bark beetle, predominated on the upper half of the logs and the Engelmann spruce beetle in the lower half. Data given hereafter pertain only to the Engelmann spruce beetle.

Results

The mean difference in survival of caged and exposed beetles was 9.75 beetles per square foot (table 1). This represents a reduction in survival of 77 percent under the exposed bark.[6] In the bark of the lower half of the prostrate main stems, where the spruce beetles were

[6] *The 99 percent confidence interval of the expected mean difference is 2.5 to 17.0 beetles per square foot by ordinary "t" test of paired differences or 6.5 to 15.2 beetles per square foot by Tukey's method (Walker, H. M., and Lev, J. Statistical inference. 508 pp. New York: Holt. 1953.) for determining confidence intervals with the nonparametric Wilcoxon paired signed rank-sum test. The latter is more desirable since the usual transformations were not helpful in the parametric test.*

Figure 1.--Cages on windfallen spruce trees installed to prevent feeding by woodpeckers. The lower cage has been replaced after a strip of bark 6 inches wide was removed around the bole for sampling the surviving brood of spruce beetles at the end of 1 year. The upper cage is opened to show the sampled strip more clearly. To the right on both trees, strips of bark have been removed to determine survival under the unprotected bark. Woodpecker work was moderate on both of these trees and most of the bark remained in place, although many beetles had been taken by the birds.

Table 1.--Number of Engelmann spruce beetles surviving on fallen main stems in protected bark and bark exposed to woodpeckers

Location and condition of bark	Area sampled	Surviving beetles				Length of egg galleries	Surviving beetles in galleries
		Larvae	Pupae	Adults	Total		
	Sq. ft.	---- No. / sq. ft. ----				In. /sq. ft.	No. /in.
Bark of upper and lower sides:							
Protected	41.3	3.0	3.5	6.1	12.6	22.4	0.52
Exposed	36.0	1.3	1.0	.7	3.0	17.2	.16
Bark of lower side only:							
Protected	20.7	4.8	6.1	11.1	22.0	29.6	.70
Exposed	18.0	2.1	1.5	1.0	4.6	25.8	.16

concentrated, the survival was reduced from 22.0 to 4.6 beetles per square foot, a reduction of 79 percent from woodpecker predation. Thus, the woodpeckers worked effectively on the under sides of fallen trees, even when the bark surface was 6 inches or less from the ground. The average height at the bottom of the lower side of the 32 logs was 14.3 inches, when the highest and lowest points for all logs were summed and the sum divided by twice the number of logs.

Adults and pupae sustained greater losses than larvae. Perhaps the woodpeckers were more successful at finding the former because the bark over the pupal cells is thinner than over the larval mines.

For the comparisons above, it was assumed that the initial density of the spruce beetle was uniform along the main stem. Nagel et al.[7] reported that the density of Engelmann spruce beetle egg galleries along the stems of 24 prostrate trap trees showed no striking variations, as indicated by similar mean numbers of egg galleries counted at 8-foot intervals between 5 and 69 feet above the root collar, except that the mean at 69 feet was much smaller than the others. It must be realized, however, that their studies[7] were made in vigorous infestations and not declining infestations.

[7] *Nagel, R. H., McComb, David, and Knight, F. B. Trap tree method for controlling the Engelmann spruce beetle in Colorado. J. Forest. 55: 894-898. 1957.*

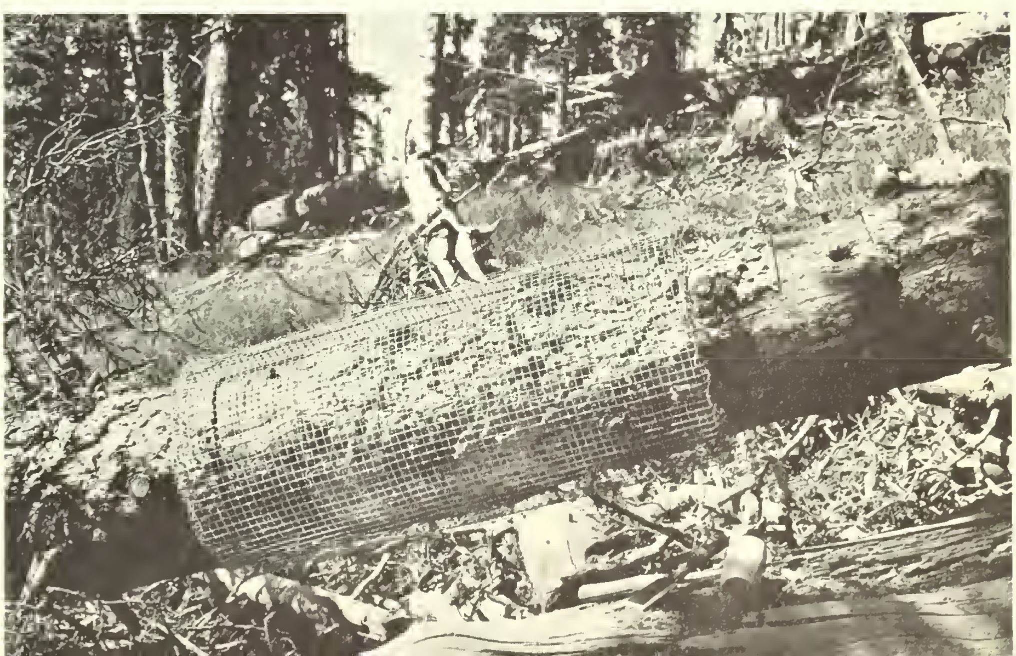

Figure 2.--This cage was installed on August 28, 1966, and the bark was sampled for surviving spruce beetles on August 6, 1967. Within the cage 73 beetles remained in a strip of bark 6 inches wide, while to the right of the cage only 8 beetles remained in a strip of unprotected bark. The lower surface of the trunk to the right of the cage is bare; all bark was removed by woodpeckers feeding on the beetles during the winter of 1966-67.

In the present case, the length of egg galleries per square foot of bark under the cages was found to exceed that at the exposed sampling sites (table 1). Either (1) woodpeckers may have removed some of the parent adults from their egg galleries in exposed bark after the cages were installed and before the egg galleries were completed, or (2) the initial densities in the caged bark may have been higher than those at the exposed sites. They could have been higher by a proportion similar to gallery length, that is, by 23 percent for the upper and lower sides combined, or by 13 percent for the lower sides. Thus, part of the lower survival could have been related to a lower initial density at the exposed sites. If initial density were lower, the expected survival at the exposed sites for upper and lower surfaces combined, in the absence of predation by woodpeckers, would be 9.7 beetles per square foot of bark. Sampling data showed the actual survival to be 3.0 beetles, a reduction of 70 percent from the effects of feeding by woodpeckers. Likewise, the expected mean survival at the exposed sites on the under surface would, if protected from woodpeckers, have been 19.2 beetles per square foot, but only 4.6 were actually found, a reduction of 76 percent. Considering the results of the two ways of estimating survival, feeding by woodpeckers reduced beetle populations from 70 to 77 percent for the upper and lower surfaces combined, and 76 to 79 percent for the lower surface only.

Further evidence as to whether or not woodpeckers seek beetles from prostrate logs, and in particular from the lower surface, was obtained by rating the proportion of bark worked on the upper and lower surfaces of 32 trees:

	Upper surface	Lower surface
	(No. of	trees)
Proportion of bark surface affected:		
1 - 25 percent	10	3
26 - 75 percent	14	12
76 -100 percent	8	17

Woodpecker work included removal of bark flakes, slitting of the bark with the bill tip in testing for the presence of beetles, and excavations resulting either in small holes or extensive denuded areas of wood (fig. 2). Woodpeckers disturbed 26 to 75 percent of the upper bark on fewer than half of the trees, while disturbing 76 to 100 percent of the lower bark on more than half of the trees. On the average, woodpecker work affected slightly more than one-half of the upper surface (mean percent with standard error, 51.3 ± 5.2) and slightly less than three-fourths of the lower surface (73.6 ± 3.1). This indicated that the Engelmann spruce beetle was an object of intensive search by woodpeckers, and that more effort at these windthrown trees was directed toward the extraction of Engelmann spruce beetles predominately in the lower sides than the smaller Ips beetles in the upper sides of the logs.

Discussion

These results are noteworthy because of a prevalent view that feeding by woodpeckers fails to reduce Engelmann spruce beetle populations significantly in infested down trees. Factors at the Beaver Creek infestation tended to maximize feeding at down logs by woodpeckers. One was the high density of woodpeckers; another was the decided scarcity of Engelmann spruce beetles in the stems of standing trees at the time of the study, which followed a year in which the beetles had been more abundant. The implication is that the woodpeckers exert important pressure on the beetles under these conditions, which are likely to occur in declining infestations.

Experience indicates that, under other conditions, woodpeckers would have less influence on survival of the spruce beetles in down trees. It appears this might be expected at a new infestation in windthrown trees not preceded by a period of buildup of a woodpecker population. It could also be expected if a superabundance of beetles in standing trees supplied essentially all the food needed by the assembled woodpeckers.

Further studies are needed to determine the conditions that either favor or discourage feeding by woodpeckers on the Engelmann spruce beetle in fallen trees and cull logs. The extent of feeding may depend upon such variables as the amount of dense foliage or branches hindering access to the bark, the duration of snow cover in the winter, the height of the bole above the ground or the extent of its contact with the ground, the availability of alternate foods, and other local factors.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 106

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Freeze Drying for Preparing Arizona Chaparral Plants for Energy Analysis[1]

James R. Davis[2]

Freeze drying yields more crude fat than ovendrying, and does not adversely affect energy measurements. Therefore freeze drying is preferred for preparing chaparral fuel samples for chemical analysis.

Fire researchers are interested in the energy content of chaparral plants, because living plants are the major fuel component in the type; others are interested because chaparral plants are food for domestic and wild animals.

Energy analysis of chaparral plants is a relatively undeveloped field. The work reported here was conducted to test general laboratory procedures for determining energy content of plants.

The main objective was to find the drying method that would cause the least change in sample materials, particularly the crude fat component. Crude fat is important because it changes with time, does not require pyrolysis for combustion, and some of it occurs on leaf surfaces where it is exposed to preheating.

Crude fat changes are important because crude fat may contain 9,300 calories per gram, over twice the average 4,100 calories for all other fuel components combined.[3] Quantitative variations in crude fat theoretically can change total fuel energy more than variations in any other component.

Freeze drying and ovendrying were compared. Freeze drying theoretically should cause fewer chemical and structural changes in plant tissue because:[4]

1. Low temperatures retard chemical reactions which could alter resins, essential oils, fatty acids, chlorophyll, and other compounds collectively called crude fat.
2. Water is evaporated from the frozen state, eliminating two effects: concentration of salts which by coagulating colloids could change solubilities, and distortion of tissue by capillary action, which makes solutes physically difficult to remove.
3. Low temperatures retard the evaporation and loss of crude fat by lowering its vapor pressure.
4. The low-pressure atmosphere reduces ambient oxygen, which largely prevents oxidation, an important, unwanted, reaction involving crude fat.

[1] *Research was carried out under a cooperative agreement with Northern Arizona University, School of Natural Sciences, under direction of Dr. Kenneth E. Bean.*

[2] *Associate Forest Fuels Specialist, located at Flagstaff, in cooperation with Northern Arizona University; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[3] *Crampton, E.W. Applied animal nutrition. 458 pp., illus. 1956. San Francisco: W. H. Freeman & Co.*

[4] *Flosdorf, E. W. Freeze-drying: drying by sublimation. 280 pp., illus. 1949. New York: Reinhold Publ. Co.*

Ovendrying has the advantage of being easily done with relatively simple equipment.

Methods

Leaves from the dominant chaparral species, shrub live oak (Quercus turbinella Greene) and pointleaf manzanita (Arctostaphylos pungens H. B. K.) were used. Three physiological conditions were tested for each species:

1. Natural leaves.
2. Naturally dried leaves from plants severed at the groundline.
3. Naturally dried leaves from plants that had been sprayed with a mixture of amine salts of 2,4-D and 2,4,5-T in water. The purpose of the variety of species and conditions was to provide a broader base for answering the objective question.

Six 50-gram samples were collected, one from five plants in each category and species. Samples were cooled immediately in a portable ice chest, frozen at -18°C. within 2 to 3 hours after collection, and held at this temperature until they were to be dried.

One-half of each composite sample was dried in a vacuum system until weight ceased to drop (approximately 20 hours) at a pressure of 50 microns (0.0065 percent of standard atmospheric pressure).

The other half of each composite sample was dried until weight ceased to drop (approximately 48 hours) in a forced draft oven at 95°-100°C. (the 7,000-foot equivalent to 102°-107°C. at sea level).

Dried leaves were ground to pass a 20-mesh screen (0.0331-inch openings).

Heat of combustion was determined on 1-gram subsamples in an oxygen bomb calorimeter. This caloric content is the benchmark for all comparisons.

Crude fat content was measured by extracting 5-gram subsamples with anhydrous ether for 7 hours at 5 to 6 drops per second in Soxhlet apparatus with fat-free, single-thickness paper thimbles. Subsequently, caloric content for both the extracted residue and the extract was calculated by drying and then burning in an oxygen bomb calorimeter.

Results and Discussion

Freeze-dried leaves of each species yielded a higher percentage of crude fat than ovendried leaves, and manzanita leaves yielded more than oak leaves:

	Manzanita (Percent)	Oak
Freeze dried	16.24	7.43
Ovendried	13.45	4.47

Differences between treatments were not statistically significant.

Manzanita leaves had more energy in whole leaves, extracted residue, and crude fat tnan did oak leaves, but there was no difference within species between freeze-dried and ovendried leaves:

	Manzanita (Average calories/gram)	Oak
Whole leaves	5,070	4,660
Extracted residue	4,704	4,490
Crude fat	9,212	8,474

Greater energy for manzanita may be due to greater amounts of crude fat, yet greater amounts of crude fat yielded by freeze-dried leaves were not associated with higher energy than in ovendried leaves. The relatively large amount of extracted residue may have masked the additive effect of crude fat on total energy, which might explain the apparent contradiction.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 107

OREST SERVICE
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Ponderosa Pine Dwarf Mistletoe in Relation to Topography and Soils on the Manitou Experimental Forest, Colorado[1]

Frank G Hawksworth[2]

The marked variations in frequency of dwarf mistletoe found on three soil types studied (granitic, limestone, and arkose) apparently were related to variation in slope steepness, with frequency highest on areas with gentle slopes. Stands on soils with a high proportion of gentle slopes (for example, arkose) had the most dwarf mistletoe; those on predominately steep slopes (for example, granite) had much less infection.

This study was undertaken to determine if there was a relationship between frequency and abundance of Southwestern dwarf mistletoe (Arceuthobium vaginatum subsp. cryptopodum (Engelm.) Hawks. & Wiens) on ponderosa pine (Pinus ponderosa Laws.) and soil types on the Manitou Experimental Forest, Colorado.

There have been no studies on the relationships of dwarf mistletoes and soils although some observations have been recorded. Douglas (1914) in journals of his 1826 travels in the vicinity of Spokane, Washington, noted that a dwarf mistletoe (presumably Arceuthobium americanum Nutt. ex Engelm. on Pinus contorta Dougl.) was most common in dry, sandy soils. Nearly 100 years laters, Korstian (1924) observed that A. campylopodum Engelm. f. campylopodum on ponderosa pine in the Payette National Forest in west central Idaho was most abundant on basaltic soils. Andrews and Daniels (1960) and Hawksworth (1959, 1961) discussed the relationships of topographic features to the distribution of Arceuthobium vaginatum subsp. cryptopodum on ponderosa pine in the Southwest, but they did not correlate them with soil types. These studies showed that the frequency of the parasite is highest on ridges, intermediate on slopes, and lowest on bottoms; higher on gentle or moderate slopes than on steep slopes; and highest at medial elevations in the ponderosa pine type.

[1] *Thanks are expressed to Dwight R. Smith, School of Forestry and Natural Resources, Colorado State University, who kindly provided information on the soil types on the Manitou Experimental Forest.*

[2] *Forest Pathologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Study Area and Methods

The Manitou Experimental Forest is located within the Pike National Forest about 30 miles northwest of Colorado Springs, Colorado. Love (1958) presented a brief account of the topography, soils, and vegetation of the Experimental Forest. These studies were conducted in the Missouri Gulch and Illinois Gulch drainages in the northern part of the Experimental Forest and in the adjacent Pike National Forest.

The ponderosa pine stands had all been cutover at least 20 years previously. The trees over 12 inches diameter at breast height (d.b.h.) were mostly from 110 to 120 years old, although occasional trees more than twice this age were encountered. The stands were sparsely stocked and averaged 103 stems per acre in trees over 6 feet high. The average stand per acre was 10 merchantable trees (those over 12 inches d.b.h.), 53 poles (trees 4 to 12 inches d.b.h.), and 40 saplings (trees 6 feet high to 4 inches d.b.h.). Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) occurred in mixture with ponderosa pine, particularly on north slopes. However, samples were taken only from plots where more than half the trees in the largest size class were ponderosa pine.

Several types of soils occur on the Manitou Experimental Forest.[3] However, some do not support ponderosa pine; and for others the ponderosa pine stands were too limited to sample for dwarf mistletoe. The three most abundant soil types that support ponderosa pine were selected for study. It was known that dwarf mistletoe was present in the general vicinity, but not whether it occurred on the areas chosen for study.

Six study areas of approximately 100 acres were selected, two in each of the following three soil types:

Granitic: Jug gravelly sandy loam-derived from Pike's Peak granite.
Limestone: Andrews loam, calcareous lithosol developed from Williams Canyon limestone.
Arkose: Westcreek and Cheesman fine sandy loams. Non-calcareous lithosols derived from Sawatch quartzite and Fountain arkose.

[3] *Fox, C. J., Nishimura, J. Y., Bauer, R. F., Armstrong, C. R., and Willmot, R. F. Soil survey report of wildlife habitat study area, Manitou Experimental Forest, Colorado. 25 pp. 1962. Mimeographed report, U. S. Forest Serv. Regional Office, Denver, Colo.*

Parallel strips, 5 chains apart with plots established at 5-chain intervals, were run by pacing and hand compass through each study area. At each plot station, three circular, concentric plots were established: a 0.25-acre plot for merchantable trees, a 0.1-acre plot for poles, and a 0.001-acre plot for saplings. Each tree was examined for dwarf mistletoe and, if infected, was rated by the 6-class system used by Hawksworth (1961). The topographic position, slope, aspect, and elevation were recorded for each plot.

On every fifth plot, ponderosa pine site quality was determined by recording data on the height and age of the three dominant trees closest to the plot center. Trees with a mistletoe rating of more than 2 or those within 20 feet of stumps were excluded. Site index was determined from the curves prepared by Morgan (1956).

Results

Data from the six study areas (table 1) revealed that dwarf mistletoe frequency (percentage of plots with infected ponderosa pines in any size class) on the 247 sample plots was highest on arkose soils (59 percent), intermediate on limestone soils (43 percent), and lowest on granitic soils (32 percent). Differences in frequency between the two areas sampled within each soil type were not significant. Measures of intensity of infection, such as percent of trees infected (table 1) and average plot mistletoe rating, showed a similar relationship.

To learn more of the frequency of dwarf mistletoe in relation to soil types, several additional factors were analyzed: steepness of slopes, site quality, elevation, aspect, and topographic position of plots. Of these, only steepness of slopes was found to be closely related to distribution of dwarf mistletoe. In fact, the correlation between frequency of the parasite and steepness of slope is so consistent that it probably accounts for most, if not all, of the differences found on the three soil types.

Site index, based on the height of dominant ponderosa pines at 100 years, ranged from 55 feet on the limestone soils to 40 to 45 feet on granite (table 1). No direct relation existed between dwarf mistletoe and site quality. The poorest soils (granite) had the least mistletoe, but the best site (limestone) was intermediate

Table 1.--Summary of dwarf mistletoe occurrence and ponderosa pine site index on three soil types on the Manitou Experimental Forest, Colorado. (Data combined for two study areas within each soil type.)

Soil type	Size of study areas	Plots		Trees over 4 inches diameter at breast height		Average site index
		Total	With mistletoe	Total	With mistletoe	
	Acres	No.	Percent	No.	Percent	
Granite	198	74	32	391	14	45
Limestone	228	90	43	790	21	55
Arkose	210	83	59	727	28	50
Total or average	636	247	45	1,908	22	50

in mistletoe frequency. The arkose soils had the most infection, but the site quality was intermediate between the granitic and limestone soils.

Dwarf mistletoe frequency was not related to difference in elevation of the three soil types sampled because they were intermixed at about the same elevations. Although average elevation of the granitic soils was somewhat higher (8,300 feet) than arkose and limestone soils (8,000 feet), there was considerable overlap.

The aspect and topographic position (bottom, slope, or ridge) of the plots were essentially the same on the three soil types, and thus were not correlated with dwarf mistletoe frequency.

Data on the steepness of slopes in relation to soil type and frequency of dwarf mistletoe (fig. 1) are based only on slope plots. Steepness was classed as gentle (less than 5 percent), moderate (5 to 30 percent) or steep (over 30 percent). Dwarf mistletoe frequency was highest on gentle slopes (87 percent), intermediate on moderate slopes (51 percent), and lowest on steep slopes (34 percent). Within each slope class differences between soil type and amount of infection were not significant (fig. 1). The proportion of gentle, moderate, and steep slopes varied considerably, however, on the three soil types; and these may account for most of the differences in mistletoe frequency. The low mistletoe frequency on the granitic areas, for

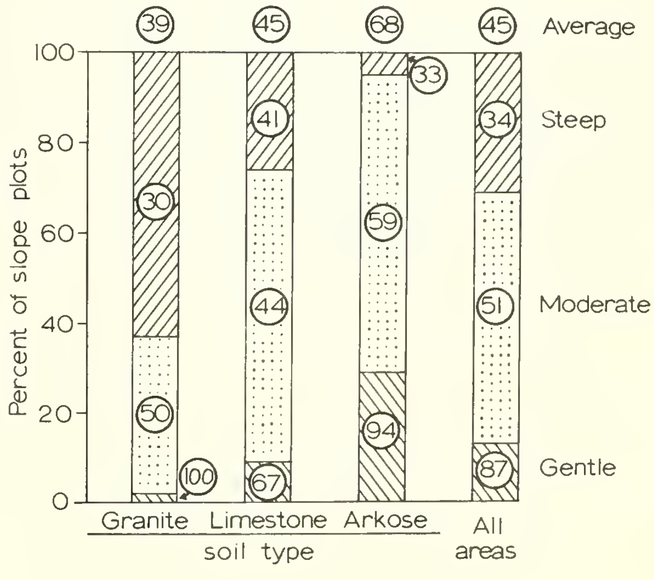

Figure 1.--Relationship of steepness of slopes and frequency of dwarf mistletoe on the three soil types. The bars show the proportion of gentle, moderate, and steep slopes in each soil type and for the three areas combined. The figures in the circles indicate the percentages of plots with dwarf mistletoes in each slope class.

example, is probably associated with the high proportion of steep slopes in this soil type. Conversely, the high frequency of infection on the arkose areas seems to be related to the high proportion of gentle slopes.

The reasons for the relationship between steepness of slopes or other site factors and dwarf mistletoe will require further investigation. Evidence from the Southwest shows that dwarf mistletoe is most prevalent on the better sites (Andrews and Daniels 1960). This might also be an underlying factor in the higher frequency of the parasite on gentle than on steep slopes, although the present study did not reveal a direct relationship between mistletoe frequency and site quality.

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Agriculture --- CSU, Ft. Collins

U.S. FOREST SERVICE
RESEARCH NOTE RM -108

FOREST SERVICE
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Production Capabilities of Some Upper Rio Puerco Soils of New Mexico[1]

R. E. Campbell[2]

Variability of plant cover within short distances is due primarily to availability of water. Even though the eight soils sampled varied from native to cultivated lands, from fine sands to firm clays, and from river bottoms to high plateaus, they were normal in moisture-holding capacity, pH, and other physical and chemical characteristics.

Plant cover on the soils of the Rio Puerco watershed in New Mexico varies widely within relatively short distances. This fact is obvious on the three San Luis experimental watersheds located north of San Luis, New Mexico, where grazing has been restricted for several years (Aldon 1964, Hickey and Garcia 1964a, 1964b). This study was made in an attempt to determine which soil factors may contribute to the variability in plant cover.

Basic soils data are limited in the Rio Puerco watersheds. A low-intensity soil survey of part of the upper Rio Puerco watershed was made jointly in 1963 by the Soil Conservation Service and the Bureau of Land Management (Folks and Stone 1968). The soils studies presented herein were keyed, primarily, to the classifications in the SCS-BLM survey. The survey indicates that 47 percent of the area is rough, broken land, stony outcrops, or badlands. Of the remaining 53 percent, 40 percent of the soils were classified as sandy loam or coarser, 23 percent as loamy, 26 percent as silt loam to clay loam, and 10 percent as clay. However, some soils classified in medium-textured groups have a fine-textured subsoil.

The clay soils in the pilot survey are generally in the broad, low river bottoms and in the broad major tributaries of the Puerco. The sandiest soils are on the high plateaus. The flood plains and small tributary bottoms vary widely in texture.

Procedures

Soil Analyses

Eight of the most predominant soils in the survey area were chosen for analysis (table 1). The samples tested were taken from sites as near to the representative soil sites as possible.

[1] *Research reported here was conducted in cooperation with the Bureau of Land Management, U. S. Department of the Interior.*

[2] *Soil Scientist, located at Albuquerque in cooperation with the University of New Mexico; central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

Table 1. --Some physical and chemical characteristics of selected soils of the Upper Rio Puerco

Soil type[1]	Extent in survey area	Paste pH	Saturated conductivity	Exch. sodium (Na)	Organic matter	Texture			Texture designation	Water saturation	Moisture holding capacity
						Sand	Silt	Clay			
	Percent		mmho/cm	- - -	- - -	- - -	Percent	- - -	- - -	- - -	- - -
Penistaja fine sandy loam	14.2	6.7	0.32	1.1	1.0	45	43	12	L	38	9.0
Berent loamy fine sand	7.7	6.9	.46	1.9	1.0	77	11	12	SL	35	4.8
Billings silty clay loam	5.4	7.7	.70	0	.9	37	38	25	L	39	9.1
Litle silty clay	4.1	7.7	2.90	0	.8	17	82	1	SI	38	8.8
Alluvial land	4.0	8.0	.96	2.7	2.8	47	36	17	L	41	8.4
Christianburg clay	3.6	7.8	.61	2.1	1.2	29	34	37	CL	54	11.6
Fruitland sandy loam	3.5	7.6	.58	8.9	.5	77	12	11	SL	33	6.1
Navajo clay	1.4	7.8	6.05	.7	1.7	18	40	42	C	45	11.5

[1] Name designations from Folks and Stone (1968).

Soil pH was determined on a saturated paste with a glass electrode. Organic matter (Walkley and Black 1934); exchangeable sodium, estimated from the sodium absorption ratio (SAR) of the saturation extract (U. S. Salinity Laboratory Staff, 1954, pp. 102-103); and soil particle size (Bouyoucos 1934) were determined by the Soil Testing Laboratory, New Mexico State University. Saturation percentage was determined by the method of Longenecker and Lyerly (1964). Electrical conductivity was determined on the saturation extract. Moisture characteristics of these soils were determined by the methods of Richards (1965).

Greenhouse Study

Four soil samples were taken from San Luis experimental watershed I for a greenhouse pot study. A fifth soil, chosen from the Rio Grande Valley north of Albuquerque, had been under cultivation and irrigation for many years.

Soil 1 was taken from a hillside on which a thin but fairly uniform stand of galleta (Hilaria jamesii) was growing. This soil was mapped (Folks and Stone 1968) as a Berent-sandstone-rockland complex. It was of sandy loam texture and sloped about 3 percent to the southwest.

Soil 2 came from a bare area which was mapped as alluvial land. The texture of the sample was clay loam. The spot sampled supported no vegetation. This bare area was of slightly finer texture than the surrounding soil. The vegetation on the surrounding area consisted of alkali sacaton (Sporobolus airoides), galleta, blue grama (Bouteloua gracilis), and some cane cactus (Opuntia spinosior).

Soils 3 and 4 were found in the flood plain of the same watershed. They appeared to be identical except that Soil 3 supported a vigorous

Table 2.--Characteristics of the five soils used in a greenhouse study, January and June 1965

Soil No.	Texture	Slope	Aspect	Ground cover	Paste pH	Saturated conductivity
		Percent				mmho/cm
1	Sandy loam	3	West-southwest	Galleta	7.7	0.33
2	Clay loam	2	South-southeast	Bare	7.5	.37
3	Sandy loam	1	South	Alkali sacaton	7.5	.67
4	Sandy loam	1	South	Bare	8.1	.94
5	Silt loam	1	West	Cropped	7.1	2.30

stand of alkali sacaton whereas Soil 4 was bare of grass. The characteristics of the five soils used are shown in table 2.

Sixty 1-gallon food cans were lined with polyethylene plastic bags, and each was filled with 8 pounds of air-dry soil which had been passed through a 4-mesh-per-inch sieve. Fertilizers were mixed throughout designated soils prior to potting.

A factorial experimental design with three replications was used. Fertilizer treatments consisted of (1) unfertilized check, (2) ammonium nitrate, 2.0 grams per pot, (3) triple superphosphate, 1.0 grams per pot, and (4) a combination of (2) and (3).

Twenty barley seeds (Hordium vulgare var. Arivat) were planted in each pot. Distilled water was added to each pot sufficient to bring the soil to about 0.1 bar matric suction (suction attributed to the soil mass).

Soil moisture was brought to 0.1 bar suction weekly or when 12 bars suction was reached as determined by pot weight. In this way all pots were kept as nearly as possible within the same moisture regime.

When barley seedlings were about 3 inches tall, they were thinned to 10 plants per pot. When about 50 percent of the plants had reached heading stage, the total aboveground portions were harvested and weighed. Dry matter yields were determined in this way for two successive crops. The first crop was planted December 8, 1964 and harvested January 22, 1965. The second crop was planted May 7, 1965 and harvested June 22, 1965. Soil 5 was planted to the second crop only.

Results and Discussion

Soil Analyses

The pH values of all soils (table 1) are within reasonable limits of good western soils. None are so high as to indicate sodium problems or to suppress appreciably the availability of plant nutrients.

The exchangeable sodium percentages of all soils except Fruitland are below 3. Even this exception with exchangeable sodium at about 9 percent is within reasonable limits, and should cause no adverse effects from sodium.

The soluble salt levels as reflected in electrical conductivity measurements (table 1) are all within reasonable limits, so no major salt effects are anticipated.

The organic matter contents of the soils tested were generally low, as would be expected on soils so sparsely vegetated. Because of low organic matter level, the reserve N supply is probably meager.

Curves relating matric suction to moisture content by weight (fig. 1) are desorption curves, and are used as a working tool to estimate the amount of water available for plant use.

The data reveal no serious basic soil problems which would preclude establishment of vegetative cover. Some of the soils are quite sandy, and therefore have meager water-holding capacity (table 1), but this condition is not extreme. That is, none of the soils are devoid of fine particles which provide reasonable water-holding capacity. Although the Litle soil has very little clay (table 1), its high silt fraction

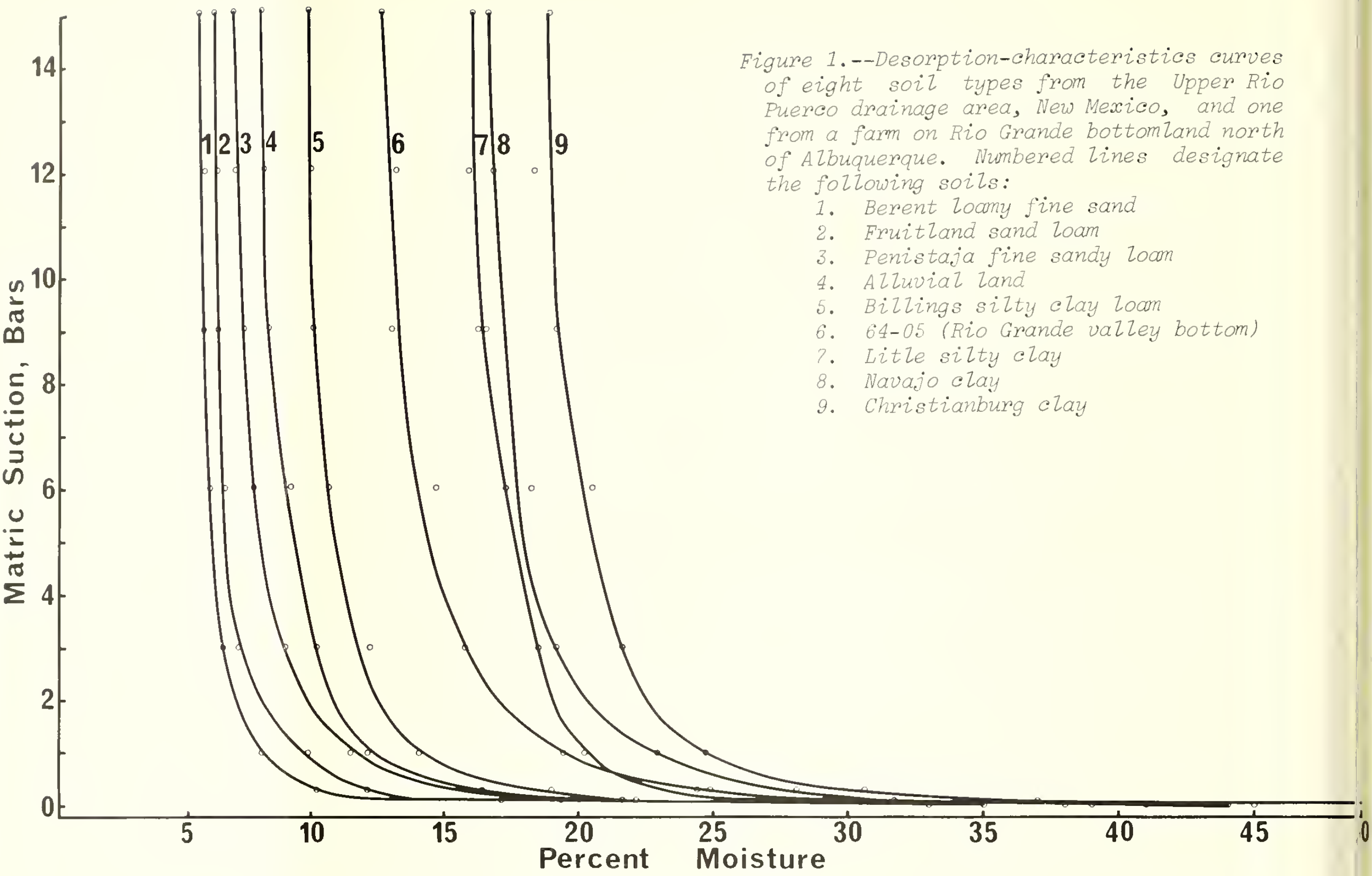

Figure 1.--Desorption-characteristics curves of eight soil types from the Upper Rio Puerco drainage area, New Mexico, and one from a farm on Rio Grande bottomland north of Albuquerque. Numbered lines designate the following soils:

1. *Berent loamy fine sand*
2. *Fruitland sand loam*
3. *Penistaja fine sandy loam*
4. *Alluvial land*
5. *Billings silty clay loam*
6. *64-05 (Rio Grande valley bottom)*
7. *Litle silty clay*
8. *Navajo clay*
9. *Christianburg clay*

provides it with moderate water-holding capacity and surface area for nutrient adsorption.

The readily available moisture-holding capacity (between 0.3 bar and 15 bars) of the soils (fig. 1, table 1) ranged from 4.8 percent by weight in the Berent soil to 11.7 percent in the Rio Grande Valley soil.

Greenhouse Study

The barley plant yields in June were appreciably greater than in January (table 3), although the growth periods were essentially the same, 45 and 46 days. The difference may be explained on the basis of available light—during the May-June period, days were longer and the light received by the plants was more intense than during the December-January period.

Phosphorus produced a yield response in both January and June (table 3). The response was evident on all soils, even though a significant Px soil interaction occurred in January. The response to P was greater in the presence of N than in the absence of N on both dates and on all soils.

The data from table 3 were evaluated in terms of the effects of N, P, and the effects of combined N and P over N and P each applied alone (table 4). The main effects only of the treatments in this factorial experiment are shown. The main effects for each soil were calculated from table 3 as follows:

$$N = 1/2\ [(N + NP) - (P + 0)]$$

$$P = 1/2\ [(P = NP) - (N = 0)]$$

$$NP = 1/2\ [(NP + 0) - (P + N)]$$

Table 3.--Effect of fertilizers on yield of greenhouse-planted barley harvested in January or in June 1965 from five types of soil

Date of harvest and soil sample	Yield, by treatment				Mean
	No treatment	Nitrogen ((N)	Phosphorus (P)	Nitrogen plus phosphorus (NP)	
	Grams per pot				
January 1965:					
Soil 1	0.69	0.52	1.36	1.95	1.13
Soil 2	2.22	1.03	2.46	2.43	2.04
Soil 3	1.02	1.57	1.13	2.34	1.51
Soil 4	1.56	.83	1.90	1.99	1.57
Mean	1.37	.99	1.71	2.18	1.56
July 1965:					
Soil 1	2.69	3.62	3.54	6.82	4.17
Soil 2	1.74	3.04	2.98	6.38	3.53
Soil 3	4.45	1.76	5.28	3.09	3.50
Soil 4	1.84	4.50	1.86	6.20	3.61
Soil 5	6.71	4.19	8.09	7.00	6.50
Mean	3.49	3.30	4.35	5.90	4.29

Table 4. --Summary of main effects[1] of fertilizer versus soils on yield of greenhouse-planted barley (see table 3)

Date of harvest and soil sample	Main effect, by treatment		
	Nitrogen (N)	Phosphorus (P)	Nitrogen plus phosphorus (NP)
	- - - Grams per pot - - -		
January 1965:			
Soil 1	0.21	1.05	0.39
Soil 2	-.61	.82	.58
Soil 3	.88	.44	.33
Soil 4	-.32	.75	.41
Overall mean	.04 N.S.	.76**	.43**
June 1965:			
Soil 1	2.10	2.03	1.17
Soil 2	2.35	2.29	1.05
Soil 3	-2.52	1.16	.33
Soil 4	3.50	.86	.83
Soil 5	-1.81	2.09	.72
Overall mean	.72**	1.68**	.82**

[1] Main effects calculated from table 3 as follows:

N = 1/2 [(N + NP) - (P + O)]

P = 1/2 [(P = NP) - (N = O)]

NP = 1/2 [(NP + O) - (P + N)]

** Indicates significance at the 1 percent level.

The overall response to N in January was not significant (table 4). Soils 1 and 4 responded positively and soils 2 and 4 responded negatively to N. The overall response in June was significant, but because of the strong interaction with soils, no general statement can be made but must be referred to each soil. The response pattern in June was partially reversed from January in that soils 3 and 5 responded negatively and soils 1, 2, and 4 responded positively to N. This inconsistency of N response has not been explained.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 109

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Detrimental Effect of Russianthistle on Semidesert Range in West-Central New Mexico[1]

Earl F. Aldon[2]

Ground cover of perennial grasses declined seriously under plots covered overwinter with dead thistle plants.

Russianthistle (Salsola kali L.) is a common plant on semidesert ranges in New Mexico. Its presence is most noticeable in the fall when, carried by strong winds, it is blown across roads and piles up against fences. This annual grows on disturbed sites, and is a vigorous competitor for limited soil moisture. On semidesert watersheds rehabilitated by mechanical ripping, reseeding, or gully control structures, thistle is quick to establish itself after treatment. Wallace et al[3] have shown that, at temperatures above about 80°F., thistle seeds germinate literally in a matter of minutes, if sufficient moisture is present. The embryo unwinds in a spiraling manner, forcing the root into the soil if the soil is loose and pliable. They conclude that, on disturbed desert soils, thistle grows extremely well with limited moisture.

Its persistence intact overwinter led to this study of the effects of thistle plants on perennial grass ground cover and vigor. The study was designed to determine what effect piling of dry thistle plants had on the ground cover, plant diameter, leaf height, and culm height of perennial grass found under them. The study was conducted in cooperation with the U. S. Bureau of Land Management on portions of the San Luis watersheds about 58 miles northwest of Albuquerque, on the semidesert range of west-central New Mexico. Vegetation, topography, climate, and soils are described by Aldon.[4] The principal grass species in the area is alkali sacaton (Sporobolus airoides Torr.), although there is some galleta (Hilaria jamesii Torr.) on the plots. Average annual precipitation is 10 inches; growing-season precipitation (April 1-November 1) averaged 6 inches in 15 years of record.

[1] *Research reported here was conducted in cooperation with the Bureau of Land Management, U. S. Department of the Interior.*

[2] *Hydrologist, Rocky Mountain Forest and Range Experiment Station, U. S. Department of Agriculture, Forest Service, with central headquarters maintained at Fort Collins in cooperation with Colorado State University; author is located at Albuquerque in cooperation with the University of New Mexico.*

[3] *Wallace, A., Rhods, W. A., and Frolich, E. F. Germination behavior of Salsola as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agron. J. 60: 76-78. 1968.*

Methods

Twelve plots, 20 feet square, were set out in a randomized block design with four replications. Treatments consisted of:

(1) no treatment (check),
(2) thistle piled 2 feet deep in October and released in early April, and

[4] *Aldon, Earl F. Ground-cover changes in relation to runoff and erosion in west-central New Mexico. U.S. Forest Serv. Res. Note RM-34, 4 pp. 1964. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colorado.*

(3) thistle piled 2 feet deep in October and released late in June.

These release dates correspond to wind pattern changes. The fall winds pile the fresh thistle initially. In April and May very high winds often redistribute thistle plants, and by late June the plants have broken down or are removed when strong winds blow in the vicinity of summer thundershowers. In only a few sheltered places do thistles persist year-round.

Ground cover of perennial grasses was determined by line intercept measurements[5] prior to treatment (October 1965) and annually thereafter (October 1966 and 1967) along five random lines 20 feet long in each plot.

Average leaf height, tallest culm height, and plant diameter were measured on 10 random plants in each plot in the posttreatment years of 1966 and 1967. Measurements were made to the nearest hundredth of a foot. All plots were protected from grazing animals during the study.

Line intercept data were compared by covariance analysis for 1965 versus 1966, and 1965 versus 1967. Analyses of variance were used to detect treatment effects on leaf height, culm height, and plant diameter.

Results

The presence of thistle plants overwinter reduced ground cover of alkali sacaton perennial grass. Ground cover declined on the plots released in June in the 1965 versus 1966 and 1965 versus 1967 comparisons; the April comparisons were not significant:

	Control	Dates of thistle release: April	June
	- - -	(Feet)	- - -
Adjusted means of ground cover per 100 feet of line intercept:			
1965 versus 1966	4.01	4.07	2.27*
1965 versus 1967	5.16	3.74	2.81*

*Significant at the 0.05 level.

When the two posttreatment years were analyzed separately, all three variables showed increases due to treatment in 1967 (table 1). The treatments had no effect on any variable in 1966.

When data from 1966 and 1967 were combined, culm height showed an increase caused by the treatments. This increase is significant; the interaction of treatment and year is nonsignificant. Leaf height and plant diameter did not differ due to treatment, but there were significant year-to-year differences as might be expected with varying precipitation.

Discussion

Soil moisture seemed greater under the plots with thistle at the April release date. By June these differences were not noticeable. Thus, any gains in accumulating or holding winter moisture by the thistle may have been gone by the time alkali sacaton began growing vigorously.

It is not known how thistle caused the serious decline in ground cover. Mechanical abrasive action, leaching of toxic, inhibitory substances, temperature changes, or combinations of these factors may account for the decline.

[5] *Canfield, R. H. Application of the line interception method in sampling range vegetation. J. Forest. 39: 388-394. 1941.*

Table 1.--Average values for leaf and culm height and plant diameter of alkali sacaton as affected by two thistle release dates

Dates of thistle release	Leaf height		Culm height		Plant diameter		Growing season precipitation	
	1966	1967	1966	1967	1966	1967	1966	1967
	- - -	- - -	- - -	Feet	- - -	- - -	Inches	
Control	0.72	1.08	1.97	2.02	0.43	0.58		
April	.92	1.32a	2.33	2.50a	.46	.66a		
June	1.08	1.31a	2.37	2.55a	.44	.61a		
Average, all treatments	.91	1.24b	2.22	2.36	.44	.62b	6.02	8.41

a = significantly higher than the control at the 0.05 level.

b = significantly higher in 1967 than in 1966 at the 0.01 level.

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RESEARCH NOTE RM - 110

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Some Observations on Temperature Profiles of a Mountain Snow Cover

James D. Bergen[1]

Measurements of the vertical temperature distribution in an annual mountain snow cover are discussed in terms of a simple model of the vertical temperature profile. The parameters describing this model are compared for measurements made for 2 winters. Day-to-day variation is found to be larger for these parameters than between different months of the same winter or between the 2 winters.

Temperatures within a snowpack were measured in a clearing of about a 70-meter radius in a mixed conifer stand and at an altitude of 3,000 meters (m.) in the Colorado Rockies. A micrometeorological station was installed 20 m. from the edge of the clearing to measure the various components of the snow-cover energy balance. These instruments and the general course of these studies are described in earlier publications.[2 3 4] Local temperatures within the snowpack were measured with bead thermistors mounted on light plastic frames designed to settle freely with the snow cover. These frames moved on a central wire which formed one arm of a bridge circuit, so that the height of a particular assembly above the soil surface could be determined within the nearest 0.5 centimeter (cm.) A new framework was deposited on the snow surface after each new accumulation of about 5 cm. over the winter. During observation periods, the thermistor resistances were measured at 12-minute intervals by a multichannel automatic recording potentiometer circuit. Temperatures of the snow-cover surface were measured with a bimetal stem thermometer laid on the snow surface in the 1962 observations. The consistency of the surface snow was usually such that the thermometer sank about a centimeter into the surface. Such measurements were made at intervals of half an hour to an hour, depending on how rapidly the snow surface temperature was changing. For the 1963 measurements, surface temperatures were measured by a thermistor mounted on a framework which could be lowered by small height intervals to the surface from a distance by means of a screw and pully system. Contact with the snow was indicated by the discontinuity in thermistor resistance as the assembly was lowered. After

[1] *Meteorologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Bergen, James D. Vapor transport as estimated from heat flow in a Rocky Mountain snowpack. Int. Union Geodesy and Geophys., Int. Ass. Sci. Hydrol., Snow and Ice Comm. Publ. 61, pp. 62-74, illus. 1963.*

[3] *Bergen, James D., and Swanson, Robert H. Evaporation from a winter snow cover in the Rocky Mountain forest zone. West. Snow Conf. Proc. 32: 52-58. 1964.*

[4] *Swanson, Robert H. A system for making remote and undisturbed measurements of snow settlement and temperature. West. Snow Conf. Proc. 36. 1968.*

adjustment, measurements were made at 12-minute intervals by the recording potentiometers mentioned above. These measurements were checked at intervals by reading with the bimetal thermometer as described for the 1962 observations, with agreement within 1°C.

The temperature measurements were grouped in periods of two to seven consecutive 24-hour periods at 3-week intervals through the winter. Over the winters of 1962 and 1963, temperatures were measured over thirty-five 12-hour observation periods.

The temperature measurements were supplemented by measurements of the snow density profile, as determined from samples taken in a nearby trench for some of the periods of observation (fig. 1). Unfortunately, such measurements were not made in February of 1962 or for the January temperature measurements in 1963.

Snow samples were taken with sharpened steel tubes of the standard SIPRE design. These were inserted horizontally at intervals of about 20 cm. above the soil surface. Densities in the 20 cm.-thick layer nearest the surface of the snow cover were estimated from a sample obtained by sinking such a tube vertically into the snow surface.

The variation of temperature with time and position in the snow cover for a typical 24-hour observation period is complex (fig. 2). The detailed features must reflect the random variations in conditions at the upper boundary, such as the net radiation balance at the snow-cover surface and the windspeed near that surface.

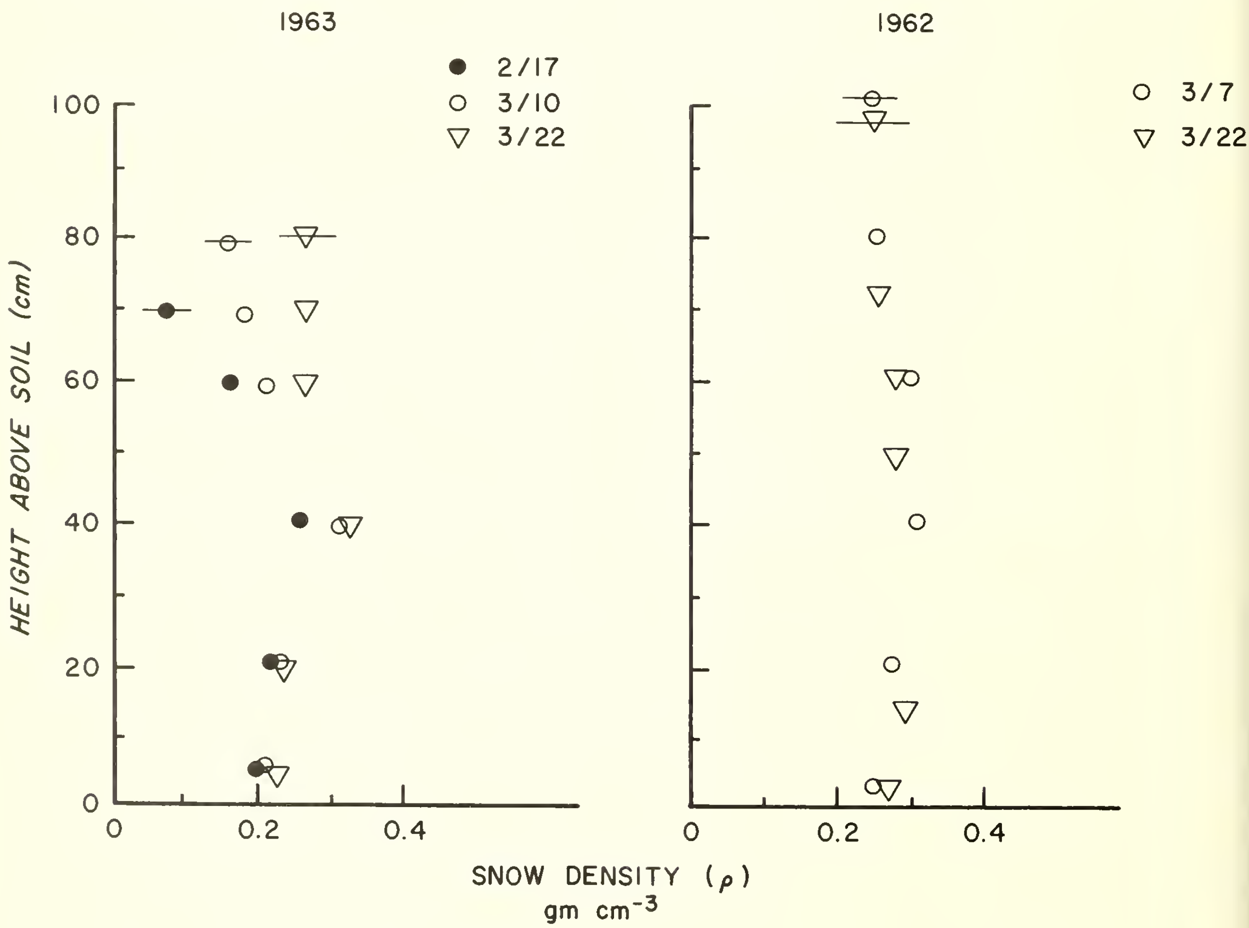


Figure 1.--Snow density profiles.

The analysis of snow-cover temperatures found in the literature[5] usually treats the cover as a uniform semi-infinite slab with a constant temperature in the lower boundary and a sinusoidal diurnal temperature variation at the upper boundary. The thermal conductivity (k) of the snow is assumed to be a function of density (ρ) in general accord with an expression attributed to Abel:[5]

$$k = 0.0068\rho^2 \text{ cal deg}^{-1} \text{ cm}^{-1} \text{ sec}^{-1}$$

[5] *Minnesota, University of, Institute Technical Engineering Experiment Station. Review of the properties of snow and ice, edited by Homer T. Mantis. SIPRE Rep. 4, 156 pp., illus. Snow, Ice and Permafrost Res. Estab., U.S. Army Corps Engin. 1951.*

The apparent thermal conductivities of the snow cover do not conform with the above expression under conditions of strong surface cooling, due probably to convective currents in the air spaces of the snow.[2] Under conditions of strong surface heating, such as found in the last half of March in 1963, movement of water into the lower regions of the snow cover may dominate the transport pattern for sensible heat. The situation is thus more complicated than that envisioned in the simple slab model, and as yet no general physical model is available which could be used to construct temperature-time patterns such as that shown in figure 2 from the density profiles and surface energy budget components. In addition to their relevance to some basic problems in the metamorphism of the snow cover, these patterns are also of practical interest in the estimation of environmental stresses on plant and animal life in such locations, as well as on manmade systems designed to operate in this environment.

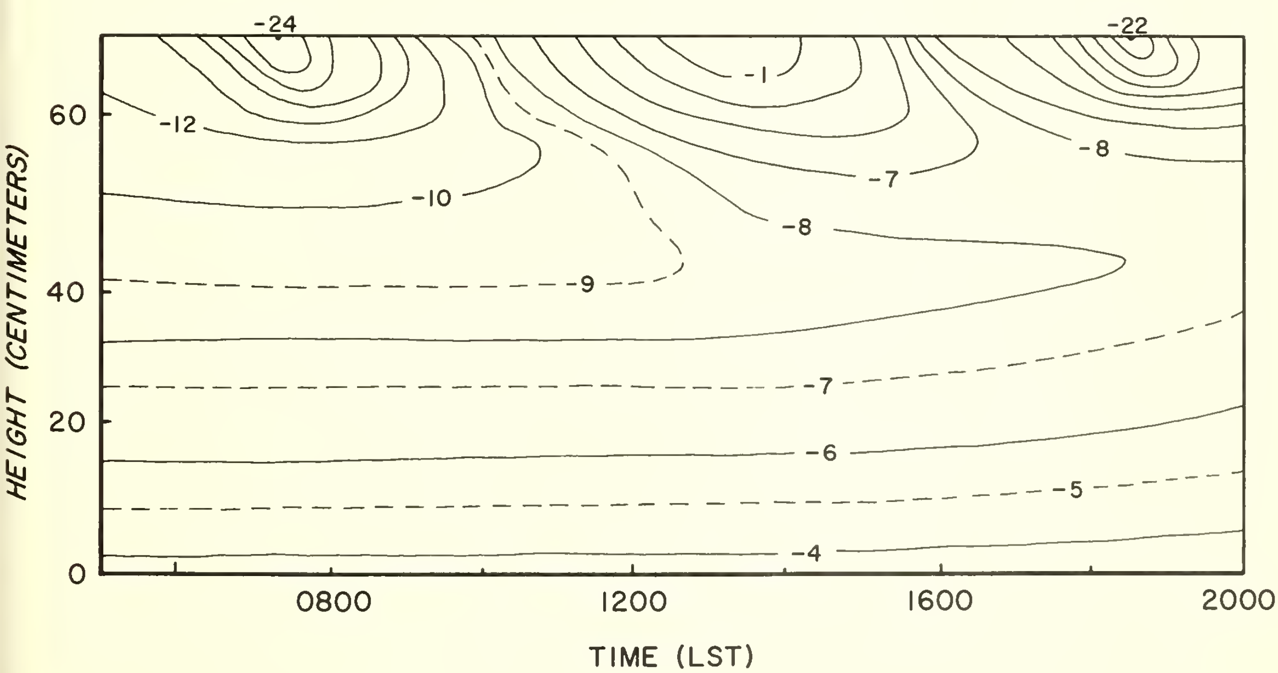


Figure 2.--Typical time-temperature plot.

In this report an attempt will be made to summarize the snow temperature profile measurements in a form suitable for these purposes.

As may be seen from the pattern of figure 2, the snow cover shows a thermally active layer extending from the surface to an inversion. Below this inversion level, the diurnal variation is relatively slight and the snow cover shows an almost constant and negative linear gradient of temperature with distance above the soil surface. The diurnal heating has penetrated to its maximum depth in the pack at about 1400 local standard time (LST). Conditions at this time are illustrated in figure 3. This maximum depth of penetration (L) is characterized by an inversion with a temperature (T_i) which shows little variation over the subsequent 12-hour period. The curvature of the temperature profile in the layer above this inversion may be roughly expressed in terms of the inversion thickness (L), which is defined as the height interval including the inversion level which includes 10 percent of the temperature drop between the inversion level and the surface; that is, T_s - T_i where T_s is the snow surface temperature at 0200 LST of the following day. The measured temperature profiles at 0200 LST above the inversion level are linear to within

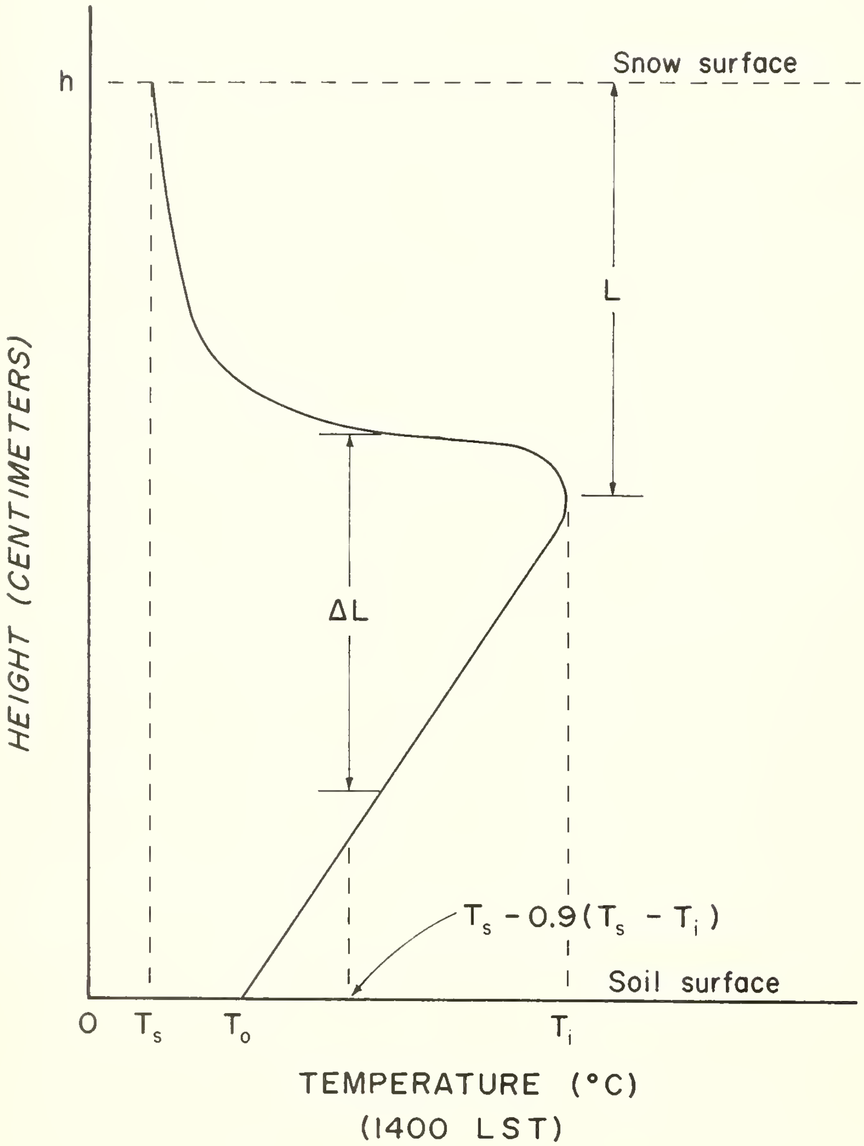


Figure 3.--Definition of parameters.

about 1 degree. The drop in surface temperature over this period, between 1400 LST and 0200 LST of the following day, is denoted as ΔT. The remaining parameter chosen to characterize the 1400 LST profile is the temperature at the soil surface (T_0), defined in this case as the value corresponding to the extrapolation of the temperature profile below the inversion to the soil surface. The day-to-day variation of T_0 is insignificant in most cases.

The variation of these parameters for the 2 years in which the observations were made is shown in figure 4, along with total snow accumulation height (h) above the soil surface.

The statistical distributions of the parameters are obviously bounded; in the case of snow temperatures, the average value for any group of observations lies below the physical bound of 0°C. by only a small fraction of the range.

In view of these difficulties and the small number of observations presently available, no statistical measures will be computed on the data in this report, although it is obvious that the specific applications suggested above will require some appropriate assumptions that allow such estimates.

As is evident from figure 4, the 1962 snow cover was warmer and deeper than that of 1963; the most radical difference between the sequences for the 2 years appears to be in the soil surface temperature (T_0). T_0 in 1962 shows no significant departure from 0°C. over the winter, as contrasted with the lower temperatures and sudden warming evident in the 1963 observations. For both years, the day-to-day variation of L, ΔL, and ΔT is larger than any discernible trend through that winter, and larger than the average difference between corresponding periods of the 2 winters.

It is anticipated that additional data on the temperature regime of the snow cover in this region will be collected in succeeding years, so that such parameters as have been discussed can be computed on a rigorous climatological basis.

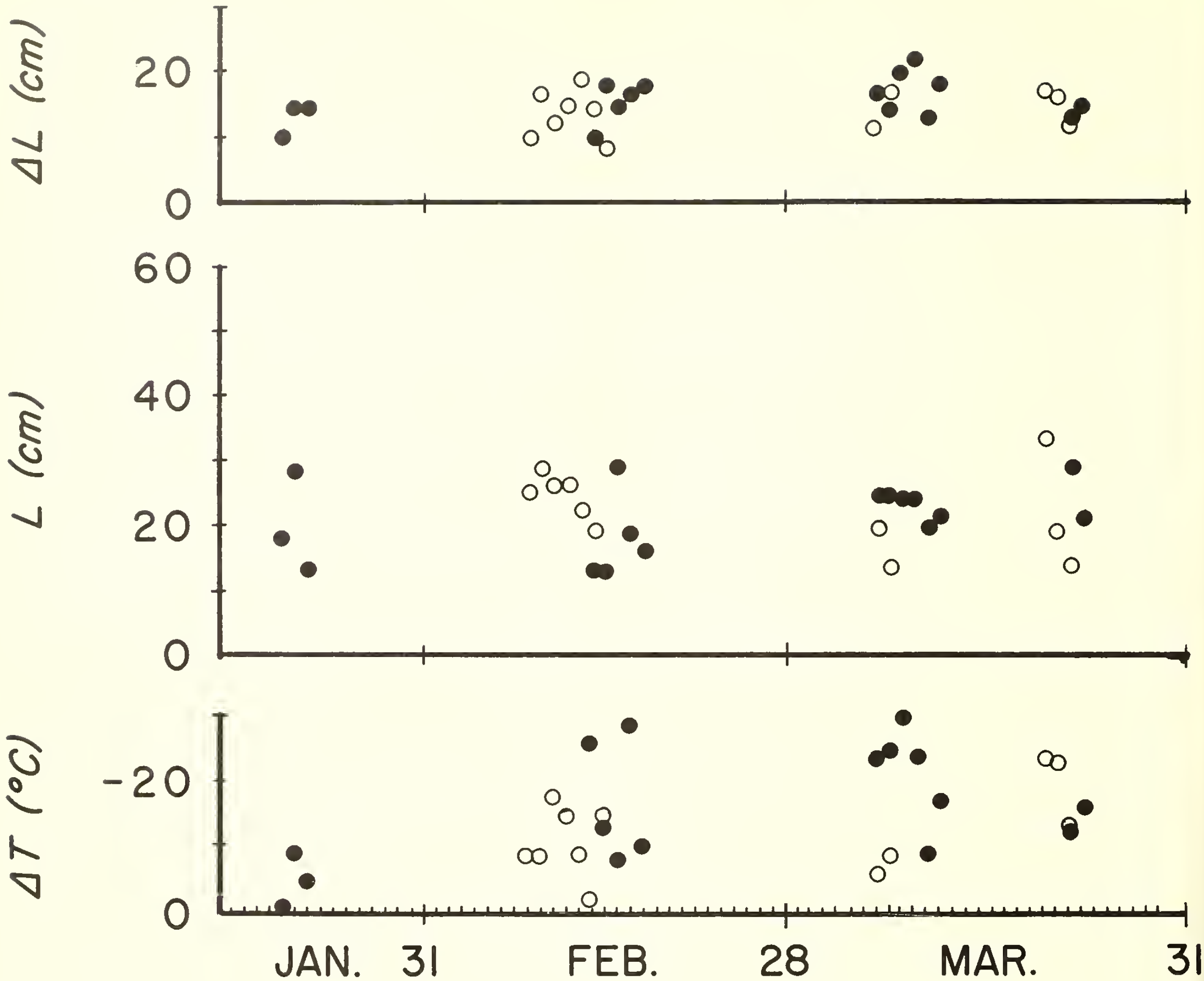
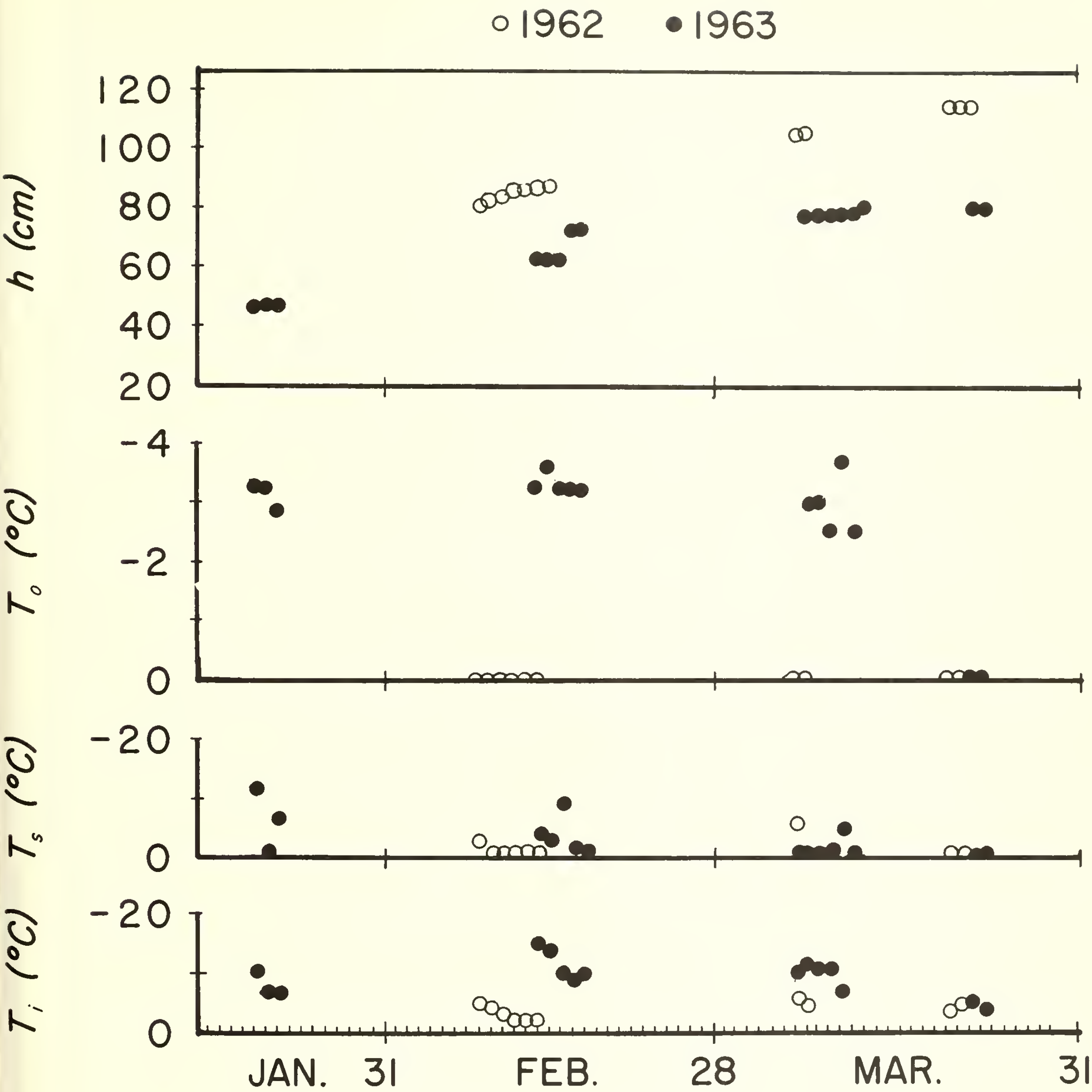


Figure 4.--Variation of parameters for 1962-63.



○ 1962 ● 1963
h (cm)
120
100
80
60
40
20
T_o (°C)
-4
-2
0
T_s (°C)
-20
0
T_i (°C)
-20
0
JAN. 31
FEB. 28
MAR. 31

1968

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Observations of Snow Accumulation and Melt in Demonstration Cuttings of Ponderosa Pine in Central Arizona

Edward A. Hansen and Peter F. Ffolliott[1]

A clearcut block on a north aspect and strips with widths of one and one-and-one-half times tree height on an east aspect increased snow accumulation and increased rates of melt and daily water loss. A strip three-fourths as wide as tree height on a west aspect increased snow accumulation. None of the strips cut on south and southwest aspects affected snowpacks measurably.

The Beaver Creek Watershed Project (Worley 1965) was established to test types of land treatments designed to increase water yield in Arizona. Several watersheds are currently being calibrated in the ponderosa pine (Pinus ponderosa Laws.) type. More than 99 percent of the annual runoff in this type occurs during the period November 15-April 15, much of it originating from snowmelt. It is apparent that patterns of snow accumulation and melt must be considered in any land treatment on Beaver Creek.

The exploratory work discussed here was designed to help form guidelines for developing land treatments in the ponderosa pine type on Beaver Creek. Subsequent evaluation studies are being carried out on the Beaver Creek pilot watersheds to provide more comprehensive information on actual treatment effects.

[1] *Associate Hydrologist and Associate Silviculturist, respectively, located at Flagstaff in cooperation with Northern Arizona University when observations were made. Hansen is now located at the North Central Forest Experiment Station, St. Paul, Minnesota; Ffolliott is a graduate assistant, Department of Watershed Management, University of Arizona, Tucson. The Rocky Mountain Station's central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

Problem

Records indicate that snowmelt in January and February produces little runoff due to low melt rates. More runoff occurs from the rapid melt of the snowpack in March and April. Consequently, delaying snowmelt until later in the winter should result in more rapid melt rates and less loss due to infiltration. Runoff produced at the end of the winter-spring runoff period, when relatively low discharges travel through long reaches of streambed, may be lost. Shortening the flow period may also minimize these conveyance losses (Hoover 1960).

Snow studies indicate that reduced timber stocking results in more snow on the ground.[2] This increased snow may contribute to additional surface runoff. These studies also conclude that snow melts earliest and most rapidly on south aspects.

On the basis of the above factors, it is believed that water yield on Beaver Creek may be increased from land treatments designed to (1) minimize winter snowmelt, (2) maximize spring snowmelt rates, and (3) minimize the length of the runoff period.

[2] *Haupt 1951, Goodell 1952, Kittredge 1953, Anderson 1956, Weitzman and Bay 1959, Packer 1962.*

Description of Cuttings and Measurements

It was hypothesized that land treatments which might best achieve the above three goals would be (1) a clearcut of all timber on north aspects, (2) a stripcut on intermediate aspects, and (3) cutting narrow strips on south aspects. The objective of this investigation was to see whether these treatment-aspect combinations might increase snowpack accumulation and spring melt rates, and if they might tend to synchronize snowmelt from the various aspects. An earlier snow accumulation and melt investigation on Beaver Creek (Ffolliott et al. 1965) provided a starting point for selecting strip widths to test on intermediate aspects.

Figure 1.--Large pole-small sawtimber adjacent to east aspect stripcut.

Cuttings

This work was carried out 40 miles southeast of Flagstaff, Arizona, during the winters of 1964-65 and 1965-66. The elevation ranges from 7,500 to 7,700 feet, and annual precipitation averages 25 to 30 inches, half of which comes during the winter period. Prevailing winds during winter storms are usually from the southwest. Timber is large-pole, small-sawtimber size, 8 to 18 inches in diameter (fig. 1). Soils are derived from volcanics, principally basalt with an intermixing of cinders, and range from loam to clay loam (Williams and Anderson 1967). Topography represents aspects and slopes common to Beaver Creek.

Timber was cut on five slope-aspect combinations prior to the winter of 1964-65. A 3-acre block on a north aspect averaging 25 percent slope was clearcut. All slash was removed from one-half of the block, while the slash was lopped and scattered on the other half. A portion of the north aspect adjacent to the clearcut block was left uncut for comparison.

A strip 45 feet in width, equal to three-fourths the height of the adjacent timber (3/4H), was cut on a west aspect of 30 percent slope. A strip 45 feet in width (1H) was cut on an east aspect of 15 percent slope, and a strip 25 feet in width (1/2H) was cut on a south aspect of 20 percent. Three strips of different width—13 feet (1/2H), 25 feet (1H), and 52 feet (1-1/2H)—were cut on a southwest aspect of 10 percent slope.

There were no replications of the various treatment-aspect combinations. All of the strips consisted of a single "opening" in an otherwise undisturbed forest, with the exception of the 25-foot strip (1H) on the southwest aspect. Two consecutive 25-foot strips were cut there with a 25-foot "leave" strip between them.

Strip width dimensions were in terms of tree bole to tree bole. All trees and slash within the cut strips were removed to reduce variability in snowpack measurements. The long axis of the strips on the west, east, and south aspects were oriented east-west. Strips were oriented northwest-southeast on the southwest aspect.

Modifications and additional timber cuttings were made on three of the cutting areas after analysis of data obtained the first winter. The remaining slash on the clearcut block on the north aspect was burned to facilitate further study of the effects of slash on snow accumulation and melt. The 45-foot strip (3/4H) on the west aspect was widened to 75 feet (1-1/4H), and an additional strip 30 feet in width (1/2H) was cut to the leeward side of the original strip. The 45-foot strip (1H) on the east aspect was widened to 67 feet (1-1/2H) to test the effects of a wider strip. The south and southwest aspects were eliminated from consideration the second winter due to the negative results from the first year.

Measurements

Total snow depth and water equivalent (WE) were measured with a snow tube and scale throughout the 2 winters. Differences between measurements were assumed to reflect snow accumulation or melt between sampling dates.

Thirty snow sampling points were located in each of the three areas on the north aspect. The points were spaced at 10-foot intervals along two lines placed near the center of each area to minimize possible edge effects. Mean WE was computed from the 30 points in each area.

Snow sampling points were located in terms of tree heights along two parallel lines running across the cut strips (fig. 2). Sample lines were also laid out parallel to the cut strips at distances of 1/2H, 1H, and 2H in the timber adjacent to both sides of the strips to describe snow in the surrounding forest. Ten sampling points were located at 10-foot intervals along each sample line in the timber. This sample design provided closely spaced points across the cut strips, where differences in snowpack characteristics would vary in short distances, while sampling lines in the adjacent timber were spaced farther apart in anticipation of smaller variations.

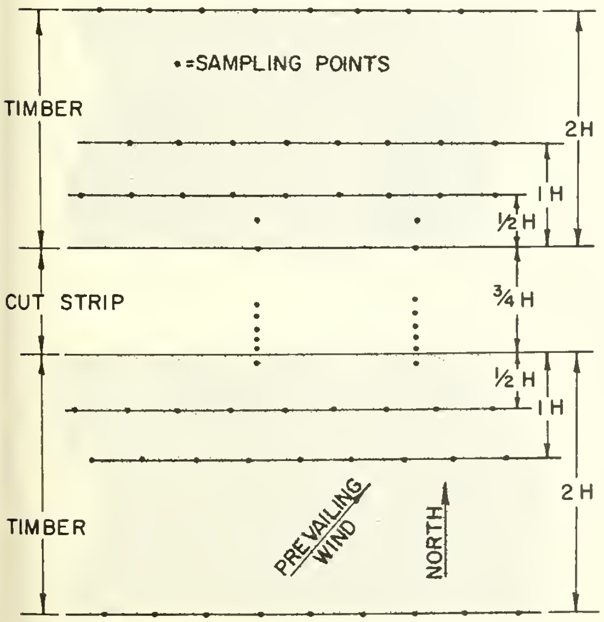


Figure 2.--Snow sample point design on a stripcut area.

Data to be presented are the average of each pair of sample points in the cut strips, and the average of the 10 sample points on each line in the timber. The effect of a cutting was estimated by comparing the average snowpack WE, snowmelt rates, and the average daily water loss for the entire area influenced by the cut strip, or "zone of influence," with corresponding parameters in the undisturbed forest. The zone of influence was defined as the area bounded by points to the windward and leeward of the cut strip which had measurable changes in the snowpack as compared to points farther from the strip.

Observations

North Aspect Clearcut

Clearcutting a north aspect resulted in 2-1/2 to 4 inches more WE in the snowpack on the date of peak accumulation the first winter of measurement, as compared to the surrounding stand of timber averaging 160 square feet of basal area (fig. 3). The variation in peak WE content of the snowpack within the clearcut area with slash was believed related to differences in slope and aspect. Consequently, the data from that area were analyzed by two different slope classes. The steeper slope had a slightly larger net WE at the time of peak snowpack.

Areas with no slash accumulated slightly more WE during the first winter than did the area with slash. Removal of the slash by burning before the second year of measurements did not change the relationship between the two areas, however. It was concluded that slash, when lopped and scattered, had no measurable effect on snow accumulation on the north aspect.

Snowmelt rates were similar on all of the clearcut areas during the major portion of the spring melt period the first winter of measurement (fig. 3). The average melt rate on the steepest clearcut area with slash present de-

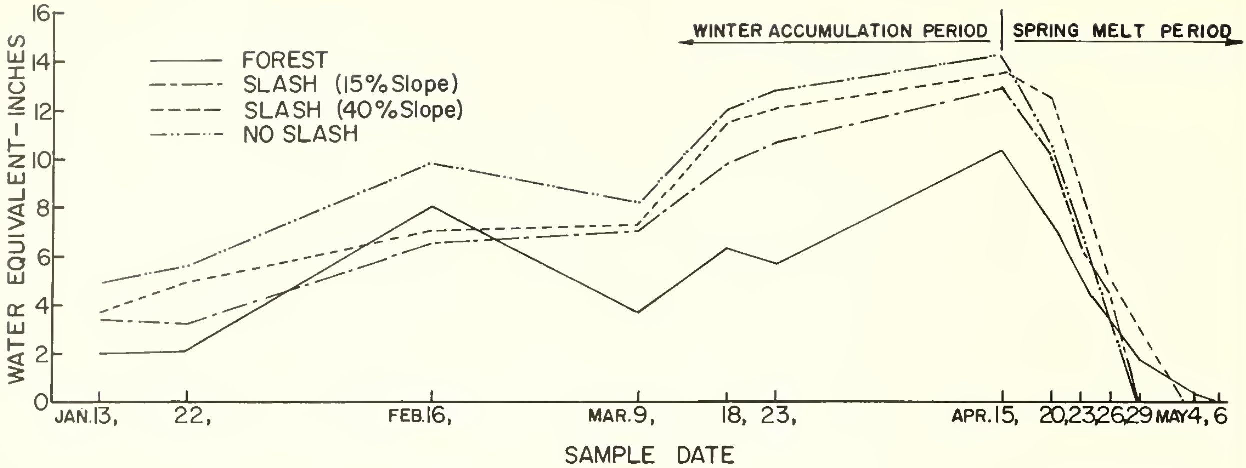


Figure 3.--Snowpack disposition on the north aspect the first winter of measurement.

creased somewhat after April 26. This was believed due to the exposure of the slash, which produced minor topographic shading on the steep (40 percent) slope. Snowmelt within the forest was slower during the entire melt season, with snow remaining 3 to 8 days longer than on the clearcut area.

West Aspect Stripcut

The west aspect selected for a stripcut had the most uniform slope and aspect of any of the cutting areas. Consequently, WE measurements were extended into the forest on either side of the cut strip to 3H, farther than at any other cut strip, to determine the limits of the zone of influence. There were no measurable changes beyond 1/2H to the leeward and 1-1/2H to the windward.

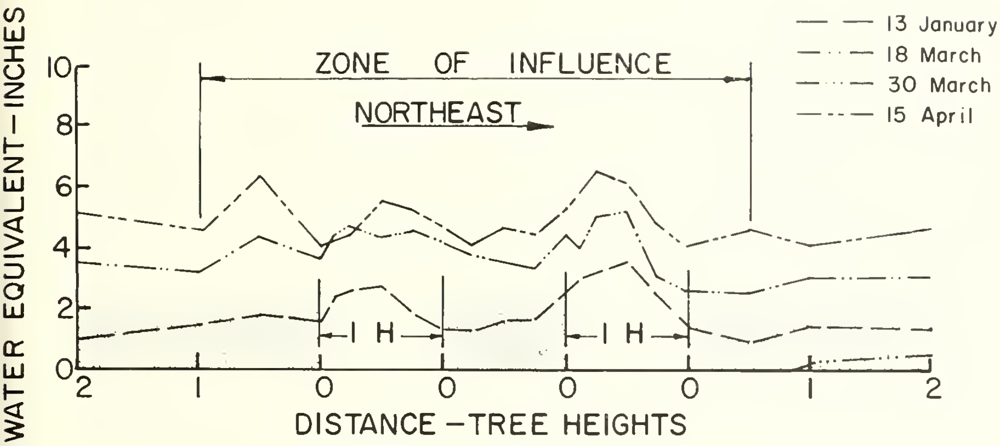
A 3/4H strip was cut in a stand averaging 190 square feet of basal area. The snowpack in the zone of influence had an average of 3/4 inch more WE than the surrounding forest at the time of peak snowpack (fig. 4A). WE of the snowpack was increased from 1/4H in the timber on the windward side to almost across the 3/4H strip. WE at the time of peak snowpack was lower in a 1-1/2H strip in the timber along the leeward side of the cut strip because of intermittent melt during the winter. Distance into the stand over which the snowpack was reduced ranged from about 1-1/2H early in the winter, when the sun angle was low, to roughly 3/4H later in the winter as the sun angle increased.

Water was lost from the snowpack earliest on the leeward (sunny) side of the strip and in the adjacent forest (fig. 4B). Snowmelt began along the windward side of the strip at the same time. However, there was no net loss of water along the windward edge of the strip for several days (see April 15 and April 19 profiles, fig. 4B) due to the slightly lower melt rate and the greater storage capacity of the deeper snowpack after April 19. Essentially the entire snowpack in the forest had disappeared by April 23, while the last snow left the cut strip 10 days later. This melt pattern would tend to lengthen the runoff period from this area.

Average rates of WE loss from the snowpack, in inches per day, were computed for points along the profile (fig. 5). Snowmelt was the same in the windward two-thirds of the strip as in the surrounding forest during a storm-free period from February 11 to March 8. Melt rates on the remainder of the strip and for a distance of 1H into the forest to the leeward were about doubled. The higher melt rates in the leeward one-third of the strip were offset by greater snow accumulation during the winter. Therefore, an approximately "normal" snowpack was present in that area at the time of peak snowpack.

The melt rates do not represent the same period, since spring snowmelt ended at different times along the profile. Periods selected for the analysis had similar daily temperature fluctuations and cloud cover. Melt rates were most rapid in the zone of influence. Maximum melt rate from the snowpack was 1.25 inches

Figure 11.--
Snowpack on southwest aspect stripcut of 1H on selected dates the first winter of measurement. Patterns were similar on the 1/2H and 1-1/2H cut strips.



A, Accumulation.

B, Melt.

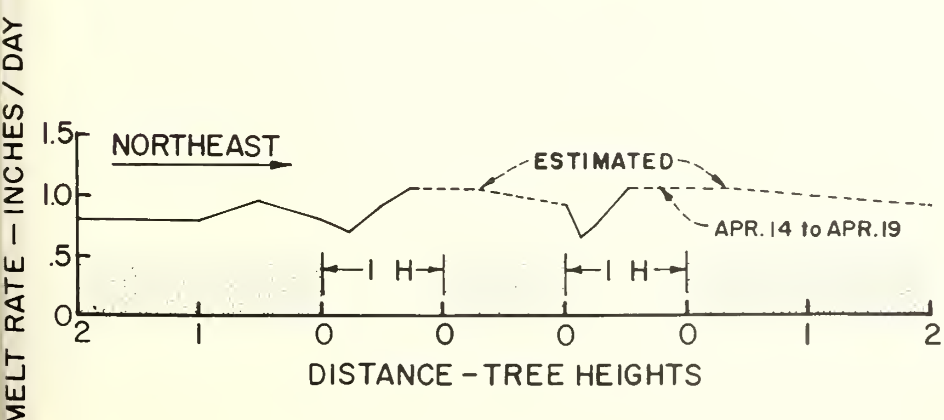


Figure 12.--
Average melt rate (WE loss) of snowpack on the southwest aspect stripcut of 1H during spring snowmelt period the first winter of measurement. Melt rates were similar on the 1/2H and 1-1/2 H cut strips.

South and Southwest Aspect Stripcuts

Stripcuts on these aspects would not produce measurable changes in the snowpack, except possibly under conditions of higher forest density or a different winter climatic regime. The major portion of the snowpack disappeared periodically throughout the winter.

Discussion

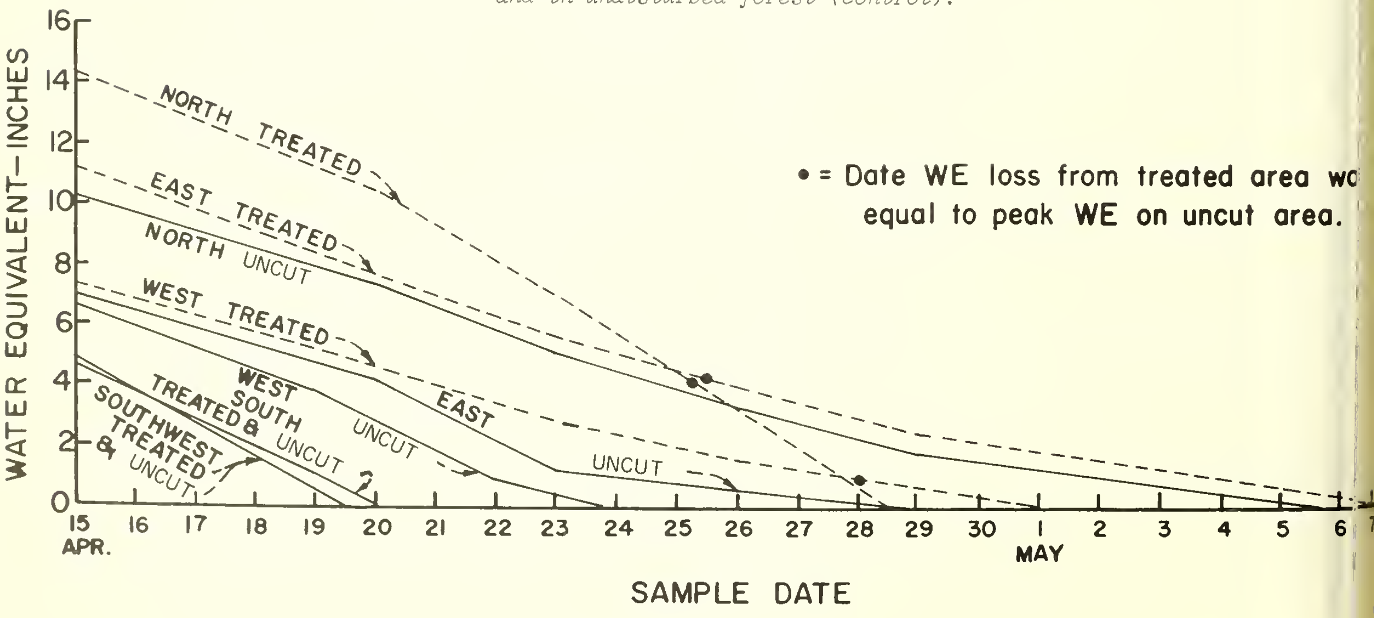
The possible effect of a particular treatment-aspect combination on peak snowpack accumulation the first winter of measurement can be illustrated by comparing it with adjacent undisturbed forest for the date of April 15 (fig. 13). For example, it can be seen that the average WE at time of peak snowpack on the treated east aspect was 11.1 inches, compared with 7.0 inches for the undisturbed area. The treatments on the north and west aspects also increased peak snowpack WE.

The average spring water loss on the treated and uncut areas is represented in figure 13 by the slope of the lines between successive dates. Melt rates on cut strips were higher than on uncut areas. However, increased snowmelt rate in the zone of influence does not necessarily result in an increase in average daily water loss from the area. The zone of influence contains a constantly decreasing area of snowpack during the snowmelt season. Increased snowmelt rates acting upon a decreased area of snowpack can result in either an increase or decrease in average water loss rate for the entire area as compared to the undisturbed forest.

The rate of water loss on the west aspect was less on the treated area than it was on an adjacent uncut area. On the east aspect, the average rate of water loss was slightly greater on the treated area than on the untreated area. Average rate of water loss from all areas generally decreased toward the end of the melt period due to the decreasing area of snowpack from which water was being contributed.

The rapid water loss on the treated north aspect relative to the other aspects should be noted. This was due in part to the increased melt rate acting uniformly upon a continuous snowpack over the entire clearcut block. It was also believed to be partially the effect of the surrounding topography and, consequently, may not be typical of north aspects in general. The clearcut was on the north-facing slope of a ravine. Opening the timber stand may have resulted in back radiation from the opposite (south) facing slope, which might have produced the high water loss rates measured.

Figure 13.--Spring snowmelt trends on cut (treated) areas and in undisturbed forest (control).



The date at which the amount of WE that had left a treated area was equal to the total amount initially present on the corresponding untreated area is shown by a circle on the "treated" lines (fig. 13). The amount of WE that had left the north aspect clearcut area by April 25 was equal to the total amount produced by the undisturbed area. This volume of water came 10 days earlier on the cut area than on the uncut area. The east aspect stripcut area produced as much WE by April 26 as did the uncut area at the time of snow disappearance 3 days later. The results were reversed on the west aspect, where it took 5 days longer for the stripcut area to produce as much WE as the nearby uncut area. In each of the above cases there was additional runoff from the treated areas after the circled date (fig. 13) due to the larger initial snowpack in the treated zone. No large treatment effect was detected, taking all the aspects together, on either the initial date of water loss from the snowpack or the date that the last snow disappeared from the area. There was considerable variation within any one aspect.

Composite Cutting Effect

Although the results from these cuttings do not cover all the possibilities of manipulating a snowpack, it is possible to synthesize from them some of the probable effects of a composite of these cutting treatments on the spring runoff pattern. These effects would vary with the proportion of a watershed in each aspect. Assuming that all aspects were equally represented on an area, the more prominent effects might be the following:

It would be expected that the duration of the spring runoff would remain unchanged, since water loss from the snowpack on a composite of all areas began and ended on about the same date on both the treated and uncut areas. The largely unchanged rate of daily water loss from the snowpack (with the exception of the north aspect) would tend to leave the seasonal peak discharge unchanged. However, the higher melt rates in the cuttings on north, east, and west aspects would result in proportionally less water "loss" to infiltration at the immediate site, and more water leaving as overland flow. This could result in additional runoff which might increase both the seasonal peak discharge and total volume of runoff. The larger initial snowpack on the treated areas would tend to sustain a high daily volume of runoff over a longer portion of the spring runoff period, and also might result in a larger volume of runoff.

Summary

This exploratory investigation was conducted to develop preliminary information on the effects of various timber cuttings on snowpack accumulation, spring melt rates, and the timing of snowmelt from several aspects. Its purpose was to provide guidelines for design of land treatments which are being tested on the Beaver Creek pilot watersheds. Observations were as follows:

1. A clearcut block on a north aspect increased snow accumulation. Both melt rates and daily water loss rates were increased, although the treatment effect was probably confounded with local topographic effects. The presence or absence of lopped and scattered slash did not have any measurable effect on either snow accumulation or melt rate.
2. A 3/4H stripcut on a west aspect increased snow accumulation. Although melt rates were increased, average daily water loss rates from the snowpack were decreased during spring snowmelt. Second-year measurements on a 1-1/4H and 1/2H strip were inconclusive.
3. Both a 1H and a 1-1/2H stripcut on an east aspect increased snow accumulation. There was an increase in both melt rates and in daily water loss rates from the snowpack during spring snowmelt.
4. Cut strips of a variety of widths on a south and southwest aspect did not produce any measurable change in snowpack characteristics at time of peak snowpack or during the spring snowmelt period.
5. Snowmelt period on the north aspect was shortened. Snowmelt period on the east and west aspects was lengthened. The net effect would be no shortening of the snowmelt period from a balanced composite of these aspects.

The results are necessarily limited to the type of weather conditions encountered. Snowpacks were moderate to heavy during the 2 years of measurements and observations. Clearcutting north aspects and stripcutting east aspects would produce snowpack changes which would tend to increase surface runoff. With similar climatic conditions, stripcutting west aspects may also produce favorable results, but possibly under more limited circumstances. Stripcutting on south and southwest aspects probably would produce no favorable results.

It is not known whether any of the cuttings were optimum in terms of desired snowpack manipulation. Factors still to be examined are other strip orientations, additional cut strip widths, leave strip widths, a variety of timber size class and stocking conditions, and the range of climatic conditions which might be experienced. The data obtained in this study do provide a starting point for development of land management treatments designed to increase water yield through snowpack management.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 112

)REST SERVICE
S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Age and Year of Collection Affect Germination of Winterfat Seeds

H. W. Springfield [1]

One- and two-year-old seeds germinated better than older seeds; nevertheless, seeds 4, 5, and 6 years old produced a fair number of seedlings, especially at temperatures of 43°F. and 57°F. Retention of viability appears to be influenced by the year the seeds were collected.

According to most investigators, seeds of winterfat (Eurotia lanata (Pursh) Moq.) lose their viability within a few years. The seeds may lose up to 50 percent of their initial viability in 1 year, and most of it in 2 years if stored at room temperatures. [2] [3] [4] Cold storage has been found to improve the retention of viability. [5]

The purpose of this study was to trace changes in the germination of seeds collected each year for 8 consecutive years, and to determine if year of collection might also influence germination.

Methods

Seeds used in the tests were collected each year from the same group of plants at an experimental site 15 miles west of Corona, New Mexico. Elevation of the site is 6,300 feet, annual precipitation 15 inches, and the soil is a sandy loam that grades into a clay loam at depths of 8 to 12 inches. Principal overstory plants are one-seed juniper (Juniperus monosperma (Engelm.) Sarg.) and pinyon (Pinus edulis Engelm.). Associated with winterfat in the understory are blue grama (Bouteloua gracilis (H. B. K.) Lag.) and western wheatgrass (Agropyron smithii Rydb.). Seeds were collected in late October or early November each year from 1960 thru 1967. All seeds were stored in paper bags in a heated garage from the date of collection until the time germination was until the time germination was tested.

Procedures for testing germination were standardized. Five replications of 50 seeds each were placed in petri dishes filled with 100 ml. of vermiculite and 50 ml. of distilled water. Most of the tests, which were begun in 1965, were conducted in a germinator programed for 76°F. (12 hours, light)—60°F. (12 hours, dark). Additional tests in 1968 were made in a refrigerator modified to give constant temperatures of 57°F. or 43°F. without light. Seedlings were counted at 1- or 2-day intervals. Seeds were considered germinated when seedlings were at least 1/2 inch long, and both the cotyledons and radicle were detached from the seed.

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[1] *Range Scientist, located at Albuquerque, in cooperation with the University of New Mexico; central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

[2] *Hilton, J. W. Effects of certain micro-ecological factors on the germinability and early development of Eurotia lanata. Northwest Sci. 15: 86-92. 1961.*

[3] *United States Forest Service. Woody Plant Seed Manual. U. S. Dep. Agr. Misc. Publ. 654, 416 pp., 1948.*

[4] *Wilson, C. P. The artificial reseeding of New Mexico ranges. N. Mex. Agr. Exp. Sta. Bull. 189, 37 pp., 1931.*

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Results and Discussion

One- and two - year - old seeds germinated better than older seeds (table 1). Seeds 4 years old, nonetheless, germinated reasonably well.

Table 1. --Germination in 1968 at three temperatures of winterfat seed collected at the Corona site for 8 years

Year seed collected	Germination temperatures		
	76°F. (12 hrs)-60°F. (12 hrs)	57°F.	43°F.
	Percent germination		
1960	0	0	0
1961	0	3	17
1962	9	30	22
1963	15	41	36
1964	35	61	62
1965	18	21	21
1966	87	92	90
1967	89	90	91

The older seeds apparently responded to the lower temperatures; seeds more than 3 years old consistently germinated better at 43°F. and 57°F. than at 76-60°F., whereas 1- and 2-year-old seeds germinated essentially the same regardless of temperature. Five- and six-year-old seeds produced a fair number of seedlings at the lower temperatures. None of the 8-year-old seeds germinated.

Germination tests conducted in previous years with these same lots of seeds yielded results similar to those obtained in 1968 (table 2). Highest germination was recorded in 1966, when 1-, 2-, and 3-year-old seeds germinated more than 90 percent. By contrast, all seeds germinated rather poorly in 1967 despite the use of the same testing procedures. Perhaps the seeds entered what is commonly referred to as "secondary dormancy" caused by subtle, but unintentional, differences in storage temperatures or humidities.

Of special interest is the fact that seeds collected in 1964 and 1966 germinated better the second year after collection than the first. These seeds may not have completed the after-ripening process until the second year following collection.

Winterfat seeds apparently differ in their capacity to retain viability over a period of years, presumably due to differences in physiological makeup. Environmental conditions during the time seeds are forming and maturing differ from year to year, and these differences no doubt are manifest as physiological differences in the seeds. For example, seeds collected in 1964 germinated 42 percent when 3 years old and 35 percent when 4 years old. On the other hand, seeds collected from the same plants in 1965 germinated only 28 percent the second year and only 18 percent the third year. These 1965 seeds, although they germinated 97 percent when 1 year old, declined in viability more rapidly than the other collections. Similarly, seeds collected in 1963 dropped sharply in viability after the second year. These comparisons suggest that differences in inherent physiological characteristics might have affected the germination behavior of winterfat seeds collected in different years. What these characteristics could be is conjectural.

Table 2. --Germination of winterfat seed collected at the Corona site for 8 years, and tested at yearly intervals, 1965-68 (germination temperature, 76° F., 12 hours - 60° F., 12 hours)

Year seed collected	Year tested			
	1965	1966	1967	1968
	Percent germination			
1960	38	11	0	0
1961	50	29	0	0
1962	50	31	8	9
1963	88	92	10	15
1964	60	93	42	35
1965	--	97	28	18
1966	--	--	65	87
1967	--	--	--	89

Results from this study partially refute the results reported by other investigators. Although the sharp decline in viability of the 1965 collection by the second year agrees with previously published information, the germination record of the 1964 collection—93 percent the second year and 35 percent the fourth year—supports the premise that retention of viability depends on the year the seeds were collected and on certain undefined physiological characteristics of that seed. Added to this is the evidence from our 1968 investigations, which shows that seeds even 5 and 6 years old retain a fair capacity to germinate provided temperatures are relatively low.

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U.S. FOREST SERVICE
RESEARCH NOTE RM - 113

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

OCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Species Interactions of Growth Inhibitors in Native Plants of Northern Arizona

Donald A. Jameson [1]

Extracts of most plants contain materials that inhibit the growth of seedlings, but the effect of inhibitors from different species varies with the test seedlings used. These interactions demonstrated in the laboratory may also be important in interspecific relationships in the field.

Many plant species contain chemicals that inhibit the germination of seeds of other species or even of their own seeds. Extracts of different species exhibit different degrees of inhibiting action, however, and seeds of various species react differently to inhibiting actions.

This study was conducted to determine the various interactions between some inhibitor and inhibited species of northern Arizona. Extracts from six species were tested to determine their effects on radicle growth of newly germinated seeds. The tests were made by germinating seeds in the extracts, and measuring the length of radicle growth.

To prepare the extracts, leaves and nonwoody stems were dried at 104° C. for 48 hours, ground to pass a 20-mesh screen, and redried for 24 hours. Five grams of the ground material were left overnight in 100 milliliters of distilled water. Four milliliters of each solution were used to wet one layer of glass filter paper in a petri dish. Inhibitor species included were Utah juniper (Juniperus osteosperma (Torr.) Little), ponderosa pine (Pinus ponderosa Lawson), pinyon pine (P. edulis Engelm.), bottlebrush squirreltail (Sitanion hystrix (Nutt.) J. G. Smith), Arizona fescue (Festuca arizonica Vasey), and blue grama (Bouteloua gracilis (H. B. K.) Lag.). Test seeds were from bottlebrush squirreltail, blue grama, and ponderosa pine.

For the grasses, 200 seeds were germinated in each extract—50 seeds in each of four petri dishes. Lengths of radicles were measured after the seeds had been in the extracts for 3 days. These radicle lengths were compared with radicle lengths of seeds germinated in distilled water. The procedure was the same for ponderosa pine except that only 25 seeds were used per dish.

Growth of grass seedlings in extracts was 30 to 99 percent less than growth in water only (fig. 1). The inhibitive effect, especially on blue grama, was more pronounced in extracts from tree leaves than from grass leaves.

Growth of bottlebrush squirreltail was almost completely inhibited in the extract from Utah juniper, and growth of blue grama seed-

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lings was only 10 percent as much as in water only. Seedling development in extracts from pinyon and ponderosa pine was nearly as poor. Though blue grama made relatively good growth in extracts from grass leaves, squirreltail was severely depressed, even when grown in extract from its own leaves.

Ponderosa pine, on the average, was less affected than the grasses, and grew nearly as well in extracts from leaves of woody plants as in extracts of grass plants. Arizona fescue was the grass most detrimental to ponderosa pine seedlings; blue grama had little effect.

These findings indicate that extracts of certain plants inhibit growth of some seedlings of associated plants more than others, and their control might be required before desirable forage plants can become established. They also might help to explain causes of plant succession, or changes in plant composition under different range management practices.

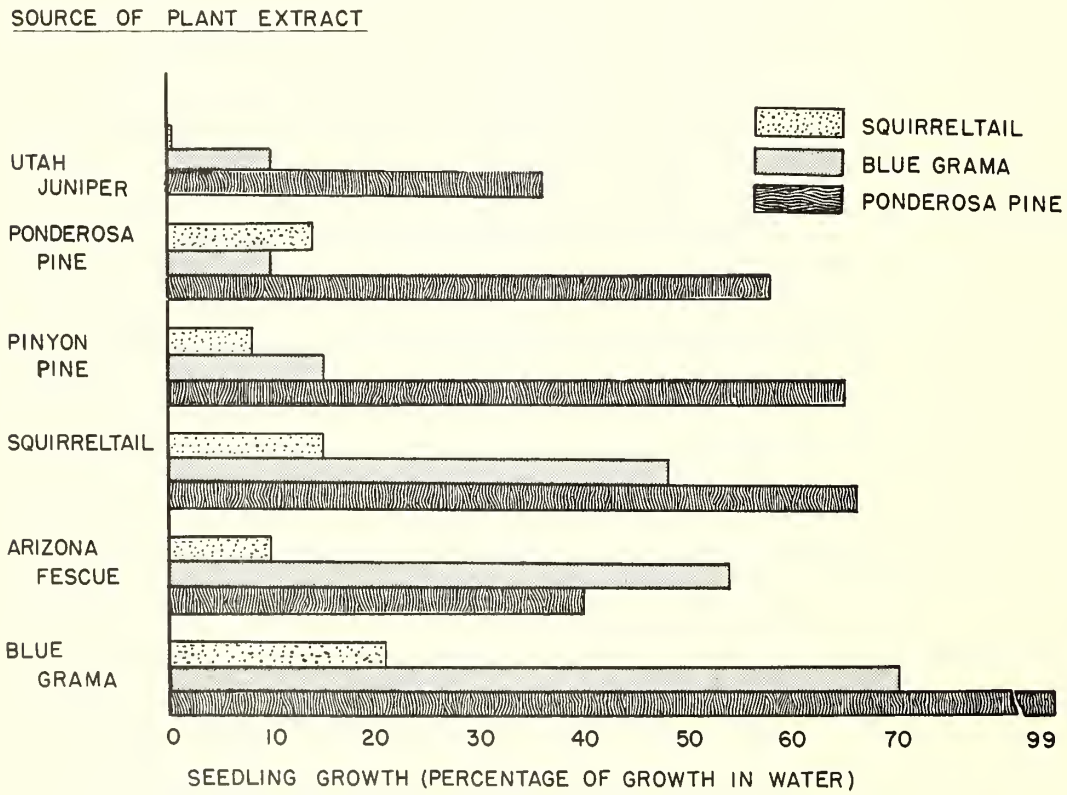

Figure 1.--Growth in blue grama, bottlebrush squirreltail, and ponderosa pine seedling radicles in plant extract solutions, expressed as a percentage of their growth in water only.

U.S. FOREST SERVICE
RESEARCH NOTE RM -114

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A Transmitter for Tracking Wildlife

David R. Patton[1], Robert T. Dickie,[2] Erwin L. Boeker,[3] and Virgil E. Scott[3]

Schematics are presented for a transmitter with an amplifier stage to increase receiving distance. Weight of the transmitter with one battery is 2 ounces, maximum battery life is 45 days, and maximum receiving distance is 2-1/2 miles.

The need to follow the movements of deer, elk, and turkeys in an enclosure prompted us to develop and perfect a suitable miniature radio transmitter. Objectives were to develop a sending unit that would have a 1- to 2-mile range with a portable receiver, have a battery life of 60 days, and be small and light enough to use on a turkey. Several transmitter designs described in the literature were tried, but none met our requirements for distance. This Note reports on a transmitter with an added amplifier stage.

The description that follows and schematics presented are intended for radio technicians or biologists that have an understanding of electronics. The authors appreciate the cooperation and assistance of the U. S. Atomic Energy Commission at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

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Transmitter Design

The transmitters used in this study were of conventional solid state design, assembled on etched circuits to speed construction and to provide a more uniform unit. The basic oscillator transmitter (fig. 1) is of the modified Colpitts type,[4] with the third-overtone crystal connected between the collector and base of the transistor. A pulsed output is achieved through the use of an RC (resistor-capacitor) combination in the base biasing circuit ($R_1 C_2$). The exact values of these components are not critical, and can be varied to give the desired pulse width and repetition rate. For the values specified, the pulse rate of the transmitter was 100 milliseconds and the repetition rate was one per second. This circuit is similar to those used in early investigations by Tester et al.[5] except in exact component size, type, and battery voltage.

[4] *Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Departments of Agriculture or Interior.*

[5] *Tester, John R., Warner, Dwain W., and Cochran, William W. A radio-tracking system for studying movement of deer. J. Wildlife Manage. 28: 42-45. 1964.*

The circumference of the loop antenna on the transmitter (fig. 1) is determined by the size of the experimental animal. The value of the capacitor (C_1) may vary considerably with the dimensions of the loop (I_1) and the crystal frequency. The value given in the figure will provide a resonant circuit in the 26-27 MegaHertz range. The necessary modifications of the transmitter to use a whip antenna are shown by the schematic in figure 2. Values are given for a 10-inch piano-wire whip. If other lengths are more desirable, suitable changes in the value of the inductor (L_2) must be made. In practice, L_2 with the antenna attached is brought to resonance at the crystal frequency by adjusting the inductor L_2. A convenient method is through the use of a grid-dip oscillator. Where more power and range are needed, an amplifier stage can be added to the basic circuit (figs. 3, 4).

All of the testing to date has been with transmitters with an added stage. The compact size of the transmitter is shown in figure 5. The weight of the unpotted unit is 63.1 grams (2 ounces). The battery weighs 50.6 grams, while the transmitter components weigh only 12.5 grams. The cost of the transmitter, including printed circuit and crystal, is approximately $15. Component parts for schematics (figs. 1-5) and instructions for coil winding are:

C_1 - Capacitor, 9-35 pF, trimmer
C_2 - Capacitor, 10 mfd, 3 volts, tantalum
C_3 - Capacitor, .001 mfd, disc, ceramic
C_4 - Capacitor, 130 pF, glass
Cr_1 - Crystal, 26-27 MHz
Q_1 - Transistor, 2N706A
R_1 - Resistor, 1 M, 1/4 watt
R_2 - Resistor, 2 K, 1/4 watt
L_1 - Loop antenna, 22-inch circumference
L_2 - Inductor, 18 turns, No. 30 Nylaclad wire, cambion coil form 3623-4
L_3 - Inductor, 24 turns, wire and coil form as above
T_1 - Transformer, 18 turns primary--3 turns secondary; wire and coil form as above
T_2 - Transformer, 18 turns primary--2 turns secondary; wire and coil form as above

Wind transformers from bottom of form, going to no higher than 10 turns before starting second layer

Figure 1.--Schematic of transmitter with loop antenna.

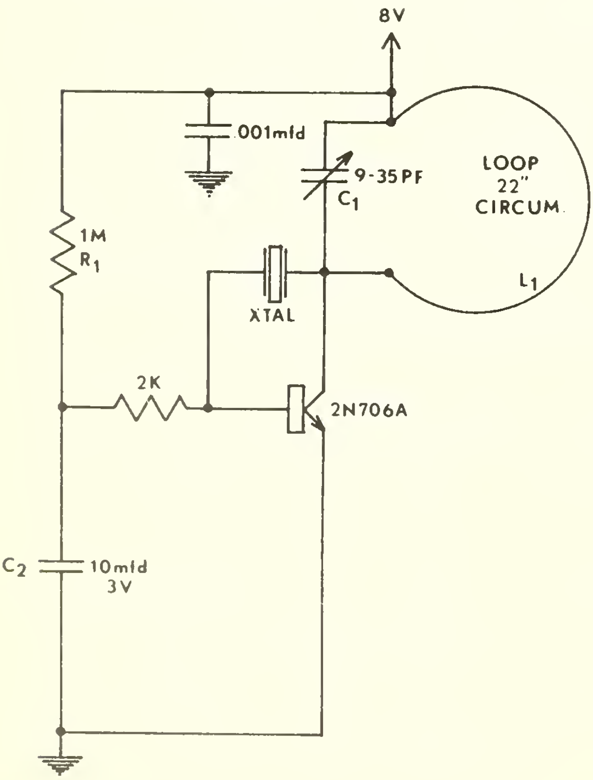
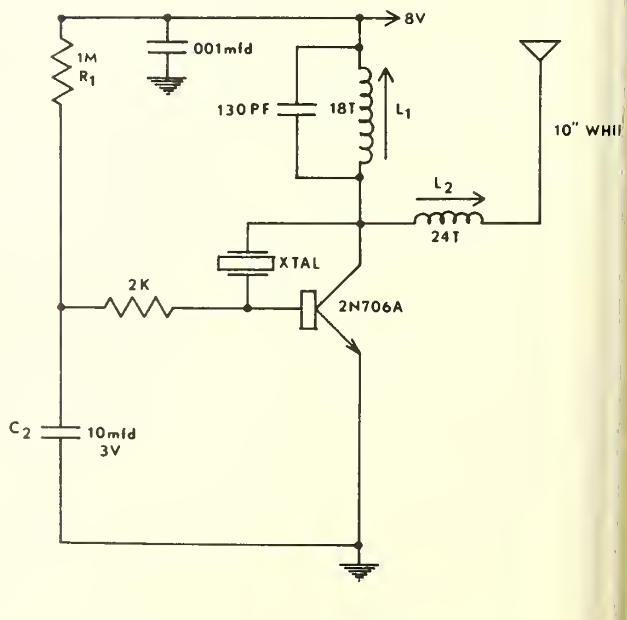


Figure 2.--Schematic of transmitter with whip antenna.



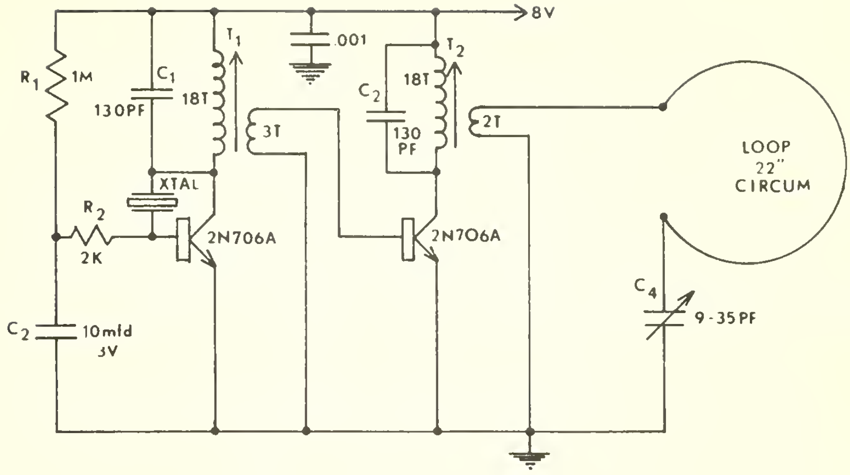


Figure 3.--Schematic of transmitter with loop antenna and added amplifier stage.

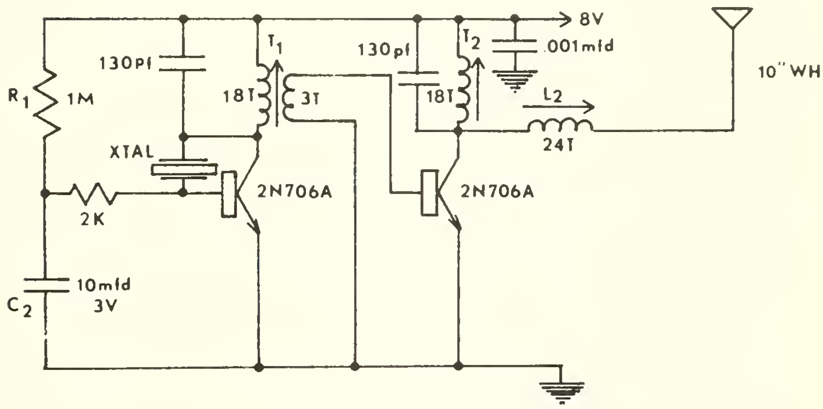


Figure 4.--Schematic of transmitter with whip antenna and added amplifier stage.

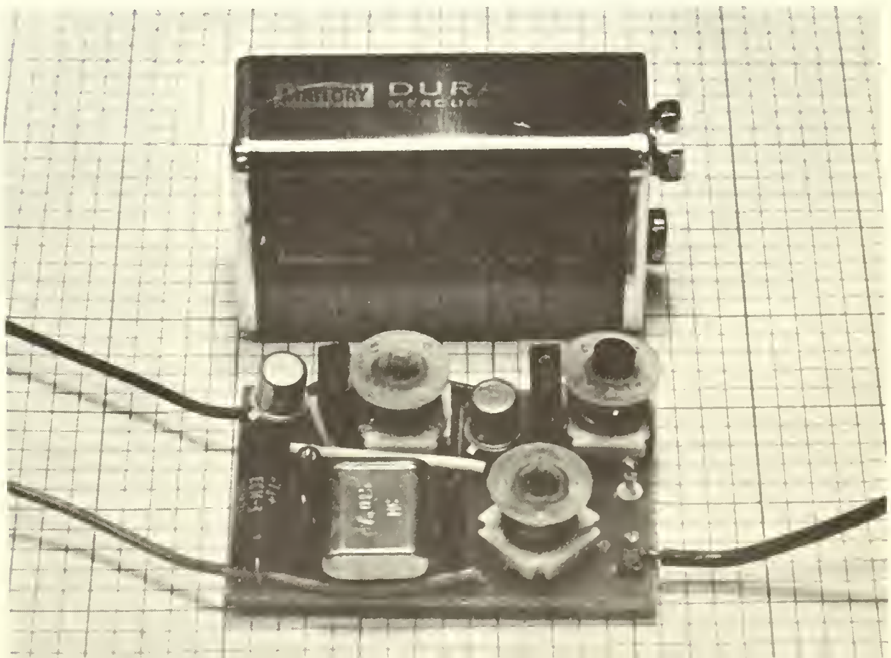


Figure 5.--Battery and constructed transmitter with whip antenna and added amplifier stage. (Graph paper: one square equals 0.1 inch)

At present, the transmitter is being tested on grouse in South Dakota by Keith Evans (U. S. Forest Service), turkeys on the Fort Apache Indian Reservation, Arizona, by E. L. Boeker and Virgil Scott (U. S. Fish and Wildlife Service), and deer and bear at Los Alamos, New Mexico, by Homer Pickens (U. S. Atomic Energy Commission) and Bob Hartway (University of California).

Results

The best results have been obtained on deer in an enclosure at Los Alamos. Pickens and Hartway used a loop antenna with the transmitter powered by four Burgess—H134R batteries (10.8 volts at 2000 mah, series-parallel combination). Maximum distance received with this power pack was 2 miles in ponderosa pine, with a custom-made receiver (superhetrodyne, dual conversion, 6 Mhz and 455 kHz, crystal controlled, 10 channel, 0.2 microvolt sensitivity at the antenna terminal) and hand-held loop antenna. Deer were tracked in an enclosure at distances of 0.25 to 0.5 mile. The transmitter had a pulse width of about 500 milliseconds, a repetition rate of one every 4 seconds, and a life of 2 months. The battery voltage dropped from an initial 10.8 volts to 4.2 volts in 10 weeks. At 4.2 volts, the signal could be received in open country at a distance of 0.4 mile.

The transmitter used at Los Alamos was not potted, but was sandwiched between foam rubber and hermetically sealed in plastic. Weight of the transmitter, batteries, and collar was approximately 3 ounces.

Battery tests were conducted on a transmitter with a pulse width of 100 milliseconds and a repetition rate of one per second. The transmitter had a whip antenna of 10 inches. With one 8.4-volt Mallory Duracell TR146X, the life was 45 days. With two batteries in parallel, the transmitter functioned for 330 days, 30 days of which were in a freezer. The transmitter still emitted a signal at a temperature of 10° F.

Line-of-sight tests were conducted on a transmitter as described above. One Mallory Duracell gave a reception distance of 2 miles. When the battery voltage was decreased the distance decreased until at 4 volts the reception distance was 0.5 mile. The receiving distance increased to 2.5 miles when the battery voltage was increased to 16.8 volts. The signal was strong and clear at this range, but could not be detected at 3 miles. A transmitter lasted only 30 days at 16.8 volts.

It will undoubtedly be possible to increase the receiving distance by using a yagi antenna to increase the sensitivity of a receiver. This antenna would be practical only in a fixed position, however, because of antenna size for the 26-27 MegaHertz frequency.

Discussion

There is one major disadvantage when using the 26-27 MegaHertz frequency for radio tracking: In an area where there are Citizens Band users, the interference may be so great that the transmitter signal cannot be detected. Federal agencies can get permission to use the Citizens Band frequencies which have been reserved for them in 27 MegaHertz range. A recent FCC ruling has shifted the CB frequency for low-powered transmitters to 49 MegaHertz. Local interference should not be as bad on this new frequency. It must be emphasized that maximum receiving distance will vary by vegetation type, topography, receiving equipment, and even time of day.

The present transmitter design with the added amplifier stage is well suited for deer, elk, and turkeys in an enclosure where working distances are in the 0.5 to 1-mile range. A single Duracell battery will provide a maximum transmitter life of 45 days. Since additional batteries will extend transmitter life, the period of effective transmission depends on the number of batteries the experimental animal can carry.

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U S D A FOREST SERVICE
RESEARCH NOTE RM-114

OREST SERVICE
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KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Transmitter for Tracking Wildlife

David R. Patton[1], Robert T. Dickie,[2] Erwin L. Boeker,[3] and Virgil E. Scott[3]

Schematics are presented for a transmitter with an amplifier stage to increase receiving distance. Weight of the transmitter with one battery is 2 ounces, maximum battery life is 45 days, and maximum receiving distance is 2-1/2 miles.

The need to follow the movements of deer, elk, and turkeys in an enclosure prompted us to develop and perfect a suitable miniature radio transmitter. Objectives were to develop a sending unit that would have a 1- to 2-mile range with a portable receiver, have a battery life of 60 days, and be small and light enough to use on a turkey. Several transmitter designs described in the literature were tried, but none met our requirements for distance. This Note reports on a transmitter with an added amplifier stage.

The description that follows and schematics presented are intended for radio technicians or biologists that have an understanding of electronics. The authors appreciate the cooperation and assistance of the U. S. Atomic Energy Commission at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Transmitter Design

The transmitters used in this study were of conventional solid state design, assembled on etched circuits to speed construction and to provide a more uniform unit. The basic oscillator transmitter (fig. 1) is of the modified Colpitts type, with the third-overtone crystal connected between the collector and base of the transistor. A pulsed output is achieved through the use of an RC (resistor-capacitor) combination in the base biasing circuit ($R_1 C_2$). The exact values of these components are not critical, and can be varied to give the desired pulse width and repetition rate. This circuit is similar to those used in early investigations by Tester et al.[4] except in exact component size, type, and battery voltage.

[1] *Associate Wildlife Biologist, located at Tempe, in cooperation with Arizona State University; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Laboratory Director, Electronics Shop, Department of Physics, Arizona State University, Tempe.*

[3] *Research Biologists, U. S. Fish and Wildlife Service, Tempe, Arizona.*

[4] *Tester, John R., Warner, Dwain W., and Cochran, William W. A radio-tracking system for studying movement of deer. J. Wildlife Manage. 28: 42-45. 1964.*

The circumference of the loop antenna on the transmitter (fig. 1) is determined by the size of the experimental animal. The value of the capacitor (C_1) may vary considerably with the dimensions of the loop (L_1) and the crystal frequency. The values given will provide a resonant circuit in the 26-27 MegaHertz range. The necessary modifications of the transmitter to use a whip antenna are shown by the schematic in figure 2. Values are given for a 10-inch piano-wire whip. If other lengths are more desirable, suitable changes must be made in the value of the inductor. In practice, the antenna is brought to resonance at the crystal frequency by adjusting the inductor L_3. A convenient method is through the use of a grid-dip oscillator. Where more power and range are needed, an amplifier stage can be added to the basic circuit (figs. 3, 4).

All of the field testing to date has been with transmitters with an added stage. The compact size of the transmitter is shown in figure 5. The weight of the unpotted unit is 63.1 grams (2 ounces). The battery weighs 50.6 grams, while the transmitter components weigh only 12.5 grams. The cost of the transmitter with amplifier stage, including printed circuit and crystal, is approximately $25. Component parts for schematics (figs. 1-5) and instructions for coil winding are:

C_1 - Capacitor, 9-35 pF, trimmer
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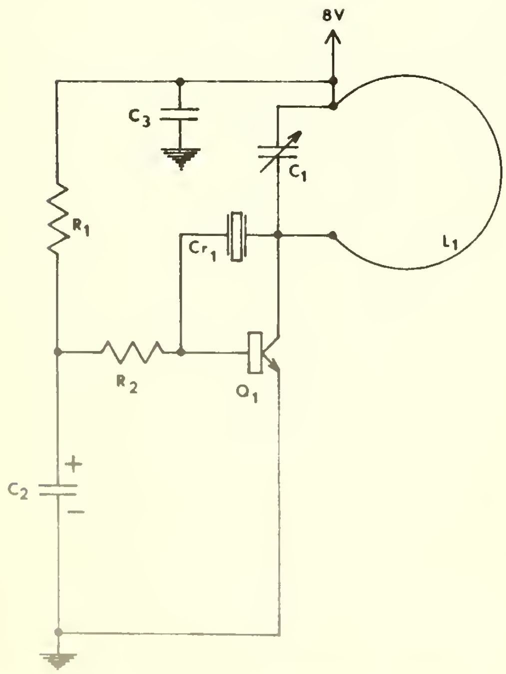

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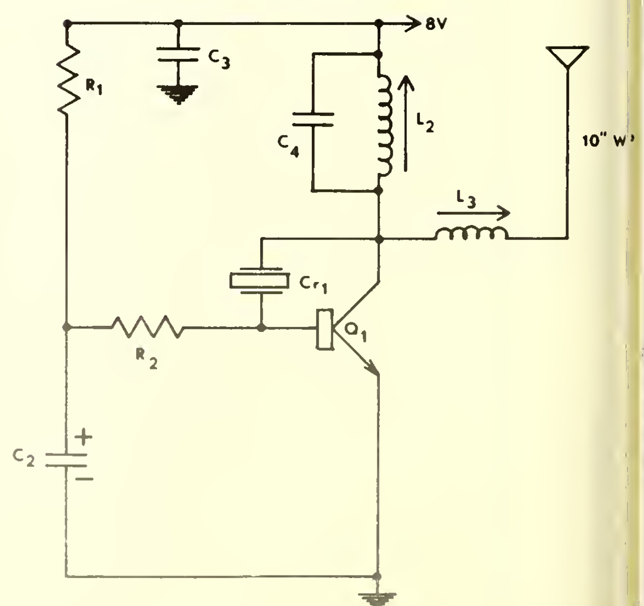

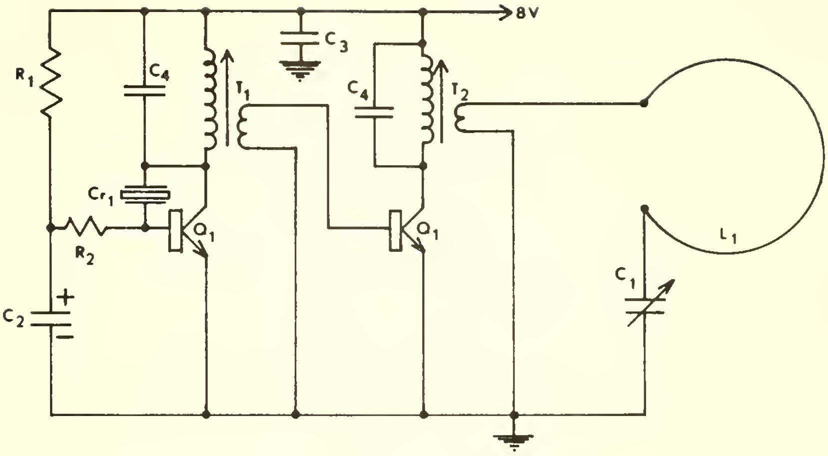

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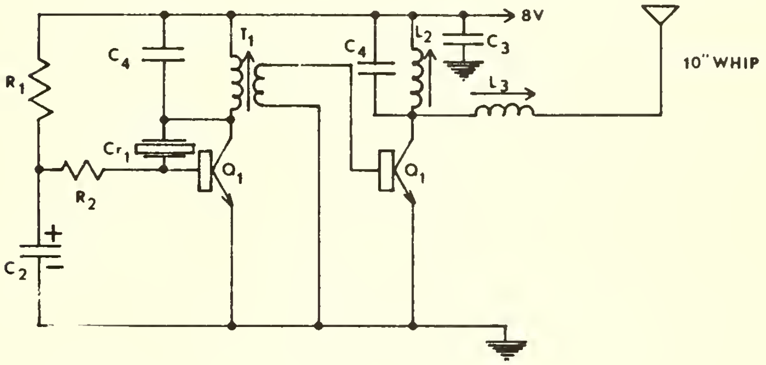

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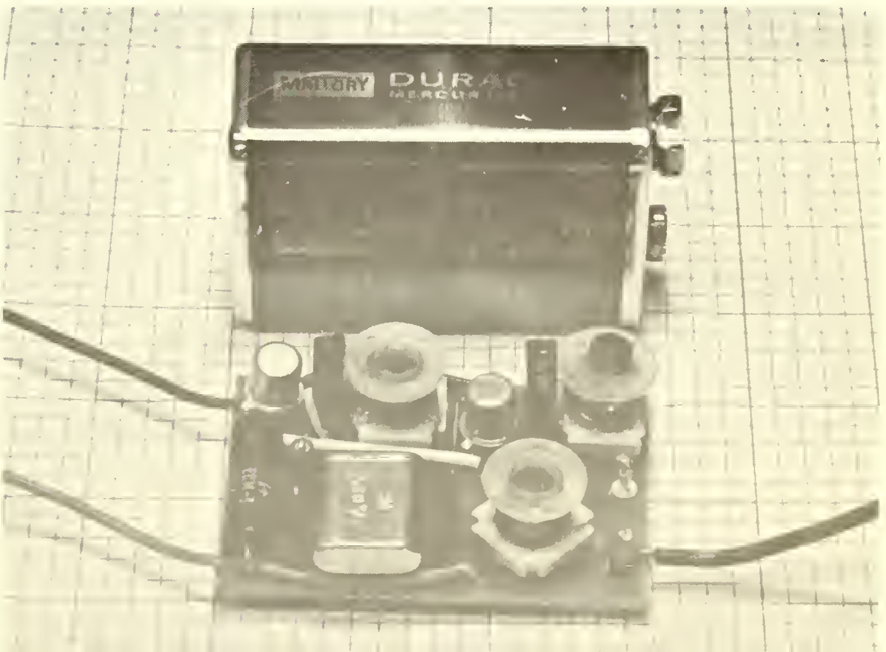

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U.S. FOREST SERVICE
RESEARCH NOTE RM -115

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

A Fire Prescription for Consuming Ponderosa Pine Duff

James R. Davis, Peter F Ffolliott, and Warren P Clary [1]

A "hot" prescribed fire was set in October 1964 to burn a specific quantity of litter in ponderosa pine. This objective was accomplished; other effects, which may be beneficial under some circumstances, included thinning of the overstory from below, increased seedling germination, and temporary reduction of fire hazard. Forage and browse were not benefited.

One potential use for prescribed fire in Arizona ponderosa pine (Pinus ponderosa Laws.) is to increase water yield. As part of the Beaver Creek Watershed Evaluation program, a comprehensive multiple use study on a 275,000-acre group of watersheds on the Coconino National Forest in northern Arizona, we were asked to prescribe fire that would consume three-fourths of the depth of a 2- to 3-inch layer of duff.[2] The fire prescribed was a moderately high intensity surface fire, with an average flame height of 2 feet.

Methods

Two one-fourth acre areas (A and B) with similar characteristics were selected (table 1). On each area, 16 sample points were systematically spaced 25 by 25 feet. Data taken included:

Duff depth.—Duff surface to mineral soil before and after burning.

Needle deposition.—Needle drop caught by 12- by 12-inch hardware cloth squares at burned and unburned locations.

Timber stocking.—Basal area estimated by point sampling with a 25-factor angle gage. Crown position, length of live crown, and d.b.h. were recorded for all trees.

Fire effects on trees.—Crown damage was classified as (1) severe—more than two-thirds crown damaged, (2) moderate—one-third to two-thirds crown damaged, (3) light—less than one-third crown damaged, and (4) none—no apparent damage. Mortality in each class was recorded for 2 years after burning.

[1] *Associate Forest Fuels Specialist, Associate Silviculturist, and Associate Range Scientist, respectively, located at Flagstaff in cooperation with Northern Arizona University; central headquarters maintained at Fort Collins in cooperation with Colorado State University. Ffolliott is currently Research Associate, Department of Watershed Management, University of Arizona, Tucson.*

[2] *The Society of American Foresters' definition of duff is followed. Three layers above the mineral soil are generally recognized: L (litter), F (fermentation), and H (humus).*

Table 1. --Characteristics of areas chosen for prescribed fire, Beaver Creek watershed, Arizona, 1964

Characteristics	Area A	Area B
Duff:		
Depth (inches)	1.7 ± 0.5	3.0 ± 0.6
Tons per acre	10.2	17.6
Overstory	Ponderosa pine poles, 5 to 11 inches d.b.h., with some sawtimbe and a few Gambel oak (Quercus gambelii Nutt.)	
Pine basal area (sq. ft.)	170	305
Understory	Scattered ponderosa pine saplings and a negligible number of seedlings, with a few Gambel oak sprouts	
Grass	Muttongrass (Poa fendleriana (Steud.) Vasey) and bottlebrush squirreltail (Sitanion hystrix (Nutt.) J. G. Smith)	
Soils	Volcanic	Volcanic
Topography	Flat	30 to 35 percent slope to southeast

Fire effects on seedling germination.—Milacres stocked, 16 on and 16 adjacent to each burned area.

Fire effects on herbage.—Weight of grass, forbs, and browse estimated before burning on 9.6-square-foot plot at each sample point and each autumn for 2 years after burning.

Conditions selected for developing the prescribed fire and those found on the two selected areas are given in table 2.

Results and Discussion

Each strip burned[3] with moderately intense surface fire, with flame heights generally 1 to 2 feet. Although the area burned was relatively small, the same procedure apparently would have worked as well on larger areas. The fuel ignited easily and carried the fire well. Fire on Area B was somewhat more intense than on Area A because of the slope, and slightly higher wind and air temperature. Ignition lines on Area B were spaced more closely than on Area A to hold flame heights to prescribed limits.

[3] *Burning was done by personnel of the Coconino National Forest.*

Effects on Duff

Fire consumed 70 percent of the total duff by depth on Area A, and 73 percent of Area B. On the combined areas the L layer was completely consumed at 70 percent of the sample points; the F and H layers were completely consumed at 12 percent of the sample points. Mean depth of duff consumed was 1.2 ± 0.5 inches on Area A, and 2.2 ± 0.7 inches on Area B.

About the same amount of litter fell on both burned and nearby unburned control areas for a short period after burning, which was done during the normal needle-drop period (table 3). During the first year, needle drop was greater on the burned area. Litter drop on the unburned area showed little change the second year, whereas litter drop decreased on the burned area, apparently the result of decreased crowns (table 3).

No large limbs or trees have fallen in the burned area. As the large fire-killed material falls, ground fuel will increase appreciably.

Table 2.--Conditions selected for developing the prescribed fire, and average burning conditions on the areas A and B when fires were set, October 3, 1964

Burning conditions	Prescribed fire	Area A	Area B
Fuel moisture:			
Upper L and F layers	6 to 12 percent	8.6 percent	8.0 percent
Lower H layer	15 or more percent	17.6 percent	26.0 percent
Fuel temperature, upper 1 inch	80°F., average	86°F. in sun; 75°F. in shade	85°F. in sun; 75°F. in shade
Air temperature	75°F. or higher	75°F.	80°F.
Wind velocity in flame zone (2 feet above surface)	2 to 5 miles per hour	1 to 4 miles per hour	3 to 5 miles per hour
Weather	Clear	Clear	Clear
Ignition pattern	Strips into the wind or downhill, spaced 10 to 20 feet, varied to maintain prescribed flame height		

Table 3.--Litter deposition and duff tonnage on the two study areas

Measurements	Area A		Area B	
	Burned	Unburned	Burned	Unburned
	- - - - - Tons per acre - - - - - -			
Litter deposition during postburn period:				
First 34 days	0.72	0.73	0.80	0.76
Remainder of first year	1.75	.96	2.72	.78
Second year	.76	1.76	1.58	2.19
Total	3.23	3.45	5.10	3.73
Difference	-.22		+1.37	
Duff tonnage:[1]				
Preburn	10.2	10.2	17.6	17.6
Consumed	-3.4	0	-6.3	0
Deposited in 2 years	+3.2	+3.5	+5.1	+3.7
Net total, 2 years after burning	10.0	13.7	16.4	21.3

[1] No allowance is made for decomposition, which was not measured.

Effects on Timber

Damage and kill were greatest in small trees, primarily suppressed and intermediate saplings (table 4). No trees less than 4.5 feet tall survived. Mortality was lower in poles and sawtimber. Of the severely damaged trees,76 percent died within 2 years. Herman[4] observed similar results—64 percent of all ponderosa pine with more than 60 percent crown damage were dead 16 months after the Fort Valley fire of 1948.

The general fire effect was a thinning from below. Area A lost 47 percent of its basal area—a reduction to 90 square feet, and Area B, 23 percent—a reduction to 235 square feet.

More seedlings started on burned areas. New seedlings occupied 85 percent of the milacre plots centered at each grid point on Area A and 95 percent of Area B 1 year after the burn, compared with 20 and 12 percent respectively, on the same number of milacre sample plots adjacent to the burned areas. Many of the new seedlings may be short lived.

Effects on Herbage

Forbs, primarily mullein (Verbascum thapsus L.), a relatively unpalatable plant, increased appreciably on Area A, but only slightly on Area B. The larger increase on Area A was probably a result of the more open residual timber overstory. Grass, grasslike species, and browse, of negligible grazing value before burning, remained practically unchanged on both burned areas.

[4] *Herman, F. R. Survival of fire-damaged ponderosa pine. U.S.D.A. Forest Serv., Southwest. Forest and Range Exp. Sta. Res. Note 119, 3 pp. 1950.*

Summary

This prescribed fire burned the amount of duff specified. Timber was thinned from underneath, but the residual stand was still above the widely accepted 80 square feet stocking guide— Area A had 90 square feet of basal area remaining in dominant and codominant trees, and Area B had 235 square feet.

Fire hazard was reduced by the consumption of 70 to 73 percent of the duff, but the reduction was only temporary. In 2 years, the litter on burned areas built up nearly to prefire levels. In addition, about 80 tons per acre of standing fire-killed material will fall to the ground in the future.

Removal of the duff created a good seedbed for ponderosa pine—new seedlings stocked an average of 6 burned milacres for each unburned milacre.

Grazing values were negligible to start with and were not changed by burning. There was an increase in mullein, a species not generally used by livestock or game, but no practical change in grasses.

Table 4. --Percentage within size class of ponderosa pines damaged and killed, by prescribed fire, October 1964

Crown damage and mortality	Saplings		Poles		Sawtimber		All trees	
	Area A	Area B	Area A	Area B	Area A	Area B	Area A	Area B
	- - -	- - -	- - -	- - -	Percent	- - -	- - -	- - -
Crown damage class:								
None	0	0	8	10	8	8	7	12
Light	20	16	20	37	22	72	22	50
Moderate	10	16	20	16	35	11	18	18
Severe	70	68	52	37	35	9	53	30
Dead after 2 years:								
None	0	0	0	0	0	0	0	0
Light	0	0	0	0	0	0	0	0
Moderate	0	5	0	6	0	0	0	10
Severe	60	68	42	30	25	6	43	20

Agriculture --- CSU, Ft. Collins

U.S. FOREST SERVICE
RESEARCH NOTE RM -116

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

Atmospheric Humidity Measurement Near the Snow Surface

James D Bergen [1]

Describes a technique for measuring atmospheric humidity in the first few centimeters over a snow cover. Results are presented for four observation periods. The water vapor density at a nominal reference level of 2 cm. above the snow surface was found to vary from less than 20 percent to 90 percent of the density corresponding to saturation at the snow surface temperature. Little diurnal variation was found for the Bowen ratio. Possible remedies for difficulties encountered in the measurements are described.

Observations of atmospheric humidity normally available in the literature tend to be at standard shelter height, 1 meter or higher above the surface. Data from such heights are seldom valid for estimating the ratio of the sensible heat flux from the surface to the evaporation from that surface—Bowen's ratio. The development of the Bowen ratio term [2] is dependent on either a laminar state of flow between the surface and the reference point for the aqueous vapor pressure, or a turbulent flow in this region in which the turbulent exchange coefficients for water vapor and sensible heat are the same. The first condition generally can occur only for levels less than a few centimeters above the surface. The wind shear and temperature gradient required for the second condition seldom extend to shelter levels, except for conditions of strong winds and weak insolation. [3]

The measurement of atmospheric humidity close to a snow cover is complicated by the low ambient temperatures. The time lag of an unventilated instrument such as the hair hygrometer or membrane hygrometers becomes so long as to mask hourly variations. The use of a strongly ventilated instrument such as an Assmann psychrometer [4] seriously disturbs the structure of the air layer in which the measurements are being made. [5]

[1] *Meteorologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins, in cooperation with Colorado State University.*

[2] *Anderson, E. R., Anderson, L. J., and Marciano, J. J. A review of evaporation theory and development of instrumentation theory. Report 159, NE121215, 70 pp., U. S. Naval Electronics Lab., San Diego, Calif. 1950.*

[3] *Priestly, C. H. B. Turbulent transfer in the lower atmosphere. 130 pp. Chicago: Univ. Chicago Press. 1959.*

[4] *Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

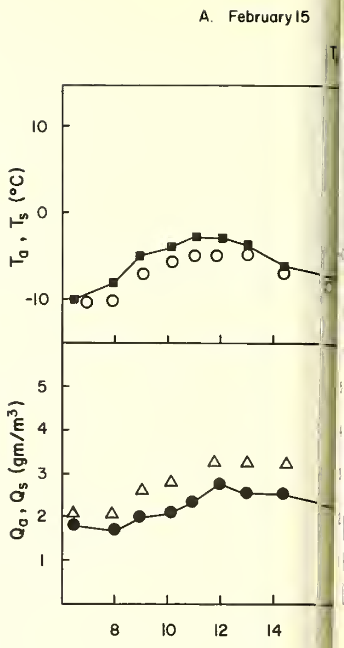
[5] *Nyberg, A. Temperature measurements in an air layer very close to a snow surface. Geografiska Annaler 20: 234-275. 1938.*

The method described in this study consists essentially of drawing a sample of air from near the snow surface, and bringing the sample to a ventilated equilibrium in a closed system with a hygrometer at a temperature within the effective operating range of that instrument. Such a method will involve measurements in the low humidity ranges; the range will be lower as the temperature at the snow surface falls and as the level of the measurement above the snow rises.

The measurements to be discussed here were made in the course of a more extended study of the energy balance of the snow surface.[6] The magnitudes of the associated radiation fluxes and other relevant data are reported in the above reference.

The sampling apparatus is shown schematically in figure 1.

[6] *Bergen, J. D., and Swanson, R. H. Evaporation from a winter snow cover in the Rocky Mountain forest zone. West. Snow Conf., Proc. 32: 52-58. 1964.*



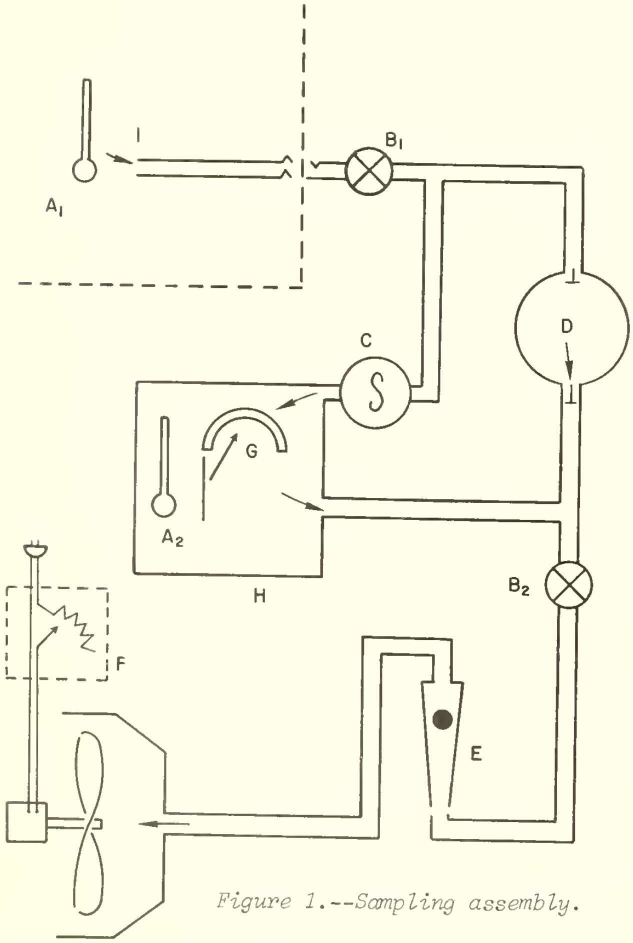


Figure 1.--Sampling assembly.

The instrument used was a Serdex membrane hygrometer designed for sample measurements in enclosed space (type HGJ-RHY-2). This instrument consists of the mechanically indicating Serdex membrane hygrometer (G) Model 201 enclosed in a metal case provided with a glass window through which the dial may be observed. The dial is also equipped with a mercury-in-glass thermometer (A_2) to indicate the air temperature within the instrument case. The instrument case is equipped with inlet and outlet taps (fig. 1).

The measurements were made by withdrawing air through a flexible plastic tube connected to an intake (I) located 2 cm. above the snow surface. The sampling flow was sustained by a vacuum cleaner pump regulated with a rheostat (F). Flow volumes were measured by a ball flowmeter (E) inserted between the instrument case and the vacuum motor. When three to four case volumes were metered through the apparatus, the stop cocks, (B_1) and (B_2) were switched to the off position, allowing the air in the case to be circulated by means of a rubber hand bulb (D) fitted with one-way check valves. Since both bulb and instrument case were flushed by the sampling flow, there was no carryover from one volume of sample air to the next.

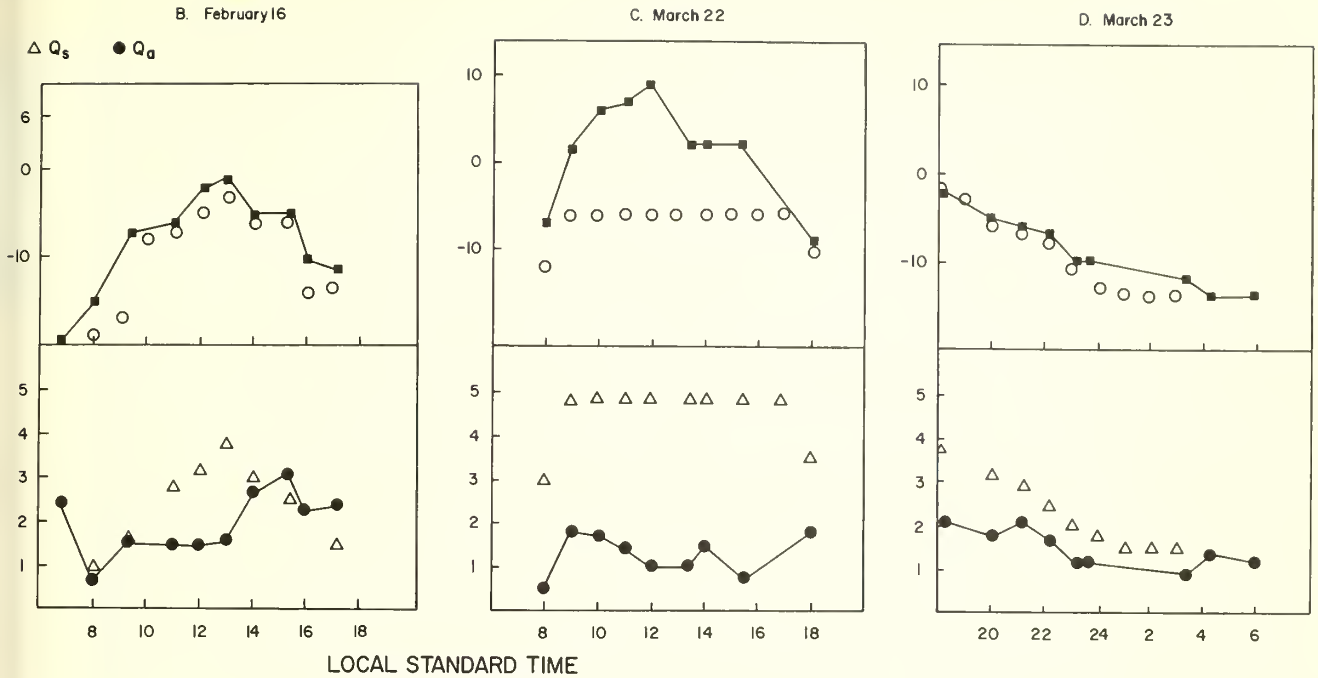


Figure 2.--Variation of water vapor density (Q_a) over the snow surface with associated air (T_a) and surface (T_s) temperatures and saturation water vapor density (Q_s) for the surface.

The inlet tube was of clear flexible vinyl plastic, about 6 mm. in diameter. During measurements, this tube was carefully examined for evidence of condensation or foreign material. If the tube clouded, it was dried by drawing air through the system from a calcium chloride moisture trap placed at (I). Air was sampled at a volume flow rate of 500 ml. per minute. The total volume of the system above the flowmeter, including the tubing, hygrometer case, and bulb, amounted to slightly less than 2 liters. The air sample was drawn over a period of 5 minutes.

The effective operating range of temperatures for the Serdex hygrometer is from 2° C. to 25° C. The operating range of relative humidities is from 5 to 95 percent, with an accuracy of ±1.5 percent. For proper operation, the airflow through the sealed case must be sustained above a minimum threshold; the presence of flow above this value is indicated by a small vane meter (C) in figure 1, mounted on the inlet tap of the hygrometer case. If Bartel's estimate for the volume of measurement for the Assmann psychometer as given by Nyberg [5] is adjusted for the lower rate of volume flow, the effective volume of measurement would be a sphere of about 1.5 cm. radius or less, depending on the ambient windspeed.

The temperature in the heated trailer, and thus the final temperature at which the relative humidity of the air sample was measured, averaged about 25° C. This was at all times at least 10° C. higher than the exterior air temperature at the inlet.

The air sample and instrument were assumed to be at equilibrium when neither temperature nor indicated relative humidity varied for 10 minutes with vigorous hand pumping. The temperature used to interpret the final humidity reading in terms of the sampling conditions were the inlet temperature at the beginning of the sampling and the instrument temperature at final equilibrium. In both cases, the thermometers could be read to within half a degree.

Air temperatures at the inlet tube were measured with a bimetal thermometer (A_1) fixed at the tube mouth.

Snow surface temperatures were measured with a bead thermistor lowered to contact the local snow surface by a vertically adjustable mounting. The thermistor resistance was measured at 6-minute intervals by a recording potentiometer in the instrument trailer. The unventilated time constant of the thermistor bead was about 3 seconds. The bimetal thermometer had a time constant of about 30 seconds.

On a number of the days of observations, the air temperature over the snow was so low that the equilibrium relative humidity at the trailer temperature (20° C.) was below the operating range of the hygrometer. This problem could have been minimized by lowering the trailer temperature to about 2° or 3° C., but such temperatures were incompatible with the operation of other equipment in the instrument trailer and with reasonable comfort. An alternative solution might have been to enclose the instrument case and bulb system in an insulated box provided with glove-type hand ports and a viewing window.

A second problem arose from blowing snow. Snow particles tended to lodge in the inlet tube, and consequently contaminated the air sample. An obvious remedy would seem to be a gauze shield at the inlet tube.

When the net radiation balance was strongly negative, as on clear nights and in the early morning, the sampling tube tended to cool below the ambient air temperature with visible condensation at the tube walls. An insulating tube cover would appear to be necessary in this situation. Since it would necessarily be opaque, it should be readily removable in order to detect condensation. A zipper closure may be suitable.

Out of 10 days of observations, only 7 were free of problems due to blowing snow, and only 3 of these days showed equilibrium relative humidities above 5 percent at trailer temperatures. Thus, as a dependable field measurement, the sampling system as used was only a limited success.

The data presented are for the observations of February 15 and 16, and March 22 and 23.

The resulting estimates of the average water vapor density (Q_a) in the lowest 10 cm. or so above the snow cover are plotted against time in figures 2A through 2D. These values were determined from the Smithsonian tables. [7] Also plotted are the associated intake air temperatures (T_a), snow surface temperatures (T_s), and the saturation water vapor density (Q_s) at the temperature (T_s) taken from the same tables.

While the vapor density near the surface may be of intrinsic interest for some problems, such as the radiation exchange at the surface, this parameter is usually of hydrologic interest only insofar as it enters into the computation of the Bowen ratio. The Bowen ratio is generally approximated by the expression: [2]

$$R = 6.1 \times 10^{-4} P (T_s - T_a) (e_s - e_a)^{-1}$$

where T_s and T_a are the snow surface temperature and the air temperature at the level of measurement respectively in °C., P is the local barometric pressure in mb., and where e_s and e_a are the water vapor pressures at the surface and at the level of measurement in mb. The pressure e_a may be determined from the inlet air temperature and the vapor density values of figures 2A through 2D by means of the Smithsonian tables. [7] The surface vapor pressure may be determined from the measured surface temperatures (e_s) and the same tables. The resulting values for R (fig. 3) for the 3 daylight periods do not show any particular diurnal trend common to the 3 days. The values show relatively little variation through the day, in spite of the large variations in surface and air temperatures.

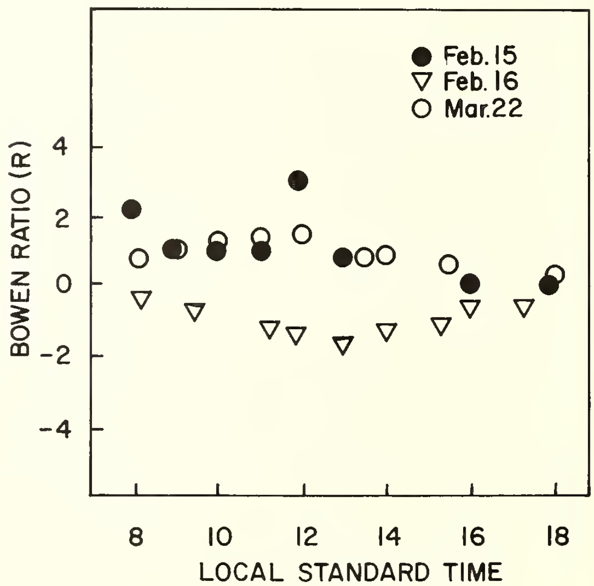


Figure 3.--Variation of Bowen ratio with time of day.

[7] *List, R. J. (ed.) Smithsonian Meteorological Tables (Ed. 6), 527 pp. 1958.*

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FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Preliminary Evaluation of Small-Diameter Black Hills Ponderosa Pine for Veneer and Plywood[1]

Lincoln A. Mueller,[2] Donald C. Markstrom,[2] and John F. Lutz[3]

Logs 8 to 15 inches in diameter produced veneer suitable for sheathing-grade plywood. Veneer cutting and drying presented no particular problems.

Introduction

The ponderosa pine stands of the Black Hills of South Dakota and Wyoming have a rather high proportion of the total volume in small-size trees. The U. S. Forest Service[4] estimated in 1964 that 76 percent of the cubic-foot volume of the sawtimber stands in South Dakota is in trees smaller than 15 inches d.b.h. Trees in this size class are frequently referred to as "blackjacks." They are characterized by the dark color and rough surface of the bark, and by the presence of numerous relatively small branches. Trees in this group are generally considered an important source of upper common grades of lumber produced in this area. They also serve as a major source of the poles produced in the Black Hills. These trees are also an excellent source of pulpwood, but present practice is to use the larger stems for pole and saw logs which have higher value.

Objective

The overall objective of this limited study was to determine the suitability of these relatively small-diameter blackjack trees for veneer and plywood production. If suitable, they could supplement the supply of larger diameter trees that would constitute the major veneer log supply for a plywood industry.

Specific objectives were:

1. To determine the volume of veneer and plywood that may be cut from 8- to 16-inch diameter logs.
2. To determine if this type and size of log presents any special veneer production problems that would require special conditioning of the logs, changes in veneer lathe adjustments, or special drying schedules.
3. To compare veneer volumes and grade yields obtained from peeling bolts to 6-inch cores and 3½-inch cores.

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[1] *The assistance of the Berman Forest Products Company of Newcastle, Wyoming, in furnishing the study logs and financing their shipment to the Forest Products Laboratory at Madison, Wisconsin, is gratefully acknowledged.*

[2] *Principal Wood Technologist and Associate Wood Technologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[3] *Forest Products Technologist, Forest Products Laboratory, Madison, Wisconsin.*

[4] *Caporaso, A. P. Forest area and timber volume in western South Dakota. U. S. Forest Serv. Res. Note INT-20, 4 pp., illus.*

Procedures

Sample logs

Ten 12-foot sample logs were selected from the log yard of the Berman Forest Products Sawmill at Newcastle, Wyoming (fig. 1). The logs were cut on a timber sale on the Black Hills National Forest approximately 35 miles northeast of Newcastle. The blackjack logs were selected on a first-come-first-served basis within the 8- to 16-inch diameter class, except that logs which obviously would not meet grade D veneer requirements were omitted.

The selected logs were scaled and graded in the millyard (table 1), and a log diagram[5] was sketched for each.

The logs were end coated with two coats of aluminum paint to reduce drying in transit and shipped to the U. S. Forest Products Laboratory at Madison, Wisconsin, where the tests were conducted.

Laboratory Procedure

Two 52-inch bolts were bucked at the 20-, 72-, and 124-inch lengths of each log and photographed. The bolts were debarked with hand tools. As a result, almost 100 percent of the wood was retained.

One bolt from each log was conditioned in water at 140° F. long enough to bring the temperature at the core to within about 5°

[5]*The grading was done according to the Forest Service Improved Ponderosa Pine Log Grades.*

Table 1. --Description of study logs

Log No.	Length	Grade	Diameter		Scribner Decimal C scale	
			Butt	Top	Gross	Net
	Feet	No.	Inches		Board feet	
1	12	5	16	13	70	70
2	12	5	9	8	20	20
3	12	3	20	15	110	110
4	12	5	11	10	30	30
5	12	5	11	9	30	30
6	12	5	14	10	30	30
7	12	5	12	11	40	40
8	12	2	13	11	40	40
9	12	5	14	12	60	60
10	12	2	10	9	30	30

of the heating medium. The second bolt from the log was held in water at 60° F. prior to peeling. Five heated bolts were from butt portions of the logs and five were from top portions.

All veneer was peeled 1/8 inch thick with a knife ground to a bevel of 21°. The face of the knife was set vertical. A rigid pressure bar, ground to a bevel of 75°, was used on the lathe. The vertical height (or lead) of the edge of the pressure bar from the knife edge was 0.030 inch. The horizontal opening (or gap) from the knife face to the edge of the pressure bar was 0.115 inch. These settings were selected to give moderately tightly cut veneer, which would be suitable for sheathing-type plywood. The more loosely cut veneer

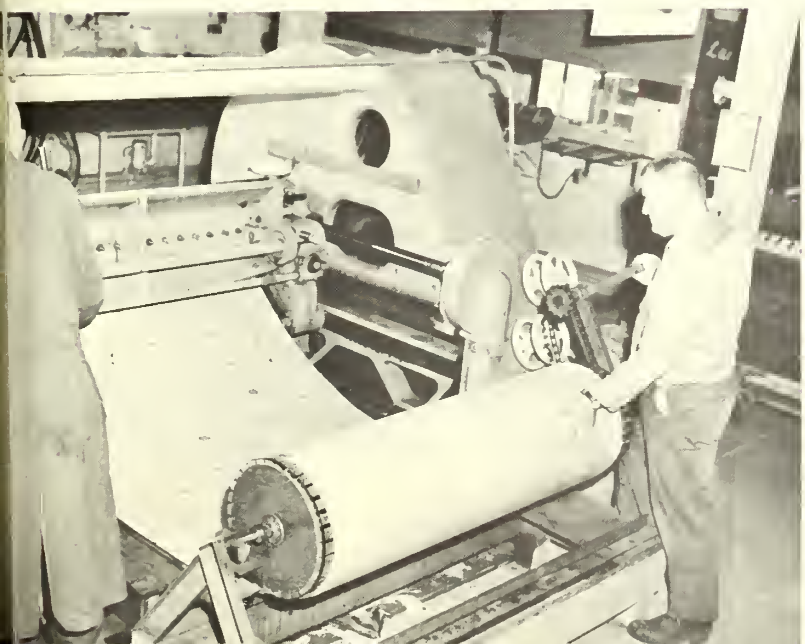
Figure 1.--Five of the study logs. The rule indicates where the butt 52-inch bolt was taken.

can be handled satisfactorily and tends to be flatter after drying than tightly cut veneer. The slight increase in face checking that may result from the looser veneer would not be a problem in utilizing the species for sheathing-type plywood. Moderate pressure on the pressure bar also means less force against the bolt during cutting and, consequently, is suitable for peeling to small-core diameters.

All 20 bolts were peeled first to a core diameter of about 6 inches on lathe chucks 5 inches in diameter (fig. 2). The two bolts from a given log, one heated and one unheated, were cut in sequence. This veneer was processed through the clipper and dryer as a unit so as to compare the effects of bolt heating and to facilitate grading as simulated 8-foot lengths.

After all bolts had been peeled to the 6-inch diameter, the lather spindles were changed and 3-inch chucks were installed (fig. 3). Because these spindles would not retract fur-

Figure 2.--
After each bolt was turned to a cylinder, the diameter was recorded,



and veneer was reeled as it came from the lathe. Veneer from each of the 52-inch bolts was reeled as soon as a continuous ribbon was formed.

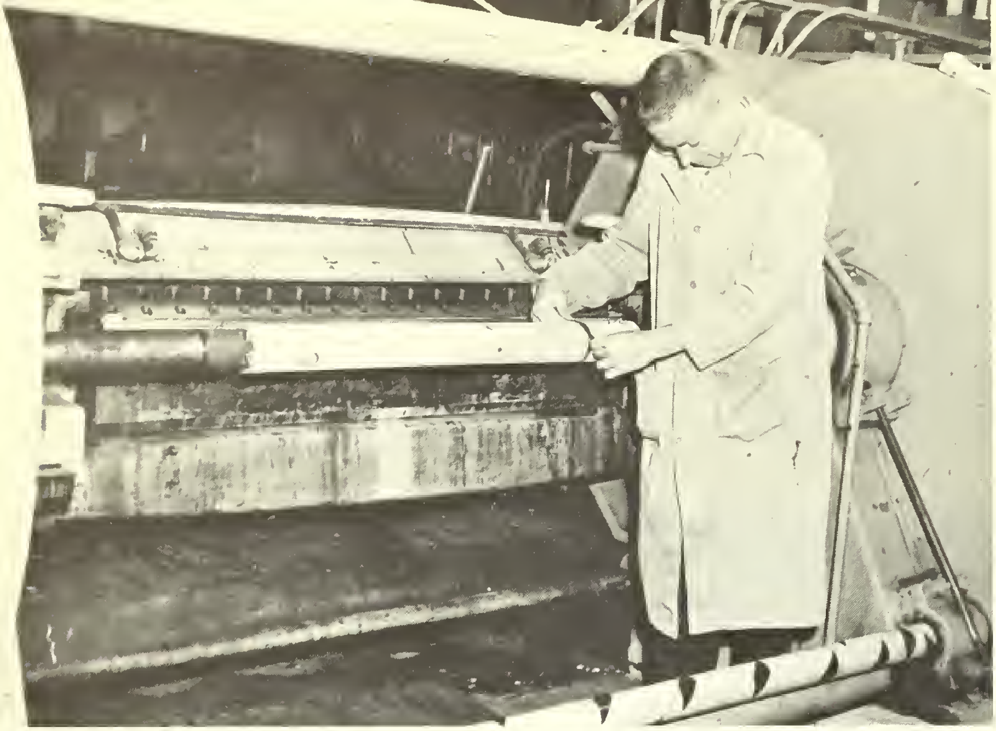


Figure 3.--A typical core turned to a diameter of about 3-1/2 inches, held on chucks 3 inches in diameter.

ther than 40 inches, 1 foot was cut from each 52-inch core before peeling it down to the smaller size. The best 12 inches of the core end was removed to avoid upgrading and to provide a more conservative estimate of the veneer grade obtainable from a full-sized bolt. Veneer peeled from the 6-inch cores down to a final diameter of $3\frac{1}{2}$ inches was pulled from the lathe as a single sheet. It was graded only as nominal 4-foot-long stock. Theoretically, 8-foot logs could be peeled to a diameter of about 6 inches, but it would be impractical to peel much smaller than this.

Green veneer grading was based on Product Standard PS 1-66[6] and as a natural grade rather than as a patchable grade. All green veneer was clipped for grade and sheet size by the following priority:

1. Nominal 4-foot sheet (55 inches) of the highest grade.
2. Nominal 2-foot sheet (29 inches) of the highest grade.
3. Random widths narrower than 29 inches but at least 6 inches wide.

Defects removed at the green clipper included wane, oversize knots and knotholes, and splits.

All green veneer was graded and tallied for each of the 20 individual bolts. Also, knotholes in individual pieces of veneer were tallied before and after drying. After drying, all the veneer was regraded and tallied. In addition, all dry veneer that had been peeled with 6-inch chucks was graded in simulated 8-foot lengths (figs. 4, 5, 6), using the same grading rules as specified for 4-foot lengths. This was done by laying out the end-matched veneer from the top and butt bolts taken from each log, starting with the sheets cut at a core diameter of 6 inches. Notches placed on the bolt ends after bucking facilitated end matching of the veneer from the two bolts taken from the same log. Veneer cut with the 3-inch chucks was graded only as simulated 4-foot lengths.

All veneer was dried to about 8 percent in a steam-heated dryer with a roller conveyor and longitudinal air circulation. Defects that occurred during drying were recorded.

[6]*American Plywood Association. U. S. Product Standard PS 1-66 for softwood plywood--construction and industrial..., effective November 1, 1966 (as reproduced from...National Bureau of Standards), 28 pp., illus. 1966.*

Figure 4.--End-matched sheets of dry veneer taken at a diameter of about 9 inches from log 1. Both the butt and top bolts yielded D grade veneer. The individual veneer sheets are about 52 by 52 inches.

Figure 5.--End-matched sheets of dry veneer, each about 52 by 52 inches, taken at a diameter of 8 inches from log 3. Veneer from the butt bolt is C grade and from the top bolt D grade. Eight-foot-long veneer from these sheets would be D grade. Figure 6 shows veneer cut from this same log but at a diameter of 4 inches.

Figure 6.--End-matched sheets of dry veneer, each about 40 inches long and 52 inches wide, taken at a diameter of about 4 inches from log 3. Both the top and butt bolt yielded C grade veneer. This veneer was not graded in 8-foot lengths. In commercial practice, 8-foot bolts are seldom peeled below a diameter of 6 inches.

Results

Comparison of Veneer Cut From Bolts at 60° F.or 140°F.

Satisfactory veneer was produced from matched bolts that were conditioned at either 140° F. or 60° F. prior to peeling. The concentric growth rings of slow-grown, fine-textured wood probably contributed to this favorable result. The veneer cut from the heated bolts was about the same in roughness as that cut from the bolts at 60° F. Knots in the veneer cut from heated bolts were smoother than those cut at 60° F., and the veneer from the heated bolts was slightly tighter and so could be handled with less chance of splitting. In no case did the knots damage the knife edge nor did there seem to be any difference in how well the knots remained in place through drying.

On the basis of this study, it would be feasible to make sheathing-grade plywood from small-diameter Black Hills ponderosa pine logs of this quality providing the wood temperature did not drop much below 60° F. Should this occur, or especially if the temperature dropped to near or below freezing at some time of the year, it would be advisable to put in heating equipment. For small-diameter logs, overnight heating in water or steam would be sufficient.

Peeling with 3-Inch Lathe Chucks

Cores of 19 of the 20 bolts were peeled from a diameter of about 6 inches to about 3½ inches. Both heated and unheated cores, 40 inches in length, peeled well until they reached a diameter of about 4 inches. At this point, many of them vibrated and some bowed during cutting. As a result, cutting was stopped at a diameter of about 3½ inches. This would not likely be a problem on a lathe with an adequate backup roll. There was no spinning out as the 3-inch chucks had adequate bearing to turn the 40-inch-long cores.

On the basis of this study, it appears feasible to cut logs of this quality to a diameter of 3½ inches on a 4-foot lathe equipped with retractable chucks and a backup roll.

Veneer Drying

Practically all of the veneer contained sapwood and was therefore dried on a sapwood schedule. Based on results of earlier studies, the dryer was originally set for 15 minutes at 300° F., and final moisture content of the veneer was about 6 to 15 percent. The schedule was then changed to 16 minutes at 305° F., which yielded veneer dried to 8 percent moisture content or less.

Many of the encased knots 1 inch or larger fell out during drying; most of the smaller encased knots and all of the intergrown knots stayed in place. The total number of knotholes in the green and dry veneer and the number of knotholes per square foot for each veneer grade within each bolt are shown in table 2.

Most of the veneer dried without splits. Splits in the green veneer opened slightly during drying but in no case lowered the grade of the veneer.

The veneer was flat as it came from the dryer. Some of the sheets cupped, however, when they reached room temperature while laid out for grading. Cupping was more pronounced in veneer cut at 60° F. than at 140° F. Knotty veneer, including that cut from bolts as small as 4 inches in diameter, had less cupping than veneer nearly free of knots. Cupping was not severe enough to be a problem in a commercial operation.

Veneer Yields by Grade and Veneer Sheet Size

A critical aspect in the evaluation of any species or grade of log for veneer and plywood production is the volume of veneer that it will yield in the various grades and in the various widths of sheets. Common plywood sheathing requires a grade C face and a grade D back. The inner ply or plies also require D grade veneer. Thus, for production of 3-ply sheathing, approximately 1/3 of the yield should be in C grade and the balance should largely be no less than D grade. The proportions of veneer required in the various grades will change with the number of plies in the plywood.

The width of the sheets of veneer that can be recovered in the different grades affects plywood production costs. High yields

Table 2. --Total number of knotholes in green and dry veneer, and number of knotholes per square foot within each veneer grade for each bolt

Bolt No.	Knotholes		Knotholes per square foot, by dry veneer grades					
	Green veneer	Dry veneer	A	B	C	D	ID[1]	Total
				Number				
1-1	1	98	--[2]	--	0.158	0.507	--	0.350
1-2	0	76	--	--	.035	.397	--	.281
2-1	4	8	--	--	0	.067	0.222	.079
2-2	0	0	--	--	--	0	--	0
3-1	0	31	0	--	.074	--	--	.073
3-2	1	39	--	--	.008	.147	--	.103
4-1	1	26	--	--	.104	.201	--	.156
4-2	1	15	--	--	--	.102	0.195	.137
5-1	0	0	--	--	0	--	--	0
5-2	0	3	--	--	.030	--	--	.030
6-1	0	36	--	--	.208	--	--	.208
6-2	0	11	--	--	0	.256	--	.072
7-1	0	37	--	--	.082	.322	--	.180
7-2	0	7	--	--	.111	.032	--	.040
8-1	0	4	--	--	.018	--	--	.018
8-2	1	19	--	--	.017	.130	--	.095
9-1	0	5	--	--	0	.022	--	.022
9-2	0	4	--	--	.017	--	--	.017
10-1	1	2	--	0	.022	--	--	.016
10-2	0	1	0	0	.011	--	--	.008
Weighted averages			0	0	.058	.182	.200	.109

[1] Grade D veneer as defined in U. S. Products Standard PS1-66 for use in center ply of five-ply standard and C-D plugged grades.

[2] Two dashes indicate that bolts did not contain any material in that grade.

of veneer in suitable grades mean very little if it is necessary to clip most of the veneers into narrow strips to attain the grade. Sheet width is also important when plywood specifications limit the number of edge-joints in the panel.

Tables 3 and 4 summarize the percent of dry veneer volume by grade and sheet width that was obtained from the study logs.

From the type of logs studied, yields can be expected to exceed 50 percent in grades C and better on the basis of nominal 4-foot bolts. When projected to 8-foot lengths, however, the yields of grades C and higher drop sharply to about 27 percent of the volume. Approximately 75 percent of the recovery can be expected in full green untrimmed width of 52 inches for either bolt length class.

Table 3.--Percent of dry veneer volume recovered by grade for 4-foot bolts, based on $3\frac{1}{2}$-inch cores

Bolt No.	Diameter, inside bark	Volume in each dry veneer grade, by sheet width class															Total volume
		52 inches wide					27 inches wide					Less than 27 inches wide					
		A	B	C	D	ID[1]	A	B	C	D	ID[1]	A	B	C	D	ID[1]	
	Inches	Percent															
1-1	13.6	0	0	43.3	43.3	0	0	0	0	3.2	0	0	0	1.8	8.4	0	100.0
1-2	12.9	0	0	32.0	57.7	0	0	0	0	3.3	0	0	0	0	7.0	0	100.0
2-1	8.6	0	0	0	68.5	0	0	0	0	0	8.9	0	0	3.2	19.4	0	100.0
2-2	7.9	0	0	0	85.6	0	0	0	0	11.1	0	0	0	0	3.3	0	100.0
3-1	15.6	0	0	90.3	0	0	0	0	2.1	0	0	1.4	0	6.2	0	0	100.0
3-2	14.9	0	0	18.4	50.5	0	0	0	7.2	9.5	0	0	0	5.7	8.7	0	100.0
4-1	10.3	0	0	41.7	52.1	0	0	0	0	0	0	0	0	4.4	1.8	0	100.0
[2] 4-2	10.0	0	0	0	0	0	0	0	0	0	8.2	0	0	0	62.6	29.2	100.0
5-1	9.1	0	0	74.7	0	0	0	0	0	0	0	0	0	25.3	0	0	100.0
5-2	8.6	0	0	87.0	0	0	0	0	0	0	0	0	0	13.0	0	0	100.0
6-1	10.8	0	0	80.0	0	0	0	0	0	0	0	0	0	20.0	0	0	100.0
6-2	10.2	0	0	67.7	22.6	0	0	0	0	0	0	0	0	4.3	5.4	0	100.0
7-1	11.6	0	0	59.1	25.3	0	0	0	0	0	0	0	0	0	15.6	0	100.0
7-2	10.7	0	0	0	89.6	0	0	0	5.2	0	0	0	0	5.2	0	0	100.0
8-1	11.9	0	0	71.1	0	0	0	0	12.3	0	0	0	0	16.6	0	0	100.0
8-2	11.2	0	0	26.1	69.6	0	0	0	0	0	0	0	0	4.3	0	0	100.0
9-1	12.6	0	0	0	43.7	0	0	0	0	26.5	0	0	0	5.5	24.3	0	100.0
9-2	12.4	0	0	93.3	0	0	0	0	3.7	0	0	0	0	3.0	0	0	100.0
10-1	9.6	0	13.4	67.2	0	0	0	0	0	0	0	0	17.6	1.8	0	0	100.0
10-2	9.3	0	13.8	69.0	0	0	0	0	0	0	0	13.5	3.7	0	0	0	100.0
All bolts		0	.9	48.2	30.3	0	0	0	2.1	3.2	.5	.6	.7	5.8	6.9	.8	100.0

[1] Grade D veneer as defined in U. S. Products Standard PS1-66 for use in center ply of five-ply standard and C-D plugged grades.
[2] Peeled only to 5.9-inch core because of split.

Table 4.--Percent of dry veneer volume recovered by grade for simulated 8-foot bolts, based on 6-inch cores

Bolt No.	Diameter, inside bark	Volume in each dry veneer grade, by sheet width class															Total volume
		52 inches wide					27 inches wide					Less than 27 inches wide					
		A	B	C	D	ID[1]	A	B	C	D	ID[1]	A	B	C	D	ID[1]	
		Percent															
1	12.9	0	0	22.5	67.5	0	0	0	0	3.9	0	0	0	0	6.1	0	100.0
2	7.9	0	0	0	74.8	0	0	0	0	0	19.4	0	0	0	5.8	0	100.0
3	14.9	0	0	10.1	55.8	0	0	0	7.9	10.5	0	0	0	6.2	9.5	0	100.0
4	10.0	0	0	0	45.7	45.7	0	0	0	0	0	0	0	0	8.6	0	100.0
5	8.6	0	0	94.5	0	0	0	0	0	0	0	0	0	5.5	0	0	100.0
6	10.2	0	0	61.4	30.7	0	0	0	0	0	0	0	0	2.9	5.0	0	100.0
7	10.7	0	0	0	87.0	0	0	0	0	6.5	0	0	0	0	6.5	0	100.0
8	11.2	0	0	10.9	65.6	0	0	0	11.3	0	0	0	0	12.2	0	0	100.0
9	12.4	0	0	0	39.5	0	0	0	0	30.7	0	0	0	0	29.8	0	100.0
10	9.3	0	21.7	65.3	0	0	0	0	0	0	0	0	13.0	0	0	0	100.0
All bolts		0	1.2	19.1	52.5	3.6	0	0	3.1	7.4	.6	0	.7	3.2	8.6	0	100.0

[1] Grade D veneer as defined in U. S. Products Standard PS1-66 for use in center ply of five-ply standard and C-D plugged grades.

Relation of Core Size to Veneer Grade and Volume Yield

Core size becomes increasingly significant as the diameter of the peeler logs declines. Many modern lathes are equipped with retractable chucks and backup rolls to allow peeling of small core sizes. In some species or grades of logs, however, the quality of the wood or the cutting becomes so poor, as the diameter approaches the usual 6- to 8-inch core size, that it becomes uneconomic to attempt to peel more veneer off the core.

Perhaps one of the most significant findings in this study was the increase in percent yield of grade C veneer resulting from peeling 6-inch cores down to 3½ inches (table 5). The grade increase is explained by the fact that limb knots declined in size as they approached the core. No appreciable changes in the quality of the veneer cutting was observed. It was concluded that 4-foot bolts, from the type and size log studied, could be advantageously peeled to a 3½-inch core.

Plywood Yields

Another important consideration is the relation of the footage of finished plywood to the log scale volume of the logs peeled. Ratios within the range of 2¼ to 2½ square feet of plywood (3/8-inch basis) per board foot of log scale are generally considered good.

With few exceptions, the study logs met or exceeded normal plywood yield requirements and in many instances by a considerable margin (tables 6 and 7). The highest yields were realized from 4-foot bolts peeled to a 3½-inch core. The yield difference shown between the two bolt lengths is largely the result of less taper and smaller diameter cores of the shorter bolts. The yield gains shown for the 3½-inch core verify the value of peeling to a relatively small core diameter.

Table 5. --Percent of total dry veneer volume recovered by grade from 4-foot bolts peeled to 3½-inch and 6-inch diameter cores, and 8-foot bolts peeled to 6-inch diameter cores

Size of bolts and cores	Volume recovered, by dry veneer grades					Total volume
	A	B	C	D	ID[1]	
			Percent			
4-foot bolts:						
3½-inch cores	0.6	1.6	56.1	40.4	1.3	100.0
6-inch cores	.7	1.9	52.4	43.4	1.6	100.0
8-foot bolts:						
6-inch cores	0	1.9	25.4	68.5	4.2	100.0

[1] Grade D veneer as defined in U. S. Products Standard PS1-66 for use in center ply of five-ply standard and C-D plugged grades.

Table 6.--Relation of square feet of finished plywood[1] to log volume for 4-foot bolts, based on Scribner Decimal C and International ¼-inch log scales and 3½-inch and 6-inch cores

Bolt No.	Diameter, inside bark	Volume, log scale		Volume, 3/8-inch 3-ply plywood		Ratio of square feet of 3/8-inch plywood to board feet of log volume			
						Scribner Decimal C		International ¼-inch	
		Scribner Decimal C	International ¼-inch	3½-inch core	6-inch core	3½-inch core	6-inch core	3½-inch core	6-inch core
	Inches	Board feet		Square feet					
1-1	13.6	30	30	80.98	70.97	2.7	2.4	2.7	2.4
1-2	12.9	20	25	78.19	68.18	3.9	3.4	3.1	2.7
2-1	8.6	10	10	29.27	19.26	2.9	1.9	2.9	1.9
2-2	7.9	5	10	23.40	13.38	4.7	2.7	2.3	1.3
3-1	15.6	40	40	122.01	111.99	3.1	2.8	3.1	2.8
3-2	14.9	40	35	109.01	98.99	2.7	2.5	3.1	2.8
4-1	10.3	10	15	48.05	38.04	4.8	3.8	3.2	2.5
4-2	10.0	10	15	31.68	31.68	[2] 3.2	3.2	[2] 2.1	2.1
5-1	9.1	10	10	33.51	23.50	3.4	2.4	3.4	2.4
5-2	8.6	10	10	28.79	18.78	2.9	1.9	2.9	1.9
6-1	10.8	10	15	50.07	40.06	5.0	4.0	3.3	2.7
6-2	10.2	10	15	44.38	34.38	4.4	3.4	3.0	2.3
7-1	11.6	20	20	59.32	49.30	3.0	2.5	3.0	2.5
7-2	10.7	10	15	50.27	40.25	5.0	4.0	3.4	2.7
8-1	11.9	20	20	63.36	53.35	3.2	2.7	3.2	2.7
8-2	11.2	10	15	57.58	47.57	5.8	4.8	3.8	3.2
9-1	12.6	20	25	68.66	58.65	3.4	2.9	2.8	2.4
9-2	12.4	20	20	69.82	59.80	3.5	3.0	3.5	3.0
10-1	9.6	10	15	37.27	27.25	3.7	2.7	2.5	1.8
10-2	9.3	10	10	36.30	26.29	3.6	2.6	3.6	2.6
All bolts		325	370	1,121.93	931.67	3.5	2.9	3.0	2.5

[1] A plywood fabrication loss of 20 percent was subtracted from volume of dry veneer to calculate plywood volume.
[2] Peeled only to 5.9-inch core because of split.

Table 7.--Relation of square feet of 3/8-inch 3-ply plywood[1] to log volume for 8-foot bolts, based on Scribner Decimal C and International ¼-inch log scales and 6-inch cores

Bolt No.	Diameter, inside bark	Volume, log scale		Volume, 3/8-inch 3-ply plywood (6-inch core)	Ratio of square feet of 3/8-inch plywood to board feet of log volume	
		Scribner Decimal C	International ¼-inch		Scribner Decimal C (6-inch core)	International ¼-inch (6-inch core)
	Inches	Board feet		Square feet		
1	12.9	50	55	134.75	2.7	2.5
2	7.9	10	15	27.03	2.7	1.8
3	14.9	70	75	199.50	2.9	2.7
4	10.0	30	30	66.31	2.2	2.2
5	8.6	20	20	32.08	1.6	1.6
6	10.2	30	30	65.92	2.2	2.2
7	10.7	30	35	81.28	2.7	2.3
8	11.2	30	35	92.56	3.1	2.6
9	12.4	40	45	102.47	2.6	2.3
10	9.3	20	20	46.47	2.3	2.3
All bolts		330	360	848.37	2.6	2.4

[1] A plywood fabrication loss of 16 percent was subtracted from the volume of dry veneer to calculate plywood volume.

Conclusions

1. Veneer grades meeting or exceeding sheathing-grade plywood specifications can be expected from 8- to 15-inch diameter black-jack ponderosa pine common to the Black Hills if logs with defects that will obviously not produce grade D veneer are eliminated.
2. Logs of this type did not appear to offer any particular problem in the veneering process. They peeled satisfactorily when conditioned to either 140° F. or to 60° F. Special lathe adjustments or marked changes in drying procedure were not required. The veneer was dried satisfactorily by a drying schedule established for the species.
3. Significant increases in better grade veneer yields were realized in peeling 4-foot bolts to a 3½-inch core instead of 6 inches.
4. For practically all logs studied, simulated plywood yields exceeded the generally accepted recovery ratio of between 2¼ and 2½ square feet of 3/8-inch plywood per board foot of log scale.
5. The logs appeared to be more adaptable to production of 4 - foot plywood panels than 8-foot panels. Both the percentage of C grade veneer and the plywood recovery ratio dropped appreciably when results were projected to an 8-foot bolt basis.

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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Soil Temperatures Under Forest and Grassland Cover Types in Northern New Mexico

Howard L. Gary[1]

Temperatures for selected soil depths (1.5 to 112 inches) under aspen, Douglas-fir, spruce-fir and grassland types on north- and south-facing aspects from 9,900 to 11,150 feet above m.s.l. are reported for 1 year. Plant cover type was more important in modifying soil temperature than aspect, elevation, or snow cover. Average annual temperature for the first 12 inches of soil ranged from 33.2°F. on the north-aspect spruce-fir at 11,150 feet to 40.8°F. on the south-aspect aspen at 9,900 feet. Depth of freezing temperatures during the period of snow cover ranged from 1.5 to 3 feet.

This Note reports a reconnaissance of soil temperatures for four cover types on north- and south-facing aspects on the west side of the Sangre de Cristo mountain range 16 miles northeast of Santa Fe, New Mexico (fig. 1, table 1). Soil temperature information for forest types of northern New Mexico has not been reported previously.

The role of soil temperature in relation to streamflow and forest management is not fully understood and needs further study. It is presently believed that soil temperature information may be useful for determining the manner in which freezing and thawing affect water movement in the soil, surface runoff, erosion, and possible flood flows under winter and spring conditions. Soil temperature is also known to influence seed germination, plant establishment, site productivity, length of growing season, and periods of most rapid plant growth.

[1]*Range Scientist, located at Albuquerque, in cooperation with the University of New Mexico; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Study Area and Plot Description

Study plots for temperature measurements were in Douglas-fir, aspen, spruce-fir, and grass types. The Douglas-fir and aspen plots (elevation about 9,900 feet) were on the Big Tesuque Creek drainage, while the spruce-fir and grass plots (elevation about 11,150 feet) were on the Rio en Medio drainage. All plots were about 0.1 acre, and were within 2.7 miles of each other. In each plant cover type, study plots were located at about the same elevation with one plot on a north-facing aspect and one on a south-facing aspect.

The surface soils (0 to 20 inches) in Douglas-fir and aspen were generally stony loam to sandy loam in texture, light brownish gray in color, slightly acid (pH 6.2), well-drained, and derived from residuum and valley fill from granite, gneiss, and schist. Surface soils (0 to 12 inches) in spruce-fir and grassland plots were generally stony loam to sandy loam in texture, light brown in color, strongly acid

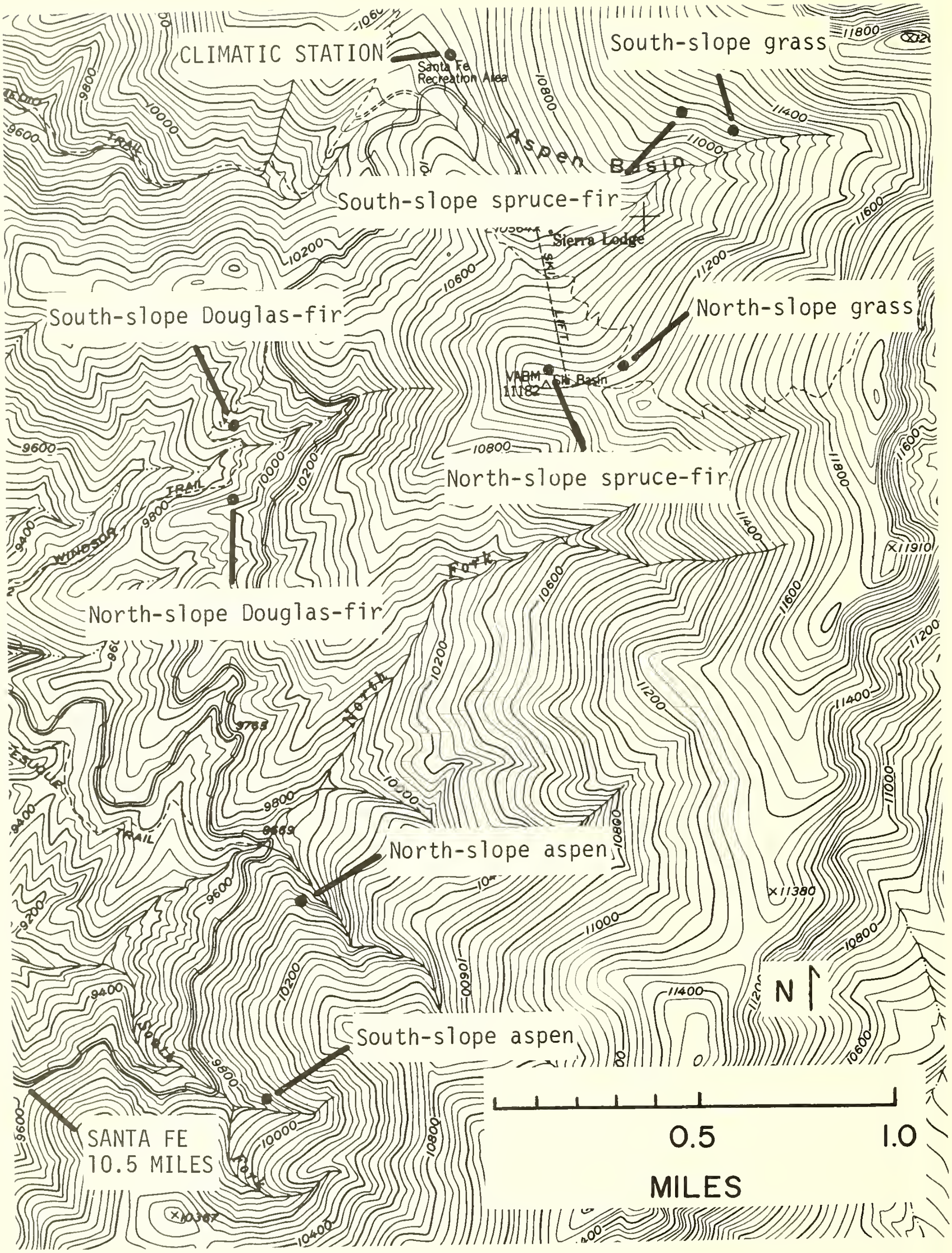

Figure 1.--Topographic map of study area (latitude 35° 46' N., longitude 105° 48' W.) with approximate locations of study plots and climatic station.

Table 1.--Description and characteristics of study plots in four forest cover types near Santa Fe, New Mexico November 1959-October 1960

Cover type, aspect and species	Elevation above sea level	Slope gradient	Slope orientation	Tree height	Trees per acre	Basal area per acre	Timber volume per acre
	Feet	Percent		Feet	Number	Square feet	Board feet[1]
DOUGLAS-FIR							
North Slope	9,940	45	N6°W	70-80			
Douglas-fir *(Pseudotsuga menziesii)*					470	188.5	
Engelmann spruce *(Picea engelmannii)*					100	7.0	
White fir *(Abies concolor)*					60	6.2	
Total					630	201.7	13,968
South Slope	9,930	38	S	60-70			
Douglas-fir *(Pseudotsuga menziesii)*					180	167.3	
White fir *(Abies concolor)*					30	2.6	
Quaking aspen *(Populus tremuloides)*					20	0.6	
Total					230	170.5	14,535
ASPEN							
North Slope	9,880	40	N22°E	40-45			
Quaking aspen *(Populus tremuloides)*					1,510	107.1	[2]12.93
South Slope	9,880	41	S20°W	45-50			
Quaking aspen *(Populus tremuloides)*					1,560	131.3	[2]19.98
SPRUCE-FIR							
North Slope	11,145	30	N	70-80			
Engelmann spruce *(Picea engelmannii)*					590	161.8	
Corkbark fir *(Abies lasiocarpa)*					1,030	91.5	
Total					1,620	253.3	10,170
South Slope	11,145	30	S19°W	80-90			
Engelmann spruce *(Picea engelmannii)*					490	223.2	
Corkbark fir *(Abies lasiocarpa)*					130	33.3	
Total					620	256.5	12,825
GRASS							
North Slope	11,150	25	N10°W				
South Slope	11,150	35	S14°W				

[1]Scribner Decimal C (10 percent cull).
[2]Cords (gross).

(pH 4.6), well drained, and derived from glacial till and residuum from granite, gneiss, and schist.[2]

Litter depth on the Douglas-fir and spruce-fir plots was less than 2 inches on the north slopes and less than 1 inch on the south slopes. There was no herbaceous ground cover on either the Douglas-fir or spruce-fir plots. The nearly pure aspen type in the study area was the result of fires during the late 1880's. No conifers were present in the immediate vicinity of the aspen plots. Herbaceous ground cover on the aspen plots was mainly Bromus, Vicia, Lathyrus, and Geranium spp. Litter depth was less than 2 inches, and down aspen logs were present on both aspen plots.

The grass type was also the result of fires 70 to 80 years ago. Ground cover was mainly grass (Poa, Festuca, and Bromus spp.). Shrubs

[2]*Meister, D. W. Soil management report for Tesuque Ranger District, Santa Fe National Forest. Region 3. U. S. Forest Serv., 102 pp. (Mimeographed report on file at Region 3 office, U.S. Forest Serv., Albuquerque, New Mexico.) 1965.*

on the grass plots were dwarf juniper (Juniperus communis L.) and Vaccinium spp. Engelmann spruce reproduction was scattered over both aspects of the grass type but not on the plots. The grass and spruce-fir plots on both north and south aspects were close together and comparable except for cover.

Climate

Winters are cold on the study area; summers mild. The first frost is usually in September, and the last one in early June. In the upper spruce-fir and grass cover types, mean monthly maximum air temperatures are usually below freezing from December through March (table 2). Annual precipitation in the general study area ranges from 25 to 35 inches, with approximately 40 percent of the precipitation occurring as snow. Precipitation received from November through April is usually snow.

Table 2.--Mean daily air temperatures by months, and total monthly precipitation at a climatic station near the study area, 1959-1960

Date	Air temperatures			Precipitation
	Maximum	Minimum	Mean	
	- - - °F. - - -			Inches
1959:				
November	38.6	19.2	28.2	0.40
December	29.4	10.7	20.0	4.50
1960:				
January	23.3	2.5	12.8	1.59
February	19.0	-0.3	9.4	2.70
March	33.1	10.0	21.5	5.75
April	41.2	19.4	30.3	1.15
May	48.2	26.8	37.5	1.40
June	62.5	37.4	50.0	2.45
July	63.6	38.6	51.1	6.85
August	64.2	38.2	51.1	3.35
September	58.1	32.8	45.5	1.50
October	44.1	23.1	33.6	3.30
November	37.3	17.1	27.2	.65

Methods

Calibrated thermistor beads in Colman[3] fiberglas soil moisture electrodes were used to measure temperature.Ohmmeter resistance readings were converted to temperature in degrees Fahrenheit. Temperature determinations were believed to be accurate to ± 1°F. One stack of fiberglas electrodes was installed on each of the eight plots. Soil pits were hand dug as deep as possible, down to apparent weathered bedrock; depth ranged from 24 to 112 inches. The electrodes were inserted along the pit walls at depths of 1.5, 4.5, 7.5, 12.0, 24.0, and 36.0 inches, and also on the bottom of soil pits. The excavated soil was repacked in the holes to duplicate thickness and arrangement of the original soil horizons.

Soil temperatures were measured once weekly during the study period. Although a considerable time span was sometimes required to complete measurements in winter, time intervals between plot measurements were generally consistent from week to week, and probably only slightly affected temperature comparisons. The Douglas-fir and aspen plots were usually measured between 9 and 11 a.m., and the spruce-fir and grass plots between 11 a.m. and 1 p.m. Diurnal changes in soil temperatures were not determined.

Average winter snow depth was determined from 10 measurements over each 0.10-acre plot.

The weather station in the study area (see fig. 1) was equipped with a recording thermograph and maximum and minimum thermometers; it was serviced once weekly.

Results

Average monthly soil temperatures (based on weekly observations between 9 a.m. and 1 p.m.) for the study period November 1959 through October 1960 (table 3) were relatively low, and showed marked seasonal fluctuations at all depths. Expected trends of temperature decrease with depth in summer and increase with depth in winter were evident on north and south aspects for all cover types.

[3]*Colman, E. A. Manual of instructions for use of the fiberglas soil-moisutre instrument. 20 pp. U. S. Dep. Agr. Forest Serv., Calif. Forest and Range Exp. Sta., Berkeley. 1947. (Revised 1952).*

Table 3.--Monthly average and mean annual soil temperatures[1] for selected depths under four cover types, November 1959-October 1960 (In degrees Fahrenheit)

Cover type and soil depth (inches)	Soil temperatures												
	November 1959	December	January	February	March	April	May	June	July	August	September	October 1960	Mean annual
						NORTH ASPECT							
DOUGLAS-FIR													
1.5	--	*23.0*	23.4	23.1	25.4	27.5	38.8	*54.1*	53.9	52.0	52.8	37.8	37.4
4.5	--	*20.1*	21.1	20.9	23.0	27.1	33.5	43.0	44.8	45.8	*47.1*	31.8	32.6
7.5	--	*19.4*	20.3	20.8	21.9	24.3	29.5	40.0	42.5	42.8	*44.1*	30.7	30.6
12.0	--	*27.1*	27.5	28.0	27.6	29.2	34.2	40.6	44.0	*46.9*	*46.9*	37.7	35.4
24.0	--	22.5	21.0	21.0	*20.9*	23.1	28.0	35.6	39.8	41.1	*41.3*	33.7	29.8
36.0	--	28.1	29.1	*27.4*	27.6	28.2	30.7	37.8	41.0	45.5	*46.8*	39.3	34.7
96.0	--	35.4	35.8	*31.1*	33.0	33.4	33.3	34.6	37.9	42.1	*44.3*	41.7	36.6
ASPEN													
1.5	28.5	*25.9*	27.0	26.6	28.8	31.6	47.7	*57.4*	56.9	52.8	53.3	38.7	39.6
4.5	28.5	*26.7*	27.1	26.9	27.9	30.8	42.2	50.8	*54.6*	49.5	49.6	38.0	37.7
7.5	29.5	*26.5*	27.1	26.8	27.6	30.6	40.5	48.6	*51.1*	48.9	48.4	37.7	36.9
12.0	28.5	*25.3*	26.1	25.5	26.2	28.0	36.7	45.3	*47.0*	46.3	45.3	36.2	34.7
24.0	34.0	30.8	30.5	*30.3*	30.4	31.8	36.6	44.3	46.4	*47.5*	47.4	41.3	37.6
36.0	36.0	33.8	33.0	32.0	*31.8*	32.4	35.8	41.9	44.8	46.0	*47.3*	42.7	38.1
112.0	39.5	39.3	38.5	37.2	37.2	37.0	*36.7*	37.9	39.7	42.0	42.9	*43.0*	39.2
SPRUCE-FIR													
1.5	27.9	24.6	24.9	*24.3*	26.0	28.6	31.2	37.8	*45.2*	42.3	41.7	32.5	32.3
4.5	30.0	27.1	26.8	*26.1*	27.0	29.3	30.8	35.3	42.7	*43.4*	42.7	33.9	32.9
7.5	31.1	28.5	28.3	*27.5*	28.1	29.6	31.0	35.4	43.3	*43.8*	43.3	35.5	33.8
12.0	32.0	29.3	*27.9*	*27.9*	28.3	29.4	31.0	35.1	42.1	*43.5*	43.4	36.2	33.8
24.0	32.0	30.0	29.0	29.0	*28.9*	29.3	30.2	33.2	39.5	*42.4*	*42.4*	36.7	33.6
36.0	33.4	31.6	30.9	30.1	30.5	*30.0*	31.0	32.1	37.1	40.1	*40.9*	37.1	33.7
108.0	36.0	35.0	33.1	32.6	33.5	*32.4*	33.2	33.0	33.5	35.6	37.2	*37.5*	34.4
GRASS													
1.5	29.0	*26.1*	28.6	28.0	29.9	31.5	34.5	46.4	*49.7*	49.1	48.9	36.6	36.5
4.5	30.0	*25.3*	27.6	26.6	29.4	31.6	33.7	48.0	*50.7*	47.1	47.3	34.7	36.0
7.5	30.8	*26.5*	28.6	27.5	29.3	32.0	33.5	45.4	*49.7*	48.5	48.9	37.1	36.5
12.0	31.7	*28.0*	29.4	*28.0*	29.6	30.8	32.7	41.9	*49.5*	*49.5*	49.4	38.7	36.6
24.0	29.7	*28.8*	29.4	28.9	29.1	29.5	29.8	36.8	44.1	44.4	*44.8*	37.4	34.4
36.0	33.0	31.5	30.8	*30.3*	30.5	30.4	30.7	36.1	44.1	45.0	*45.8*	39.8	35.7
96.0	33.5	35.1	33.6	32.4	32.6	*32.3*	*32.3*	33.4	37.8	38.9	*42.0*	41.2	35.4
						SOUTH ASPECT							
DOUGLAS-FIR													
1.5	--	28.5	28.1	27.3	*27.0*	32.0	37.0	43.6	46.4	48.8	*52.5*	37.2	37.1
4.5	--	27.3	27.1	*25.1*	*25.1*	28.6	33.0	40.0	43.0	45.6	*47.5*	36.2	34.4
7.5	--	31.9	31.5	29.8	*29.6*	33.3	37.0	43.8	47.9	50.8	*51.9*	41.8	39.0
12.0	--	31.1	32.0	30.1	*29.4*	32.4	35.8	43.1	47.5	51.0	*52.1*	43.2	38.9
24.0	--	30.3	30.9	28.9	*27.9*	30.4	34.3	38.8	42.6	47.4	*49.3*	41.8	36.6
ASPEN													
1.5	37.5	31.8	31.3	30.5	*30.3*	45.0	48.0	53.0	55.4	51.8	*56.5*	46.7	43.2
4.5	35.0	31.4	30.6	30.3	*30.1*	38.3	41.3	47.5	50.5	48.3	*51.1*	--	39.5
7.5	35.3	33.0	32.1	31.5	*30.8*	38.6	40.8	47.5	50.6	49.4	*51.4*	41.5	40.2
12.0	36.1	33.6	33.0	32.4	*31.8*	37.7	40.1	45.6	49.0	48.8	*50.4*	42.2	40.1
24.0	37.1	35.1	34.0	33.5	*33.0*	37.2	39.5	43.5	47.3	47.5	*49.9*	44.0	40.1
36.0	38.0	37.2	36.2	35.3	*34.9*	36.9	39.0	43.0	45.7	46.3	*49.0*	46.0	40.6
54.0	38.0	36.8	35.5	35.0	*34.9*	36.0	37.8	40.5	43.2	43.4	*46.5*	44.5	39.3
SPRUCE-FIR													
1.5	30.6	26.7	*26.4*	26.6	27.8	30.9	31.2	38.9	44.1	*44.8*	*44.8*	35.5	34.0
4.5	30.0	26.8	26.2	*26.0*	27.1	29.8	30.3	37.3	40.1	42.6	*43.1*	35.3	32.9
7.5	31.3	26.8	26.3	*26.1*	26.9	29.0	30.0	36.6	39.3	42.8	*43.0*	36.0	32.8
12.0	33.0	29.0	*27.9*	28.0	28.1	30.5	31.3	36.3	40.2	43.9	*44.4*	38.0	34.2
24.0	33.8	30.5	*28.8*	29.3	*28.8*	30.5	31.2	34.6	38.9	43.0	*43.9*	39.1	34.4
36.0	34.1	31.6	29.8	29.8	*29.3*	31.5	31.7	33.4	36.9	42.0	*43.5*	39.1	34.4
96.0	36.3	34.8	32.5	32.4	*32.1*	32.6	32.5	32.6	33.6	38.1	*39.9*	39.5	34.7
GRASS													
1.5	31.9	*28.3*	30.3	30.4	31.0	34.3	44.7	54.5	*57.9*	56.8	56.5	42.3	41.6
4.5	30.5	*28.5*	28.8	28.6	28.9	31.2	39.3	47.0	48.7	46.6	*51.8*	38.2	37.3
7.5	32.9	*30.4*	*30.4*	*30.4*	*30.4*	31.9	38.2	46.1	47.2	48.0	*51.5*	40.0	38.1
12.0	35.1	31.6	31.3	31.3	*31.0*	32.4	39.5	46.8	48.5	49.9	*53.1*	43.2	39.5
24.0	38.6	35.0	34.0	33.3	*32.5*	33.8	39.7	47.4	48.8	51.0	*53.6*	44.7	41.0
36.0	37.0	33.4	32.4	32.0	*31.0*	31.1	35.7	41.6	43.9	45.1	*48.6*	41.7	37.8
96.0	41.3	37.6	36.7	35.5	*35.0*	35.1	37.2	40.4	42.4	44.9	*47.8*	45.7	40.0

[1] Minimum temperatures (November-May) and maximum temperatures (June-October) are in italics.

Soil warming in the spring was not evident until the end of snowmelt. On south aspects, soil warmed most rapidly in April under the leafless aspen cover, in May under Douglas-fir, and in June under grass and spruce-fir.

The average soil profile temperature reached a maximum in July for the north-aspect aspen plot, and in September for all other plots. September temperatures for the 12- to 36-inch soil depths averaged about 48.9°F. on south aspects and 45.1°F. on north aspects. Comparison between cover types in September for 12-to 36-inch soil depths indicated little difference between the Douglas-fir[4] (47.6°F.) and aspen (48.2°F.) types. The highest temperature was in grass (49.2°F.) and lowest in spruce-fir (43.1°F.). Mean monthly air temperatures in the general study area were highest (51.1°F.) in July and August.

Average monthly soil temperatures changed most for all plots between September and October. The marked decrease in soil temperature indicated the start of the winter period, when inflowing radiant heat became less than heat leaving the soil surface. All study plots were snow covered by mid-December, and soil profile temperatures generally reached a minimum from January to March. In the 3-month midwinter period, temperature on north aspects for 12- to 36-inch soil depths averaged about 28.5°F., or about 2.7°F. lower than on south aspects. Comparisons between cover types in the same period and depths showed less than 1°F. spread between the bare aspen (31.7°F.) and grass (30.8°F.) types. Average temperatures were slightly lower under protection of Douglas-fir (27.8°F.) and spruce-fir (29.0°F.) canopies. Mean monthly air temperatures were lowest in January and February at 12.8°F. and 9.4°F., respectively.

[4] *Temperature estimated for 36-inch depth in south aspect Douglas-fir.*

Effect of Aspect

Aspect affected soil temperatures under forest and grass covers in both warming and cooling seasons (table 4). Mean annual soil temperature from 1.5- to 24.0-inch depths was about 34.8°F. on all north aspects and 37.7°F. on all south aspects.

In the Douglas-fir and aspen types, summer temperatures averaged about 2° to 3°F. higher on south aspects than on north aspects. The largest soil-temperature difference in summer between north- and south-facing aspects was 4°F. in the grass type. Temperature difference between aspects in summer was not striking, but generally similar to results reported for deciduous forest and grass covers in widely separated areas in the United States.[5]

Winter temperatures in Douglas-fir and aspen types were about 5° to 6°F. higher on south aspects than on north aspects. Temperature difference between aspects in the grass

[5] *Smith, Guy D., Newhall, Franklin, and Luther, H. Soil-temperature regimes, their characteristics and predictability. U. S. Dep. Agr. Soil Conserv. Serv. Tech. Pap. 144, 14 pp. 1964.*

Table 4.--Mean soil temperatures on north and south aspects for depths of 1.5 to 24.0 inches during warming and cooling seasons, 1959-60 (In degrees Fahrenheit)

Cover type	Soil temperatures					
	Warming season (April-September)			Cooling season (October-March)		
	North Aspect	South aspect	Difference	North aspect	South aspect	Difference
Douglas-fir	[1]39.2	42.4	3.2	25.5	31.7	6.2
Aspen	43.8	46.1	2.3	29.5	35.1	5.6
Spruce-fir	38.8	37.5	-1.3	29.7	29.7	0
Grass	41.6	45.6	4.0	30.4	33.4	3.0

[1]Weighted average using soil depths 0 to 24 inches.

type during the winter season was 3°F., about the same as observed during summer. Soil-temperature difference between north and south aspects would be expected to be greatest during winter months, which coincide with the maximum difference in the angle of incoming solar radiation.[6]

In the spruce-fir type, aspect did not affect soil temperature.

Effect of Elevation

Elevation effects on soil temperatures are relatively complex, and are confounded by site, vegetation, and weather variables. Elevational effect on soil temperature for the 1,200-foot difference in elevation between Douglas-fir (elevation 9,930 feet) and spruce-fir (elevation 11,145 feet) was masked by the presence of cover, but a difference was evident on south aspects and during the summer season (see table 4). For south aspects, summer temperatures for the 1.5- to 24.0-inch soil depths averaged about 5°F. lower in spruce-fir than under the less dense Douglas-fir (basal area two-thirds that of spruce-fir). On north aspects, summer temperatures for the same soil depths were similar for spruce-fir and Douglas-fir types. In winter on north aspects for the above soil depths, temperatures under Douglas-fir were 4°F. lower than under spruce-fir, and on south aspects temperatures averaged about 2°F. lower under spruce-fir.

For 36-inch and 96- to 108-inch soil depths, mean annual temperatures (see table 3) were about 1° to 2°F. less on north-aspect spruce-fir than on north-aspect Douglas-fir. Temperatures could not be compared for deeper depths on south aspects because of bedrock at 24 inches under Douglas-fir.

Effect of Snow Cover

Soils at all observed depths began cooling in October. By the time of the first persistent snowpack in November and December, 32°F. isotherms were observed to a depth of 3 feet on all north-slope plots and the south-slope spruce-fir plot. Under Douglas-fir, aspen, and grass on south slopes, 32°F. isotherms were observed to a depth of about 6 inches.

Figure 2 shows snow depth on the study plots, and the 32°F. isotherm in the upper 3 feet of soil. On north aspects, 32°F. isotherms were observed to a depth of about 3 feet as long as snow cover was present. This was also true for the south-slope spruce-fir. Soil temperatures below 2 feet under south-slope Douglas-fir could not be measured. Except during early December and a 1-week period in early January, temperatures were 32°F. or less to a depth of 2 feet during the period of snow cover over the plot. Within 2 weeks after snowmelt over the south-slope Douglas-fir plot, temperatures at the observed depths were above freezing. After a small snowstorm in late April, however, freezing temperatures were again observed to a depth of 8 inches for the first 2 weeks in May.

The depth of the 32°F. isotherm under south-slope aspen was significantly less than in other plots. During the period of snow cover, the depth of freezing temperature averaged about 7 inches from December to mid-January, but the soil warmed to above freezing in late January. The soil warming period was preceded by a period of snow settlement without any apparent decrease in snowpack water equivalent. This was followed by an extension of the freezing level to a maximum depth of 19.5 inches in March. The average depth of freezing temperature from February until complete snowmelt averaged 10 inches.

Under south-slope grass, depth of freezing temperatures ranged from about 6 inches in November to 21 inches in March. The thermistor at 36 inches also indicated some periods of freezing from January to mid-April. After snowmelt in mid-April, temperature was above freezing at all soil depths. As on the south-slope Douglas-fir plot, freezing temperatures were again observed to a depth of 9 inches in early May following the late April snow.

The presence and character of frost in soil profiles was not followed, but weighted average soil temperatures in the first 7.5 inches of soil for the period when snow cover was 6 inches or greater were as follows:

	Soil temperature	
	North aspect	South aspect
	- - -(°F)- - -	
Douglas-fir	23.5	27.4
Aspen	27.9	30.7
Spruce-fir	27.6	28.0
Grass	28.8	29.8

[6]*Cantlon, John E. Vegetation and microclimates on north and south slopes of Cushetunk Mountain, New Jersey. Ecol. Monogr. 23: 241-270. 1953.*

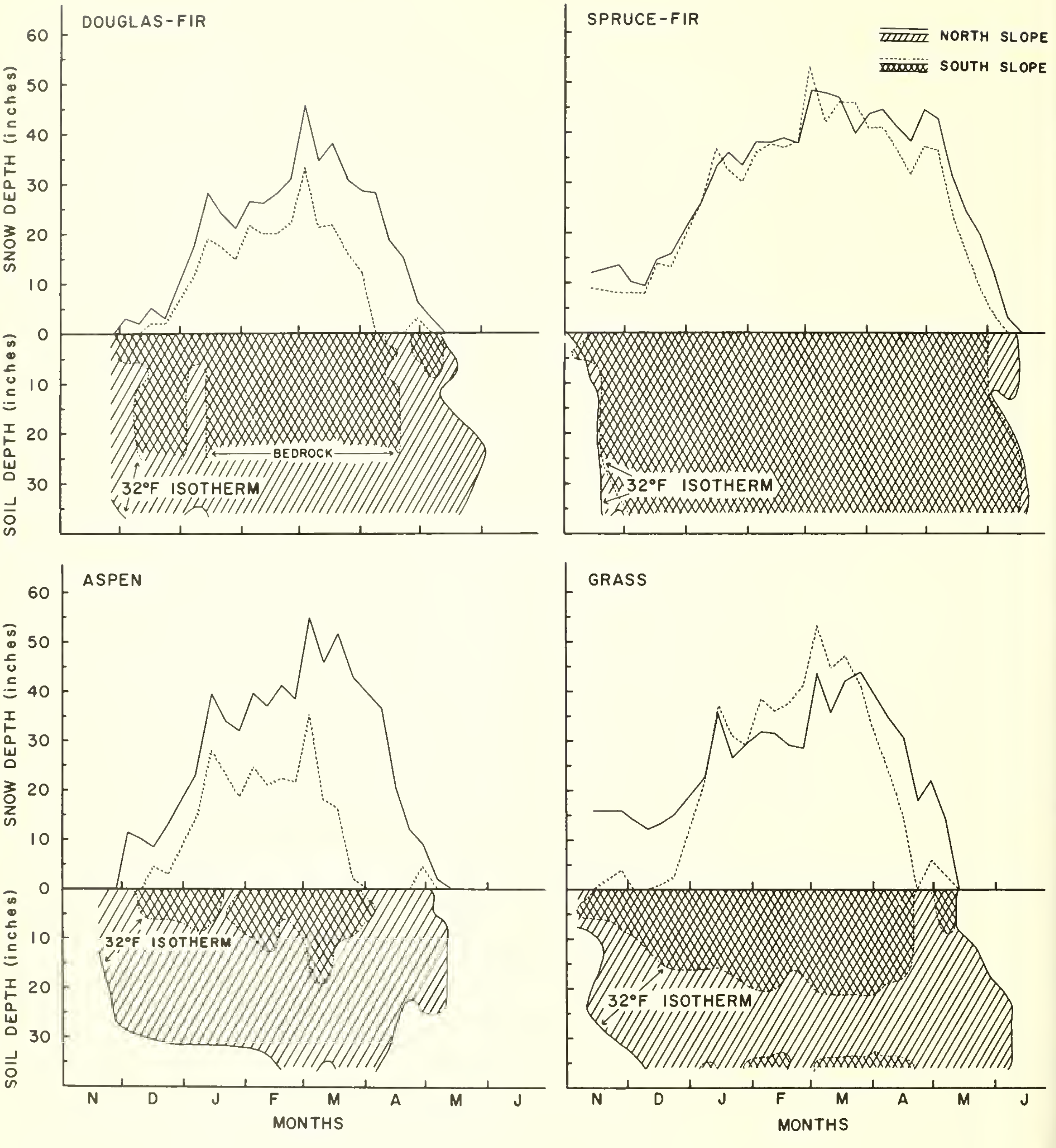

Figure 2.--Snow depths and 32°F. isotherms in the first 3 feet of soil under cover types on north and south aspects.

The lower temperatures under north-slope Douglas-fir than under other types was apparently related to the considerably greater heat loss before the establishment of snow cover. The snowpack did not reach 6 inches until 4 to 6 weeks later on this plot than on other north-aspect plots, and the temperature of the first 7.5 inches of soil dropped to about 20°F. This same soil layer on the other north-slope plots was 28° to 30°F. when snow reached a thickness of 6 inches. The Douglas-fir and aspen types had the greatest temperature difference between aspects for the period of snow cover. Under spruce-fir and grass, temperature differences between aspects were less than 1°F. The insulating properties of snow were most evident from January through March when all plots were generally covered with more than 10 inches of snow, and temperature fluctuation in the 1.5- to 7.5-inch soil depths was less than 5°F.

Effect of Cover Type

Soil temperatures in Douglas-fir and aspen types are not directly comparable since plots were located on different slopes and were 1.2 to 1.6 miles apart. However, average soil temperature was usually 4° to 5°F. less under Douglas-fir on both north- and south-facing aspects during warming and cooling seasons.

Spruce-fir and grass types were adjacent on both north- and south-facing slopes, and cover effects on soil temperature are directly comparable (fig. 3). An approximate balance

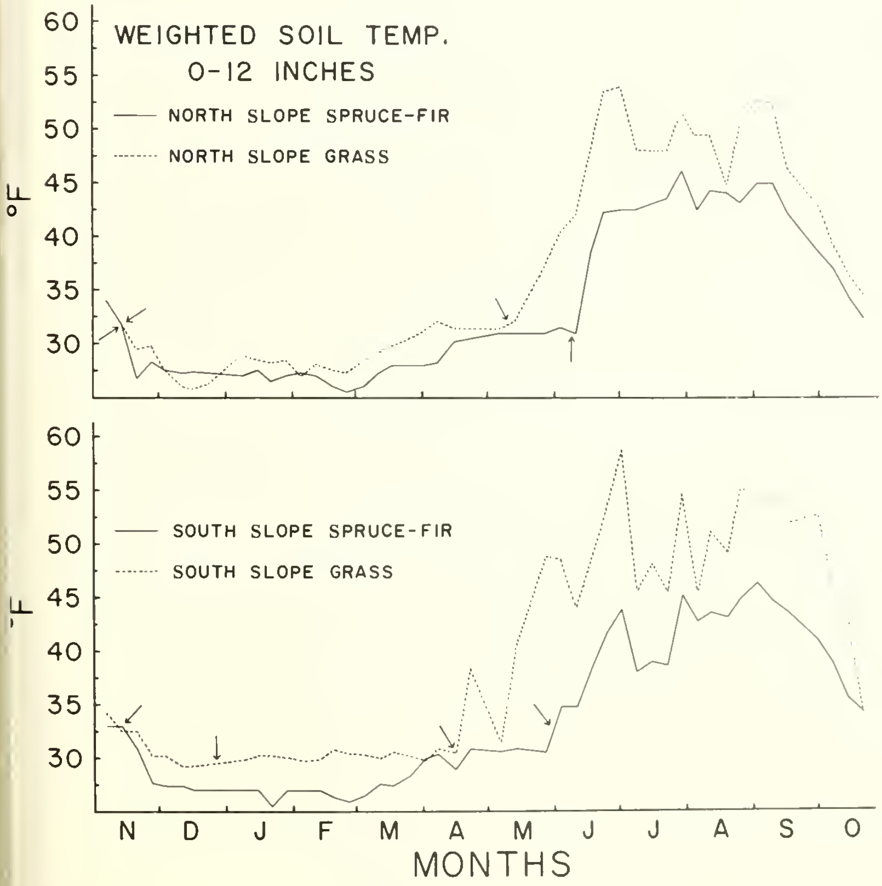

Figure 3.--Weighted average temperatures for 0- to 12-inch soil depths under spruce-fir and grass cover for a 1-year period. Snow depth was more than 6 inches during time period between arrows.

between heat losses and gains was apparent in these types on both aspects by the end of November. The temperature balance was variable but generally maintained from December through February. For the period of snow cover, temperatures for 1.5- to 12.0-inch depths averaged 1° to 2°F. higher on both aspects of grass:

	Soil temperature	
	North aspect	South aspect
	- - - (°F) - - -	
Spruce-fir	28.2	28.2
Grass	29.0	30.2

Temperature increased rapidly following snowmelt for these plots, and a difference between spruce-fir and grass cover was apparent. Temperature divergence between these types was widest during June. In the primary growing season from June through September, average temperature for the 1.5- to 12-inch soil depth was as follows:

	Soil temperature	
	North aspect	South aspect
	- - - (°F) - - -	
Spruce-fir	41.5	41.3
Grass	48.3	50.6

Temperatures for the 24-, 36-, and 96- to 108-inch soil depths under spruce-fir and grass cover are summarized in table 5. From April through September, soil temperature under grass on both north and south aspects was higher at all depths. In the cooling period from October through March, temperature for 24- and 36-inch soil depths on the south aspect was also higher under grass. Temperature during the cooling period on the north aspect was not significantly different between spruce-fir and grass for 24-, 36-, and 96- to 108-inch soil depths and for the 96- to 108-inch soil depths on the south aspect.

Discussion and Conclusions

Weekly measurements reported in this reconnaissance study give an indication of the range of soil temperatures associated with cover type, aspect, elevation, and snow cover over a 1-year period. Seasonal and monthly summaries of data obtained weekly between 9 a.m. and 1 p.m. do not reflect daily extremes that may influence plant growth, although daily fluctuations of soil temperature decrease with depth and density of plant cover, and change slowly from week to week for depths below 12 inches.[7]

[7]*Pearson, G. A. Forest types in the Southwest as determined by climate and soil. U. S. Dep. Agr. Tech. Bull. 247, 143 pp. 1931.*

Table 5.--Average soil temperatures at various depths under spruce-fir and grass types during warming and cooling seasons, 1959-60 (In degrees Fahrenheit)

Soil depth and aspect	Soil temperatures					
	Warming season (April-September)			Cooling season (October-March)		
	Spruce-fir	Grass	Difference	Spruce-fir	Grass	Difference
24 inches:						
North	36.1	38.8	2.7**	30.5	30.2	-0.3
South	37.3	46.1	8.8**	31.1	35.6	4.5**
36 inches:						
North	35.3	39.4	4.1**	31.9	32.2	0.3
South	37.4	42.8	5.4**	31.9	34.0	2.1**
96-108 inches:						
North	33.9	36.3	2.4**	34.4	34.5	0.1
South	34.9	41.4	6.5**	34.2	38.0	3.8

**Significant at 1 percent level of probability based on "t" test for paired plot data.

The greatest difference between aspects within types was under grass cover, where summer temperatures at 1.5 inches averaged about 7.5°F. higher for the south aspect. In contrast, there were no apparent temperature differences between north and south aspects under spruce-fir. The effects of aspect and elevation were generally obscured by increasing soil depth and plant cover.

The most important factor modifying average soil temperature in summer was the presence of cover. Comparisons between spruce-fir and grass types at similar elevations and on north and south aspects indicated that soil temperatures from 1.5 to 12 inches ranged from 7° to 9°F. higher under grass cover. The higher soil temperatures under grass cover in summer are considerably below temperatures known to be injurious to forest-tree seedlings, and are apparently favorable for rapid root growth.

The accumulation and retention of snow, and resulting frost penetration, depend on type and amounts of plant cover.[8] In the present study, temperatures during the period of snow cover were generally 32°F. or less to soil depths of 3 feet, except under aspen and grass types on south-facing aspects. Silvicultural systems that favor early snowmelt would result in earlier soil warming and possibly extend the period of root and tree growth.

Much of the usefulness of soil temperature information lies in evaluating its effect upon root growth. The relatively low temperatures reported in this study suggest a short period for root elongation and slow tree growth. Buds burst and new leaves appear in late May or early June in the aspen type, and in June in the Douglas-fir and spruce-fir types. Based on 40°F. soil temperatures for the initiation of root growth,[9] the active growing period was generally from June through September.

The relatively shallow snowpack in the general study area begins active melt from mid-March through early June, and without noticeable overland flow. Rain on snow and winter flooding events are also uncommon to the study area. Thus, apparent freezing of the first few inches of soil during the mid-winter period from about December to early March on all north aspects and south aspects under Douglas-fir and spruce-fir cover is of minor hydrologic importance.

[8] *Pierce, Robert S., Lull, Howard W., and Storey, Herbert C. Influence of land use and forest condition on soil freezing and snow depth. Forest Sci. 4: 246-263. 1958.*

[9] *Richards, S. J., Hagen, R. M., and McCalla, T. M. Soil temperature and plant growth. In Soil physical conditions and plant growth (Byron T. Shaw, ed.). Agron. Monog. 2: Acad. Press, New York, pp. 303-480. 1952.*

U.S.D.A. FOREST SERVICE
RESEARCH NOTE RM- 119

FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Thinning, Clearcutting, and Reseeding Affect Deer and Elk Use of Ponderosa Pine Forests in Arizona

Henry A. Pearson[1]

Logging or slash disposal after thinning may decrease deer but increase elk populations. Deer and elk did not significantly affect forage utilization measurements.

The ponderosa pine type of Arizona provides important livestock range and game habitat during spring, summer, and fall. It is also important for timber production, watersheds, and recreational areas.

This Note reports deer and elk use of a ponderosa pine range in northern Arizona, as measured by pellet dropping groups on the Wild Bill study area (Pearson 1964). Specific objectives of this study were:

1. To determine the effect of thinning, clearcutting, and forage reseeding treatments on deer and elk use in ponderosa pine forests, and
2. To determine the effect of deer and elk on forage utilization measurements in the study areas.

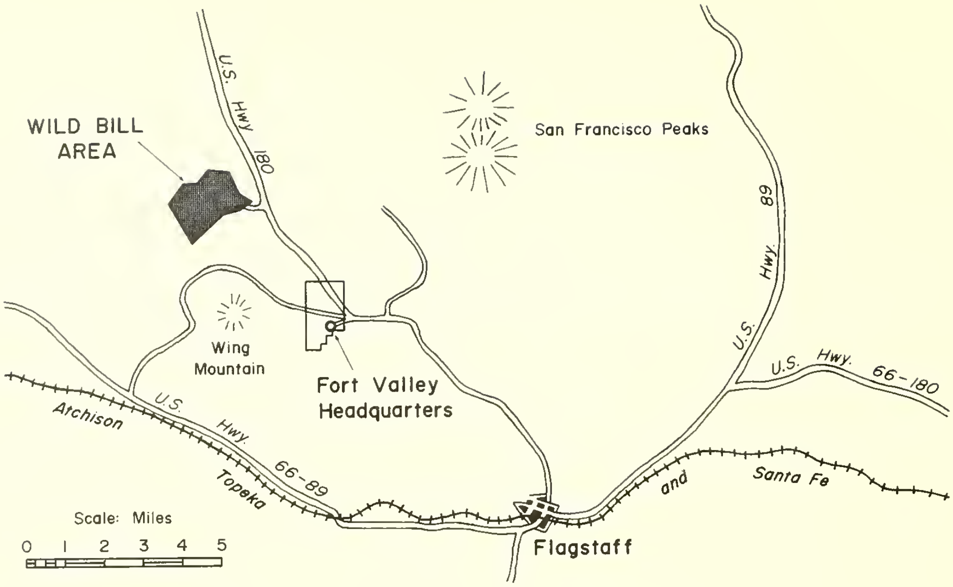
Study Area

The Wild Bill study area is located 13 miles northwest of Flagstaff, Arizona, on the Coconino National Forest. It covers approximately 900 acres of ponderosa pine-bunchgrass range on the Coconino Plateau. The land is generally level to moderately sloping toward the southwest. The elevation varies from approximately 7,400 feet to over 7,800 feet. Average precipitation is approximately 23 inches.

The area includes seven range units (fig. 1), and cattle graze them from June to October. Two of the units were clearcut, four were thinned to different tree densities, and one was left untreated. After thinning and clearcutting, the slash was piled and burned. Treatments were begun in 1962 and continued into 1965. One of the clearcut units was seeded to crested and intermediate wheatgrasses (Agropyron cristatum (L.) Gaertn. and A. intermedium (Host.) Beauv.), and yellow sweetclover (Melilotus officinalis (L.) Lam.). Vegetation in all other units is native.

Overstory on the Wild Bill is ponderosa pine (Pinus ponderosa Lawson). Arizona fescue (Festuca arizonica Vasey) and mountain muhly (Muhlenbergia montana (Nutt.) Hitchc.) make up the major portion of the understory. A variety of forbs include lupine (Lupinus spp.), senecio (Senecio spp.), thistle (Cirsium spp.), and many others. The only browse species in the area is Fendler ceanothus (Ceanothus fendleri Gray). Bottlebrush squirreltail (Sitanion hystrix (Nutt.) J. G. Smith), sedge (Carex geophila Mackenz.), and various forbs have increased following treatments.

[1]*Range Scientist, located at Flagstaff in cooperation with Northern Arizona University; central headquarters maintained at Fort Collins in cooperation with Colorado State University.*



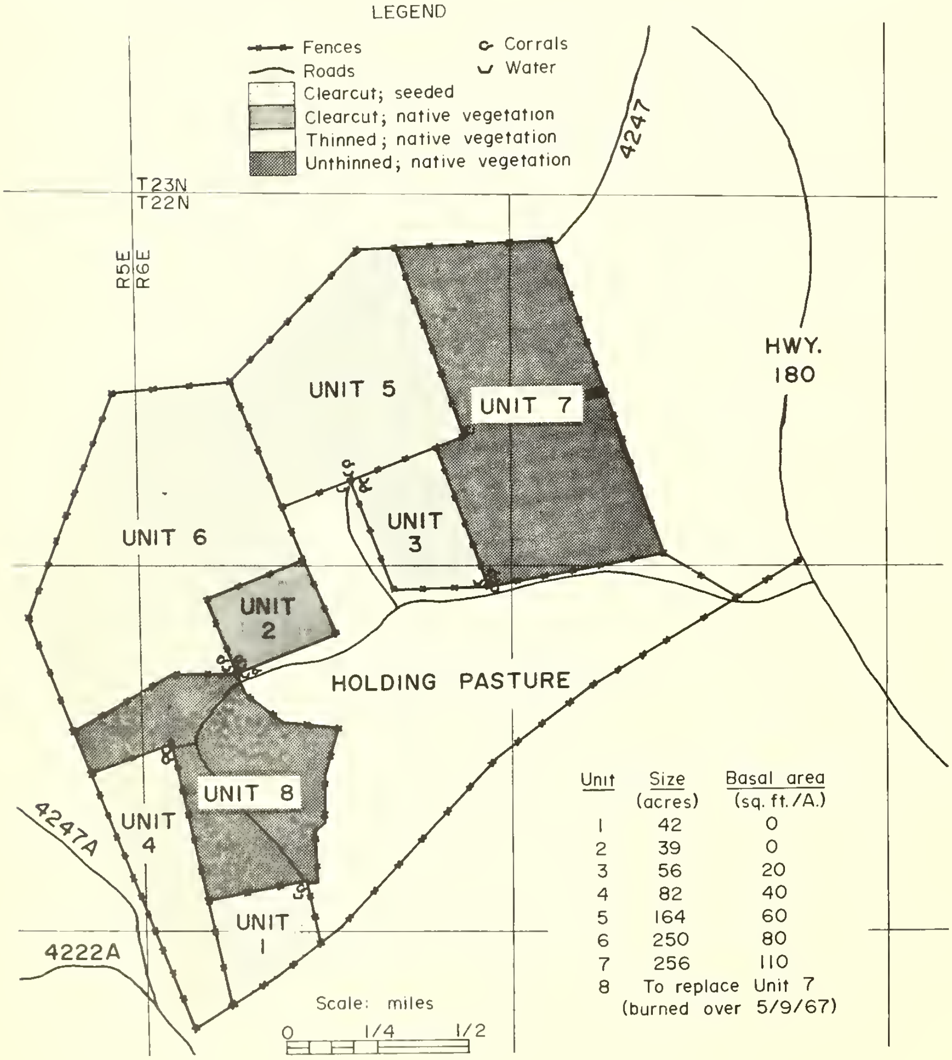


Figure 1.--The Wild Bill study area northwest of Flagstaff, Arizona.

Methods

Deer and elk pellet groups were counted from 15 stratified random sampling clusters of three permanent circular plots (0.01 acre) in each range unit. Plots were cleared of pellets in the fall of 1962 and after semiannual counts. Yearly forage production was estimated from caged plots (9.6 square feet) near the pellet group plot locations.

Results and Discussion

Deer Use

Comparison of deer pellet groups among years indicated a general downward trend in deer use (table 1). Factors responsible for the decrease in deer numbers are not explainable from the data; increased activity on the area, slash disposal practices, or logging may partially explain this response. Previous studies have shown deer use to decrease similarly after slash cleanup and logging (Reynolds 1962, 1966a).

Deer were observed on the study area during the spring, summer, and fall; they apparently migrated to lower elevations during the winter.

The pattern of deer use on the different treatment areas was not consistent between years. The data suggest, however, that deer use was not significantly different among the various overstory treatments.

At a defecation rate of 13 pellet groups dropped per day (Smith 1964), average yearly deer use during 1963-66 was 2.5 deer days per acre. Only 0.3 deer day use per acre was measured during 1966. Since deer consume approximately 3.5 pounds of air-dry forage per day per hundredweight of deer (Smith 1953), the deer population is not significantly affecting forage utilization measurements on the area. Average yearly herbage production during 1965 and 1966 was 389 pounds per acre, while yearly removal of forage by deer was less than 5 pounds.

Elk Use

Contrary to deer pellet group counts, yearly elk pellet group counts do not show any trend. No elk pellets were found during initial clearing of the plots. Elk use increased immediately after the forest treatments, then remained relatively constant (table 1). At a defecation rate of 12.5 pellet groups dropped per day (Neff et al. 1965), average yearly elk

Table 1. --Yearly deer and elk pellet group counts per acre on the Wild Bill study area

Range unit	Deer pellet groups					Elk pellet groups				
	1963	1964	1965	1966	Mean	1963	1964	1965	1966	Mean
					Number per acre					
1	50.6	15.6	6.7	6.7	19.9	2.2	26.7	64.4	13.3	26.7
2	164.4	42.2	11.1	11.1	57.2	22.2	8.9	2.2	2.7	8.9
3	57.8	4.4	13.3	2.2	19.4	2.2	6.7	8.9	2.2	5.0
4	53.3	124.4	31.1	2.2	52.8	8.9	13.3	4.4	2.2	7.2
5	28.9	35.6	33.3	2.2	25.0	0	6.7	11.1	2.2	5.0
6	46.7	33.3	0	0	20.0	2.2	4.4	4.4	0	2.8
7	97.8	17.8	4.4	0	30.0	0	0	0	0	0
Mean	71.4	39.0	14.3	3.5	32.0	5.4	9.5	13.6	3.2	7.9

use was 0.6 elk day per acre. Elk consume 9 to 10 pounds of forage per day (Lang 1958). Visual observations of elk, forage disappearance, and pellet group counts indicated 80 to 90 percent of the elk use occurred during May:

	Elk pellet groups (Percent)	
	November-April	May-October
1962-63	0	100
1963-64	7	93
	November-May	June-October
1964-65	93	7
1965-66	89	11

Elk was highest in clearcut units and lowest in the thinned unit with the least trees removed (table 1). No elk pellet groups were found in the untreated unit during the 4-year period. Elk use was highest in the clearcut unit with native species during 1963, but shifted to the clearcut unit seeded with exotic species in 1964. This shift was probably due to the early growth of the exotic grasses and their high production during later years. The native unit produced approximately 600 pounds of grass per acre, while the seeded unit produced approximately 1,000 pounds after 1963. More elk use of open areas than forest areas is consistent with results from other elk studies in Arizona (Reynolds 1966b).

Since cattle do not enter the study area until June, and the average yearly elk use is relatively small, the elk population is not significantly affecting forage utilization measurements on the area.

Conclusions

This study was made on a relatively small area under unique circumstances. Deer and elk populations apparently are not significantly affecting forage utilization measurements on the area. Some management implications based on these results include:

1. In ponderosa pine forests, openings can be an important segment of habitat for elk; no apparent advantage was gained in the deer habitat.
2. Assuming that varying densities of pellet groups reveal relative amounts of time spent foraging in these areas, elk preferred the introduced crested and intermediate wheatgrasses to the native Arizona fescue and mountain muhly, especially during spring.
3. Logging or slash disposal after thinning may adversely affect deer populations, but elk populations may increase.

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U.S.D.A. FOREST SERVICE
RESEARCH NOTE RM- 120

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KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Shielded Thermistor Probe with Portable Instrument for Measuring Snowpack Temperatures

G. J. Gottfried and C. J. Campbell[1]

A phenol-resin-based shield has been designed to protect a thermistor probe that can be inserted into a snowpack. The shield also serves as an insulator between the thermistor and the aluminum pole used to push the probe assembly into the snowpack. With the probe and Wheatstone bridge circuit, temperatures can be measured within the snowpack to 0.1°C.

Temperature and density profiles of snowpacks are important to watershed managers for the evaluation of runoff potential. In Arizona, winters are warmer than farther north, with the result that snow frequently melts between storms, and total snowpack is generally less than 6 feet.

Snow temperatures are measured at either temporary or permanent installations. The permanent installation usually contains thermometers or thermistors mounted at given heights above the ground and are attached to recording or direct readout instruments. This type of installation is expensive to install and maintain, and will only give information from one sample point. For temporary installation one method is to dig a trench and make measurements at the desired depths.

We have assembled a portable instrument[2] to be used with a shielded thermistor probe that can be inserted into the snowpack. Measurements to within 0.1°C. throughout the snowpack, high mobility, and rapid measurements at any depth up to 5 feet are possible.

Temperatures are detected by a thermistor. The steel-encased thermistor tip can withstand pressures, but the necessary protection against bending is provided by a phenol-resin-based shield. This shield also insulates the thermistor from the threaded aluminum pipe used to push the assembly into the snowpack. The pipe is marked at half-foot intervals to indicate snow depth. The top of the pipe is sealed with silicone rubber to prevent a possible short circuit. An extension can be added for deeper snowpacks by using a threaded joint.

Laboratory Evaluation

The instrument was checked by embedding the thermistor in a 25-pound block of ice cooled below 0°C. The ice was then put into a cooler maintained at approximately 2°C. When the ice warmed to 0°C., resistance readings were taken for 4 days. The average of all Wheatstone bridge[2] readouts during the period was 499. The range was from 501 to 498; the mode value was 499.

The instrument functioned consistently during the test period. The difference between 500 and 499 is well within the specified accuracy of ±0.1°C.

[1]*Associate Hydrologist and Botanist, respectively, located at Tempe, in cooperation with Arizona State University; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Swanson, Robert H. A low-cost instrument to measure temperature or resistance accurately. U. S. Forest Serv. Res. Note RM-80, 4 pp., illus. 1967. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colorado.*

Field Operation

In field operation, the probe is inserted into the snow to the desired depth, the bridge is turned on, and the dial read when the needle stabilizes. The dial reading is converted to temperature values (table 1). The needle takes longer to stabilize during the first reading because it takes time for the thermistor to adjust from air temperature to snow temperature. Approximately 120 seconds are required for stabilization of the meter needle after the initial insertion of the probe. At lower depths with smaller temperature differentials, readings can be taken in 90 seconds or less.

Table 1.--Temperature (T) vs. dial readings (N) for temperature probe

T	N	T	N	T	N	T	N
°C.		°C.		°C.		°C.	
[1]-5.0	565	2.5	532	0.0	500	2.5	469
4.9	564	2.4	531	+0.1	499	2.6	468
4.8	562	2.3	530	0.2	498	2.7	467
4.7	561	2.2	529	0.3	496	2.8	465
4.6	559	2.1	527	0.4	495	2.9	464
4.5	558	-2.0	526	0.5	494	+3.0	463
4.4	557	1.9	525	0.6	493	3.1	462
4.3	555	1.8	523	0.7	492	3.2	460
4.2	554	1.7	522	0.8	490	3.3	459
4.1	552	1.6	520	0.9	489	3.4	458
-4.0	551	1.5	519	+1.0	488	3.5	456
3.9	550	1.4	518	1.1	487	3.6	455
3.8	549	1.3	516	1.2	485	3.7	454
3.7	547	1.2	515	1.3	484	3.8	453
3.6	546	1.1	513	1.4	483	3.9	451
3.5	545	-1.0	512	1.5	482	+4.0	450
3.4	544	0.9	511	1.6	480	4.1	449
3.3	543	0.8	510	1.7	479	4.2	448
3.2	541	0.7	508	1.8	478	4.3	446
3.1	540	0.6	507	1.9	476	4.4	445
-3.0	539	0.5	506	+2.0	475	4.5	444
2.9	538	0.4	505	2.1	474	4.6	443
2.8	536	0.3	504	2.2	473	4.7	442
2.7	535	0.2	502	2.3	471	4.8	440
2.6	534	-0.1	501	2.4	470	4.9	439

[1] For temperature and respective dial readings greater than ±5°C., see Swanson[2]

Temperature should be measured as the probe is inserted into the snow to keep the sensitive tip in relatively undisturbed snow. Care must be taken to prevent water from entering the conductor cord contact points, since it would cause higher temperature readings and erratic needle movement.

The thermistor operates with a Wheatstone bridge circuit. Reference resistance was increased to 7,355 ohms within the circuit, to give a readout of 500 at 0°C. (table 1).

A stainless steel cover with a welded cap (fig. 1) was designed to protect the thermistor when not in use.

e 1.--
o temperature probe (s)
atstone bridge (i)
inless steel cover (c)

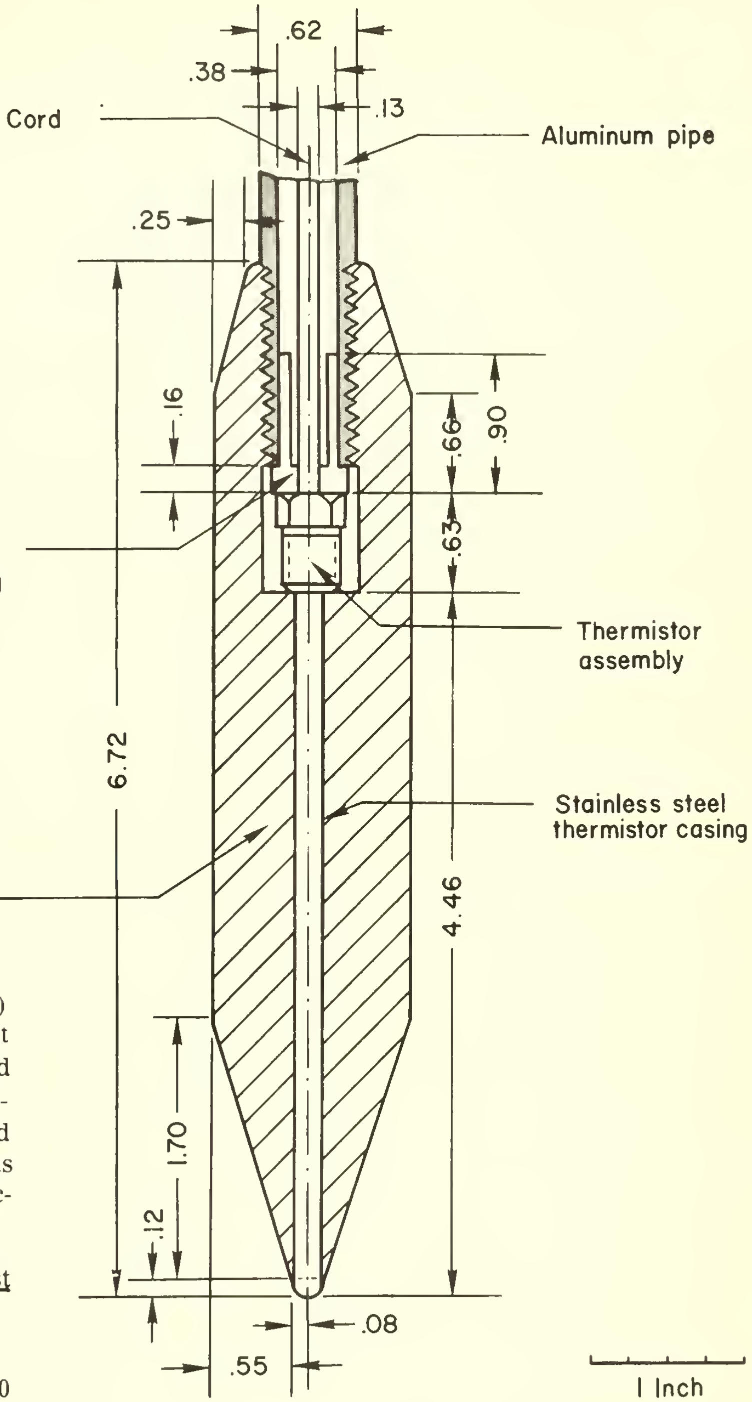

Figure 2.--A schematic diagram of the probe and shield. This shield design has been successfully used, but dimensions do not have to be followed exactly.

Cost

The probe assembly and meter (fig. 1) consists of three main parts, which cost about $120 to construct. Most of the expense involved is in the machine tooling of the solid phenol-resin-based rod that forms the protective shield (fig. 2) around the thermistor probe. Parts and their approximate purchase or manufacturing costs are shown below:

Part	Cost
Probe shield of canvas-base phenol-formaldehyde resin rod and insulator cap	$45.00
Yellow Springs Instrument Company[3] thermistor 400 series (1,000 ohms at 25°C.)	27.50
Wheatstone bridge instrument	40.00

[3]*Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

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I.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effects of Soil Freezing on Water Yields

Arnett C. Mace, Jr.[1]

Concrete and granular types of soil freezing in the White Mountains of Arizona influence the disposition of snowmelt water. Concrete frost occurs in the open grassland areas, and appears to increase surface runoff. Only granular frost occurs in the timber types, and appears to decrease surface runoff and increase soil moisture recharge. Concrete freezing causes increased soil moisture and reduced bulk densities in the zone of freezing, whereas granular freezing has no effect on these properties.

Soil freezing influences the disposition of snowmelt water. Post and Dreibelbis (1943) recognized the differences in structure of frozen soils — concrete, honeycomb, and stalactite— help explain differences in permeability. Hale (1950) has observed a fourth type, designated as granular. Concrete frost increases surface runoff, whereas granular, stalactite, and honeycomb frost may increase soil moisture recharge (Trimble et al. 1958).

The effect of vegetation upon the depth of soil freezing is attributed to influence of vegetation upon soil moisture, soil types, snow depth, and litter by many authors as summarized by Pierce et al. (1953). Trimble et al. (1958) found concrete frost to be impermeable in both forest and open areas, but frozen soils in the forest contained large open holes that allowed water to enter. Augustine (1942) and Lutz and Chandler (1946) indicated that, even though the forest soil may be frozen to the same depth as soil in open areas, it is more permeable. Other authors (Jaenicke and Foerster 1915, Pearson 1911, Stoeckler and Weitzman 1960) indicated that forest cover types tend to favor the more porous type of freezing.

Previous work has indicated that type of soil freezing may be related to soil texture. Stoeckler and Weitzman (1960) indicated that infiltration rates are substantially higher in frozen sandy soils than in frozen silt loams. Their data from sandy soils indicated that high soil moisture is associated with the more impermeable types of soil freezing. Belotelkin (1941) noted that frost penetrates deeper and stays longer in a poorly drained soil, and fine-textured soils resemble the poorly drained soils. Since fine-textured soils retain more moisture than coarse-textured soils, these experiments may indicate that soil moisture is a factor directly related to type of soil freezing.

Pearson (1911) found that frost depth under ponderosa pine (Pinus ponderosa Laws.) was one-half of that present in open areas. Jaenicke and Foerster (1915), working in northern Arizona, found the same relationship. Storey (1955) surmised that the soils in Arizona only freeze intermittently, and that freezing has a relatively minor hydrologic influence.

[1]*Research Forester, located at Tempe, in cooperation with Arizona State University; central headquarters maintained at Fort Collins in cooperation with Colorado State University. Mace is now Assistant Professor, School of Forestry, University of Minnesota, St. Paul.*

Frozen soils have been observed in the White Mountains of Arizona, and could have a significant influence on water yields. As much as 75 percent of the total annual runoff from this area may occur in the 4-month period of January to April; part of this runoff is attributed to melting snow water running over frozen soils.

In view of the hydrologic importance of frozen soils, and the lack of data specific to Arizona, a study was started in 1962 to measure types of soil freezing, certain physical factors involved in soil freezing, and influence of frost on water yields.

Methods

The study area is located near Pole Knoll, elevation 9,200 feet, between Eagar and McNary on the Apache National Forest in eastern Arizona.

Four 25-square-foot plots were located in each of the following sites: (1) a north-facing grassland, (2) a south-facing grassland, (3) a mixed-conifer area, and (4) an aspen area. White, wooden sideboards, sealed with plastic roofing compound, were used to prevent lateral movement of snowmelt water off or onto the plots. These walls were kept at approximately the same height as the snowpack (fig. 1). To prevent entry of surface water, plots were trenched to 10 inches and bound by wooden sides (wood is a low conductor of heat) and sealed with plastic roofing compound. Surface runoff and soil moisture recharge were measured to follow dispostion of snowmelt water. Surface runoff was collected from the bordered plot, and soil moisture recharge was measured by the neutron-scattering technique at two locations in each plot to a depth of 6.0 feet. Soil moisture was measured before freezing, during frozen conditions, during snowmelt, and immediately after snowmelt. Snow was measured twice weekly on each plot.

Type and depth of soil freezing were determined weekly by means of a King tube sampler and open pits at two sampling points adjacent to each plot. Soil moisture of the concrete frozen soil in the north-facing grassland was determined by samples taken at 0- to 1- and 1- to 3-inch depths. Bulk density for north-facing grassland, mixed conifer, and aspen soils under frozen conditions was determined for depths of 0 to 1.5 and 4 to 6.5 inches. Expansion as a result of concrete freezing in the north - facing grassland was computed by drying frozen samples of a known volume and determining shrinkage for depths of 0 to 1.5 and 3 to 4.5 inches.

Results

The first year's data indicate both concrete and granular types of soil freezing occurred (table 1). Concrete soil freezing occurred in the silt loam soil type in the open grassland throughout the snow season, and was observed under at least 24 inches of snow for short periods. Granular freezing occurred in the sandy loam soils of the mixed conifer and aspen types. Ice layers in the litter in the mixed conifer and aspen plots averaged 1.5 inches in depth. These ice layers were present only after thawing and freezing periods, whereas concrete frozen soil in the grassland areas prevailed throughout the entire snow season. Average daily air temperatures and average air temperatures below freezing at the study site for the period of study were:

	Average air temperatures		
	Daily	Below 32°F.	
	(°F.)	(°F.)	(Hrs. /day)
December	21.7	17.0	19.5
January	19.0	17.1	19.3
February	27.9	22.0	16.9
March	29.5	24.2	11.5

Figure 1.--Frost study plots, with sideboards at approximate level of snow.

Table 1.--Average depth of snow, and of concrete and granular frost

Plot conditions	Average depth of soil freezing			
	December	January	February	March
	Inches			
North-facing grassland:				
Concrete frost	4.87	4.94	4.06	4.12
Granular frost	.25	1.19	2.25	2.25
Average snow depth	10.25	11.85	6.50	7.80
North-facing mixed conifer:				
Concrete frost[1]	2.00	1.31	.10	.86
Granular frost	.50	.75	.25	.75
Average snow depth	3.25	8.60	6.80	8.60
North-facing aspen:				
Concrete frost[1]	1.50	2.00	.06	1.00
Granular frost	0	.75	.25	.63
Average snow depth	6.25	12.40	12.10	18.25
South-facing grassland:				
Concrete frost	3.00	5.33	4.19	3.00
Granular frost	0	.50	1.19	1.06
Average snow depth	12.25	19.00	15.40	19.15

[1] In litter only.

Surface runoff was significantly greater (5 percent level) on plots where concrete frost was present. Relationships between surface runoff and soil moisture recharge for each area are shown in table 2.

Concrete frost in the grassland areas reduced infiltration and increased surface runoff. Soil moisture was recharged in these areas during the latter part of the snowmelt period when the soil was rapidly thawing. Observations indicated that soils thawed largely from the top, with minor thawing from below, and the thawed surface soil was saturated with free water on the surface.

Soil moisture recharge in the mixed conifer and aspen plots indicates that these ice layers melt during the early part of the snowmelt period, and do not influence infiltration. Also, granular frost in the timber soils does not impede, but may actually increase infiltration due to consolidation of soil particles, which in turn creates larger pores.

Soil moisture for the north-facing grassland at the 0- to 1-inch zone was 107.8 percent by dry weight, while at the 1- to 3-inch zone soil moisture was 54.8 percent by dry weight. Higher values at the 0- to 1-inch zone are attributed to moisture migration due to the ther-

Table 2.--Average frost type and depth, and relationship of total surface runoff to soil moisture recharge on study areas

Average frost type and plot	Frost depth	Surface runoff	Soil moisture recharge	Total moisture	Ratio: runoff to recharge
	Inches				
Concrete:					
North-facing grassland	4.49	2.38	3.36	5.74	0.71
South-facing grassland	3.88	2.49	3.09	5.58	.81
Granular:					
Mixed conifer	1.09	.89	4.29	5.18	.21
Aspen	.41	.47	4.45	4.92	.11

mal gradient in the freezing zone, or from snowmelt water. Bulk densities were taken on February 6, 1963, when the north-facing grassland had 4.25 inches of concrete frost, and the mixed conifer and aspen had 0.5- and 0.25-inch concrete frost in the litter, respectively. Bulk densities were taken again on May 13, 1963, with neither frost in the soil nor snow on the ground. Densities for these two periods for three cover types and soil depths are shown in table 3.

Bulk density for the 0- to 1.5-inch depth in the north-facing grassland under concrete frost is shown to be lower than under non-frozen conditions, while there are only minor differences at lower depths. This difference—which was computed to be 23 percent in the 0- to 1.5-inch depth and 6 percent in the 3- to 4.5-inch depth—is attributed to increase in soil moisture and expansion as a result of concrete freezing in the north-facing grassland.

Bulk densities in the mixed-conifer area for depths of 0 to 1.5 and 3 to 4.5 inches appeared to be higher when the litter contained ice layers. This may indicate movement of moisture from the soil to the freezing litter layer, which would cause drying and shrinking, and consequently increase bulk density.

Table 3.--Relationship of soil bulk density to soil freezing during two periods, 1963

Depth of sample and date taken	North-facing grassland		Mixed conifer		Aspen	
	Bulk density	Frost depth	Bulk density	Frost depth	Bulk density	Frost depth
		Inches		Inches		Inches
0 to 1.5 inches:						
February 6	0.93	4.5	1.33	0.5	1.31	0.25
May 13	1.43	0	1.13	0	1.47	0
3 to 4.5 inches:						
February 6	1.33	4.5	1.52	0	1.41	0
May 13	1.52	0	1.32	0	1.55	0
5 to 6.5 inches:						
February 6	1.46	0	1.45	0	1.49	0
May 13	1.56	0	1.40	0	1.55	0

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OREST SERVICE
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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

The 24-inch Branch as a Sample Unit for Egg Mass Surveys of the Western Budworm

M. E. McKnight[1]

Estimates of the density of western budworm (Choristoneura occidentalis Freeman) egg masses on needles of Douglas-fir are not different on a 24-inch branch sample and the conventional half-branch sample. The smaller 24-inch branch sample is gathered by a small field crew using a pole pruner. The foliage can be gathered in one-third the time and examined in the laboratory in half the time required for half-branch samples.

The techniques currently used in the Central and Southern Rocky Mountain Regions to predict population trends of the western budworm (Choristoneura occidentalis Freeman) are essentially those recommended by Carolin and Coulter.[2] Predictions are based on year-to-year changes in the density of new egg masses on half-branch samples collected from the midcrowns of the host trees, usually Douglas-fir (Pseudotsuga spp.). About 10,000 square inches of foliage consisting of two samples from each of five trees are examined on each plot. A smaller sample is needed because examination of the foliage in the laboratory is time consuming and consequently expensive.

Densities of new egg masses, foliage areas, examination times, and collection times were compared on 24-inch branch samples and half-branch samples taken from five plots in 1963 and 1964. The 24-inch branch sample was defined as all of the foliage on both sides of the terminal 24 inches of the main stem of the branch. The half-branch sample was defined as all of the foliage on one side of the the main stem of the branch.

The average densities of new egg masses on the 24-inch branches and half branches were not significantly different, 0.650 and 0.736 per 100 square inches, respectively.

The average half branch contained more than twice as much foliage area as did the average 24-inch branch, and examination times were correspondingly twice as long, 26.8 minutes per half branch and 13.0 minutes per 24-inch branch. A two-man crew using a pole pruner collected ten 24-inch branch samples per man-hour; a three-man crew collected 3.3 half-branch samples per man-hour by climbing trees to mid-crown.

Because the preliminary sampling in 1963 and 1964 indicated that the 24-inch branch

[1]*Entomologist, located at Bottineau in cooperation with the North Dakota School of Forestry; central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

[2]*Carolin, V.M., and Coulter, W.K. Research findings relative to the biological evaluation of spruce budworm infestations in Oregon. U. S. Forest Serv., Pacific Northwest Forest and Range Exp. Sta., Portland, Oreg. 39 pp. 1959.*

sample was at least as satisfactory as the half-branch sample, the Forest Pest Control Branch, Rocky Mountain Region, U. S. Forest Service, agreed to test it on an operational basis in 1965 and 1966. Forty-one survey plots on five National Forests were sampled with equal numbers (10) of 24-inch branches and half branches.

The data were analyzed in two ways. In the first analysis, the data for 1965 and 1966 were analyzed on the assumption that all budworm populations on the same National Forest can be regarded as the same population, which may not be true. A "t" test indicated that the overall mean densities of new egg masses on the 24-inch branch sample and the half-branch sample were not significantly different.

A second analysis was performed using only the data for 1965 from the San Juan National Forest and the data for 1965 and 1966 from the San Isabel National Forest. The "t" tests indicated that mean densities of new egg masses on 24-inch and half-branch samples were significantly different only in 1965 on the San Juan National Forest; 24-inch branch samples showed significantly higher egg mass densities.

The components of variance associated with plots, trees, and branches were segregated. The component of variance associated with plots was large because densities sampled ranged from very low to high. It averaged about 2.5 times larger when plots were sampled with half branches than when they were sampled with 24-inch branches.

The variance component associated with branches averaged about the same for 24-inch branches as for half branches. It was 1/6 to 1/20 the magnitude of the variance component for plots.

The variance component associated with trees was low because the trees were not sampled at random. In fact, the field crews probably were consistent in choosing similar trees having similar densities of budworm egg masses. The variance component for trees was about half as large as the variance component for branches.

These data show that 24-inch branches can be used instead of half-branches to show year-to-year changes in the density of new egg masses of the western budworm on Douglas-fir trees. As many plots as possible should be sampled when population densities are highly variable from plot to plot. If field crews continue to select similar trees, no more than five trees need be sampled per plot; one-tree plots might be feasible. At least two samples should be taken from each tree.

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Relationship of Different Forest Floor Layers to Herbage Production

Warren P. Clary, Peter F. Ffolliott, and Donald A. Jameson[1]

Herbage production decreases as individual layers and total depth of ponderosa pine forest floor increases. The H layer or total depth of the forest floor accounts for more variation in herbage production than the L or F layers. Management practices which remove only the L and F layers of the forest floor cannot be expected to increase herbage production appreciably.

The forest floor, or the accumulation of organic matter above mineral soil, is important in land management because of its effect on such factors as fire danger, water retention, and herbage production. Normally only the total forest floor has been considered and it has not been determined what influence different individual forest floor layers may have. Three forest floor layers are distinguished: an **L** or litter layer, consisting of unaltered organic matter; an **F** or duff layer, consisting of partly decomposed organic matter; and the **H** or humus layer, consisting for the most part of well decomposed organic matter (Kittredge 1948).

Previous work led us to expect that herbage production would decrease as the total amount of forest floor increased (Wahlenberg et al. 1939, Gaines et al. 1954, Pase 1958, Jameson 1966). To allow more precision in land management prescriptions, however, the study reported here was designed to investigate the relationships between herbage production and the individual layers of a ponderosa pine (Pinus ponderosa Lawson) forest floor.

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Study Area

The study was conducted on the Beaver Creek watershed (Worley 1965) in north-central Arizona. Ponderosa pine comprises over 85 percent of the tree cover on the study area, with Gambel oak (Quercus gambelii Nutt.) and alligator juniper (Juniperus deppeana Steud.) occurring as intermingled species. Annual precipitation averages 23 inches within this zone. Soils are developed from basalt and volcanic cinders, with surface textures ranging from clay loam to loam.

Important grasses and grasslike plants include blue grama (Bouteloua gracilis (H.B.K.) Lag.), bottlebrush squirreltail (Sitanion hystrix (Nutt.) J. G. Smith), mutton bluegrass (Poa fendleriana (Steud.) Vasey), and sedges (Carex spp.). Principal half-shrubs and forbs are broom snakeweed (Gutierrezia sarothrae (Pursh) Britt. & Rusby), showy goldeneye (Viguiera multiflora (Nutt.) Blake), showy aster (Aster commutatus (Torr. & Gray) Gray), spreading fleabane (Erigeron divergens Torr. & Gray), and western ragweed (Ambrosia psilostachya DC.).

Methods

Ponderosa pine forest floor depths, by individual layers and total, were measured at 228 permanently located timber inventory sample plots. Four measurements were taken within 2 feet of each plot center, one in each "quadrant." These measurements were obtained without compressing the layers. Material from herbaceous plants was not considered part of the forest floor. An average of the four measurements, recorded to the nearest 0.1 inch, was assumed to be representative of forest floor depth, by layers and total, at each of the sample plots.

Herbage production by species was determined by the weight-estimate method (Pechanec and Pickford 1937). A 9.6-square-foot circular plot was centered at each sample plot to measure herbage production.

Herbage production was transformed to logarithms on the basis of preliminary examination and the study data subjected to regression analysis.

Results and Discussion

Herbage production decreased from over 300 to less than 10 pounds per acre as total forest floor accumulations increased from essentially zero depth to over 2.5 inches. This general trend was similar to that found in previous studies.

Sample plots with zero depths of forest floor do not represent nontimbered conditions. There were areas with no measurable accumulation of forest floor throughout the timber stand as a result of uneven stocking. These areas were still influenced by the timber overstory, however, because similar areas with all timber overstory removed produced two to five times more herbage than the areas included in this study (Clary et al. 1966).

Herbage production also decreased as individual layers of forest floor increased. Equations empirically describing relationships between the depth of forest floor in inches (individual layers and total) and logarithm of herbage production in pounds per acre are summarized below:

1. $\text{Log } Y = 2.3691 - 2.0321 X_L \quad r = 0.42$
2. $\text{Log } Y = 2.4164 - 2.3712 X_F \quad r = 0.44$
3. $\text{Log } Y = 2.3396 - 1.7655 X_H \quad r = 0.61$
4. $\text{Log } Y = 2.6001 - 0.8888 X_T \quad r = 0.58$

Correlations between the **L** or **F** layers and herbage production were significantly smaller (at the 1 percent level) than correlations between the **H** layer or total depth and herbage production. Therefore, a smaller amount of the variation in herbage production, as indicated by r^2, can be accounted for by the **L** and **F** layers than by the **H** layer or total depth. Correlations between the **L** or **F** layer and herbage production were not different; neither were correlations between the **H** layer or total depth of the forest floor and herbage production.

Significant correlation coefficients do not necessarily mean that a cause-and-effect relationship exists. For management recommendations, however, it is of interest that the **H** layer provided a significantly better correlation with herbage production than did either of the upper two layers. This indicates that management practices, such as prescribed burning, that remove only the upper layers of forest floor should not be expected to increase herbage production appreciably (fig. 1).

A, Entire forest floor originally consumed by fire.

B, Only upper forest floor layers originally consumed by fire.

Figure 1.--Herbage production observed 4 years after a prescribed burn in ponderosa pine (Davis et al. 1968).

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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Observations of Snowpack Accumulation, Melt, and Runoff on a Small Arizona Watershed

Peter F. Ffolliott and Edward A. Hansen[1]

Intensive measurements of snow and streamflow on a 425-acre ponderosa pine watershed indicated that more than 90 percent of the snowpack left the watershed as runoff. Snow accumulation was inversely related to forest density, which indicates a possible opportunity for increasing snow accumulation through more intensive forest management.

A large portion of the runoff from the Beaver Creek watershed (Worley 1965) in north-central Arizona, comes as snowmelt. More than 99 percent of the 4-inch annual water yield from the ponderosa pine type comes off during the period of November 15 to April 15, much of it originating from snow.

Description of the Investigation

The exploratory work discussed here was designed to: (1) determine how peak snowpack accumulation is affected by differences in timber stocking, elevation, and insolation, (2) describe the resulting snowmelt trends, and (3) determine what portion of the peak snowpack contributes to snowmelt runoff. The results will help form guidelines for developing land treatments in the ponderosa pine type on Beaver Creek. Subsequent evaluation studies are being carried out on the Beaver Creek pilot watersheds to provide more comprehensive information on actual treatment effects. Only 1 year's data are used in the investigation, and interpretations must be made within this limitation.

Study Area

The work was conducted on a 425-acre watershed during the late winter of 1965-66. Ponderosa pine (Pinus ponderosa Laws.) comprises over 70 percent of the timber stocking, with Gambel oak (Quercus gambelii Nutt.) and alligator juniper (Juniperus deppeana Steud.) intermingling species. Timber was last cut in a period from 1943 to 1950, when one-half of the estimated merchantable sawtimber was removed. Current sawtimber volume averages 3,700 board feet per acre. Site index (Meyer 1938) varies from 45 to 60 feet.

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Soils, derived from volcanics, principally basalt with an intermixing of cinders, are classified into the Brolliar and Siesta-Sponseller soil management areas (Williams and Anderson 1967). The elevation ranges from 6,800 to 7,300 feet. Few slopes exceed 15 percent, and the general aspect is southwest. Annual precipitation averages 24 inches, half of which comes during the November 15 to April 15 period. The peak snowpack water content prior to the start of snowmelt runoff averaged 3.36 inches.

Methods

Total snow depth and water equivalent (WE) were measured with a snow tube and scale at 197 permanently located sample points on five sampling dates throughout the snowmelt runoff period.[2] Two measurements were taken within 1 foot of each sample point and averaged. Sample points corresponded to timber inventory plots, and were located in a systematic sample design with four random starts (Shiue 1960). The points were spaced at 3-chain (198 ft.) intervals along sample lines running perpendicular to the major drainage.

Initial measurements were made on March 4, 1966, the time of late winter peak snowpack accumulation, just prior to the start of runoff. Subsequent measurements were made throughout the runoff period on March 10, 13, 16, and 20.

Data necessary to develop timber stocking and insolation variables were obtained from timber inventory data. Two measurements of timber stocking were developed by point sampling techniques. The number of trees tallied with an angle gage corresponding to a basal area factor of 25 was determined at each sample point. This measurement is an index of the amount of crown closure over sample points.[3] Trees were also tallied using additional basal area factors of 5, 10, 50, 75, 100, 125, 150, 175, 200, and 250 to determine how close they were to sample points. The smaller the basal area factor, the larger the plot radius factor, and, consequently, the greater is the distance the tree can be from the sample point. Trees tallied exclusively with small basal area factors are farther from sample points than trees tallied with additional larger basal area factors.

Potential insolation in Langleys (gram calories/cm^2) received on an index date (January 23) selected to represent the accumulation period was obtained from slope and aspect measurements (Frank and Lee 1966). The elevation of each sample point was estimated from a 7½-minute U. S. Geological Survey topographic map with 20-foot contour interval.

Measurements of surface runoff were obtained from a gaging station (fig. 1). Discharge volumes, expressed in area inches, were computed from a water stage-discharge relationship.

Figure 1.--Stream gaging station on the study area.

[2] The snowmelt runoff period, as defined in this study, began with the general melting of the late winter peak snowpack and ended when diurnal fluctuations in surface runoff, as measured by a hydrograph, ceased.

[3] An unpublished study conducted on Beaver Creek showed percent of overhead crown closure measured from canopy photographs (Brown 1962) to be highly correlated with basal area estimated by point sampling with a basal area factor of 25.

Results and Discussion

Effect of timber stocking, elevation, and insolation on peak snowpack accumulation

Timber stocking, elevation, and insolation variables were included in a linear regression analysis to determine their combined effect on peak snowpack accumulation, which is expressed as percent of the maximum peak accumulation measured on the study area, 8.0 inches of WE. This adjustment was made to obtain a base for estimating WE on each sample point independent of the annual precipitation. The resulting regression, which accounts for 46 percent of the variation in peak snowpack accumulation, is

$$Y = -372.15 - 3.769X_1 - 0.082X_2 + 0.068X_3 - 0.080X_4$$

where

Y = percent of maximum WE on the study area

X_1 = number of trees tallied with a basal area factor of 25 at sample point

X_2 = largest basal area factor (5, 10, 25, 50, 75, 100, 125 150, 175, 200, or 250) used at sample point

X_3 = elevation at sample point

X_4 = potential insolation (Langleys) received at sample point during solar day (January 23)

This regression, while based on only 1 year of data and on a single study area, suggests possibilities of empirically identifying comparative hydrologic potentials (Anderson 1966) of different strata on a watershed.

A greater water content was measured in sparsely stocked than in dense timber stands, which is consistent with studies made elsewhere.[4] The WE of the snowpack increased from less than 1 to over 7 inches as timber stocking levels decreased from 250 to less than 25 square feet of basal area per acre. This general relationship held on all aspects and elevations. Statistical differences in WE under stands of similar stocking levels but different size class compositions could not be demonstrated, possibly due to the frequent intermingling of size classes.

A greater water content was also measured at sample points located away from trees than near trees. An average WE of over 4 inches was measured at sample points where trees were tallied exclusively with a basal area factor of 10. Conversely, less than 2 inches WE was measured at sample points where trees were tallied with a basal area factor of 250.

It is not known whether the smaller amounts of snow under dense stands or near trees represented a loss to the watershed in terms of potential runoff. Casual observations prior to the snowmelt runoff period indicated some snow was blown from tree canopies into small openings in the stand, which possibly resulted in a redistribution of the snowpack (Hoover 1960).

Greater amounts of snow accumulated at higher than lower elevations, which indicates more precipitation and lower temperatures at higher elevations. This pattern has been reported by others (Packer 1962, Anderson and West 1965). WE increased linearly from less than 2 to over 6 inches with an increase in elevation from 6,800 to 7,300 feet. There was no apparent relationship between elevation and timber stocking.

Snowpack accumulations were greater on "cool" than "warm" sites. The relationship was weak, however, due to the relatively limited range in insolation values. There was little representation of northerly or easterly aspects, or slopes over 15 percent. Furthermore, there appeared to be little relationship between insolation and other variables.

Snowmelt Trends

Snowmelt rates were relatively uniform on the study area during the snowmelt period. The variability in melt rates was not significantly related to the variables tested as to their effect on peak accumulation. Much of the variability may have been the result of insufficient sampling at the sample points.

Melt rates can only be determined from sample points where snow was measured on successive sampling dates, which resulted in fewer sample points as the snowmelt period progressed. Daily water loss from the snow-

[4] *Haupt 1951, Goodell 1952, Kittredge 1953, Anderson 1956, Weitzman and Bay 1959, Packer 1962.*

pack averaged 0.75 inch for the period of March 13 to 16. Daily snowpack water loss for the entire snowmelt period averaged about 0.45 inch. The latter average is less because the early cool portion of the period is included, when snow at almost all sample points was either melting slowly or still ripening. Late-period melt rates were higher, but few sample points contained snow.

The weather during the snowmelt period remained consistently clear, with a gradual warming trend (fig. 2).

Snowmelt-Runoff Relationships

The snowmelt-runoff period involved in this study had been preceded by an unusually wet winter, and it can be safely assumed that the soil mantle was thoroughly saturated. Winter precipitation had been approximately 17 inches (about half rain and half snow), and 7 inches of runoff had already been produced, most of it from rainstorms in November and December. Streamflow at the start of the melt period was at a low level, 0.02 inch per day, and dropped to this same level at the end of the period. These amounts of flow were considered insignificant and were omitted in the analysis.

Essentially, the snowmelt runoff period lasted from March 4 to March 20. The first significant runoff above "base flow" was on March 5, the day following the first snowpack measurements.

Snowpack ablation and runoff were computed for the study period (fig. 3). Daily runoff values were accumulated from the date of initial snowpack measurements, and compared with the corresponding reduction in snowpack. No corrections for intermittent precipitation were necessary. The shape of the cumulative snowpack water loss curve between sampling dates was inferred from the runoff curve.

Almost all snow appeared to leave the watershed as runoff. The mean WE of the snowpack at the start of melt was 3.36 inches. There was 0.05 inch residual water in the snowpack on March 20, indicating that 3.31 inches had been depleted by melt or evaporation. During the same period, 3.08 inches of runoff were measured at the gaging station, which represented 93 percent of the snowpack.

There appeared to be a close relationship between snowmelt and runoff during most of the runoff period, indicating melt water left the watershed immediately as measured runoff. The divergence of the curves later in the period, however, (fig. 3), suggests water loss to factors other than streamflow. Even so, melt water that did not produce runoff averaged less than 0.02 inch per day during the second half of the runoff period. Since antecedent moisture was not measured, it is not

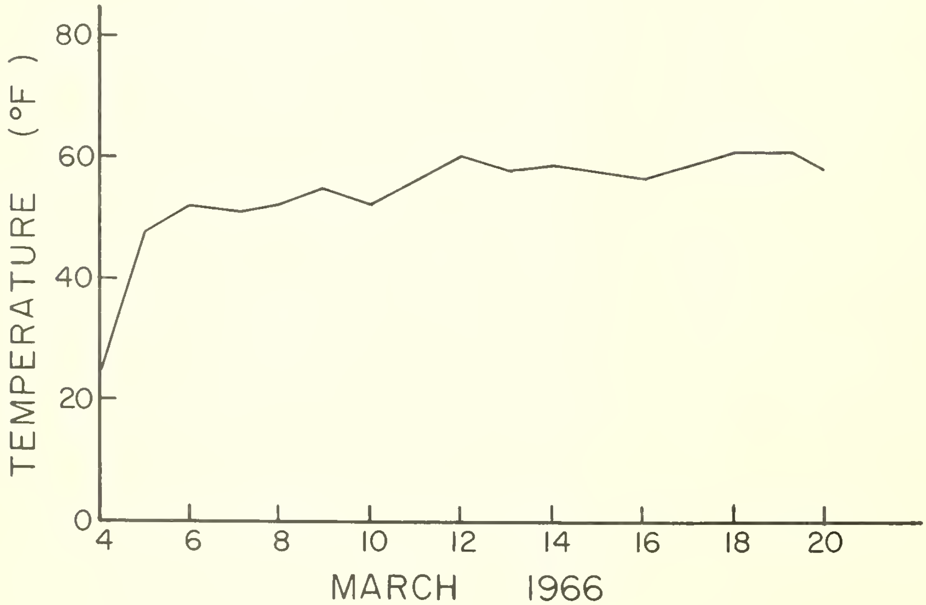
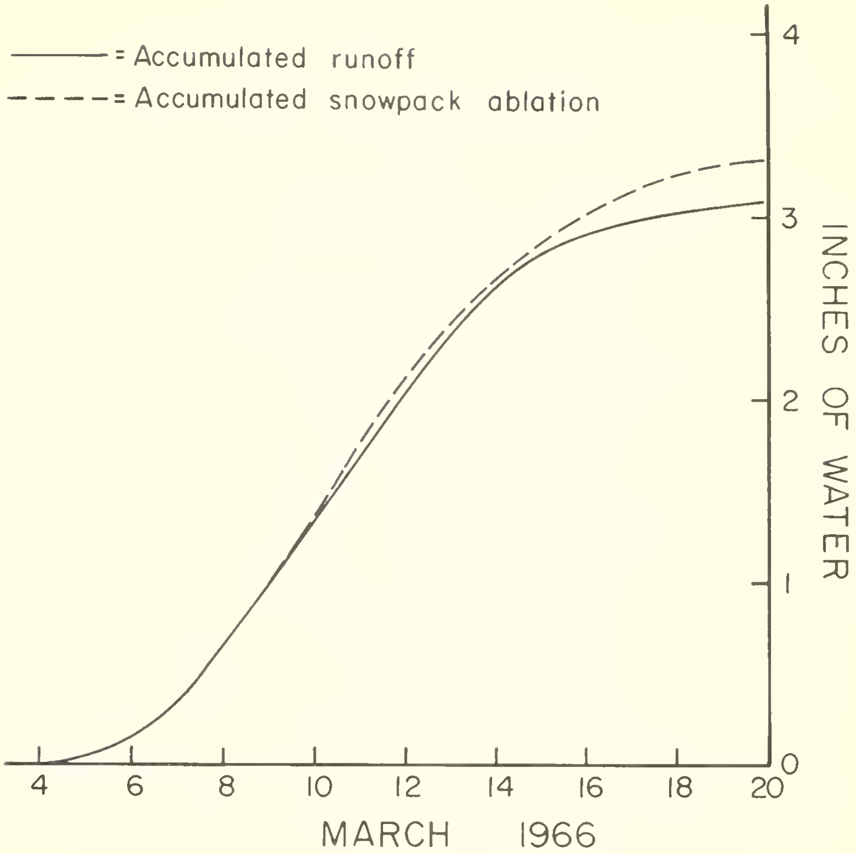


Figure 2.--Maximum daily temperature during the study period.



Fiugre 3.--Accumulated snowpeak ablation and runoff for the study period.

known whether this high correlation between snowpack ablation and runoff is typical.

Areal snowpack depletion, expressed as a percentage of the total number of sample points with snow on different sampling dates, decreased at almost a constant rate throughout the study period. In contrast, snowpack ablation was more rapid during the middle of the period (fig. 4). Snow started to disappear immediately after the first snowpack measurements, and remained on less than 7 percent of the area on March 20, in isolated drifts leeward of dense timber.

Fifty percent of the accumulated runoff occurred by March 11, the date of peak daily discharge (fig. 4). Approximately one-half of the snowpack WE was ablated and 42 percent of the area was bare of snow at this time. The residual snowpack on the date of peak daily discharge was greater than previously reported in central Colorado (Brown and Dunford 1956).

Conclusions

The high percentage of snowmelt measured as runoff on the study area suggests that additions to the peak snowpack may produce nearly corresponding increases in streamflow. Reductions in timber stocking, the only variable related to peak snowpack accumulation that can be manipulated, may result in more snow on the ground. Runoff might be further increased by shortening the end of the snowmelt runoff period. The larger-than-average losses that occur at that time might be reduced. Such losses are very small compared to the total volume of runoff, however, and partial elimination of them would not have much impact on total water yield. The results of this study did not suggest any possibility for increasing snowmelt rates. Therefore the most promising possibility for increasing streamflow runoff during the snowmelt period may be to increase peak snowpack accumulation. This might be accomplished by reducing forest density through more intensive management practices such as thinning or creating openings in the forest canopy.

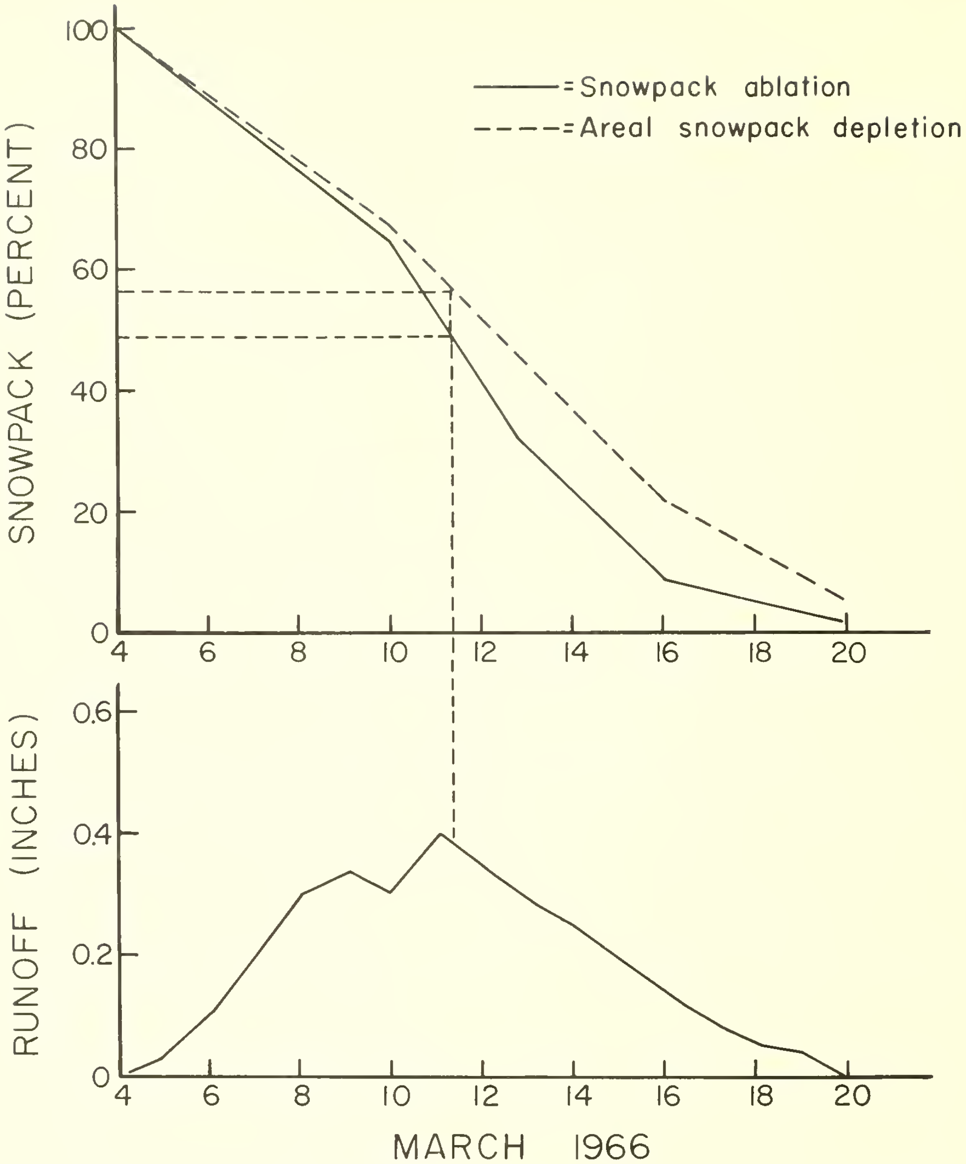


Figure 4.--Snowpack ablation and aereal depletion, and mean daily discharge for the study period.

This exploratory investigation was conducted to develop information on how peak snowpack accumulation is affected by timber stocking, elevation, and insolation, describe the resulting snowmelt, and determine what portion of the peak snowpack contributes to snowmelt runoff. Its purpose was to provide guidelines for developing land treatments to be tested on the Beaver Creek pilot watersheds. It is emphasized that the results of this investigation must be limited to the type of weather conditions encountered during the study year and the specific watershed studied.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Douglas-fir Beetle Brood Densities and Infestation Trends on a New Mexico Study Area

John F. Chansler[1]

The density of callow adult beetles before flight is a good indicator of the trend an infestation will take. It should be possible to devise a systematic sampling system to determine adult numbers that would enable the entomologist to predict infestation trends quite accurately.

During the past 10 years, the Douglas-fir beetle, Dendroctonus pseudotsugae Hopkins, has killed many thousands of Douglar-fir trees, Pseudotsuga menziesii (Mirb.) Franco, in Arizona and New Mexico. Some of the outbreaks have been so severe that timber management plans were adversely affected (fig. 1). A study was started in 1959 to determine the relationship between preemergence brood density in standing infested trees and the number of trees attacked during subsequent flight as a possible basis for predicting the course of outbreaks. The study was made in a 2-year-old infestation on the Sante Fe National Forest in north-central New Mexico. The study area lay on a north slope between 7,800 and 9,200 feet elevation, and included about 2,500 acres of heavily stocked virgin mixed conifer forest. The brood density and number of trees killed in the area were determined each year until the outbreak collapsed in 1965.

Methods

Brood densities were sampled in May in 25 infested trees selected from 6 to 10 groups scattered throughout the study area. Six-inch-square bark sections were taken from both the north and south sides of each sample tree at heights of 5 and 10 feet (fig. 2). Numbers of living and dead bark beetles were recorded by life stage. Diameter at breast height, attacks (entrance holes), inches of egg gallery, and parasite numbers were recorded for each sample tree to help interpret the brood density data.

The study area was aerially surveyed each June or July to determine annual increase or decrease in tree kill. The surveys were made by two observers flying at 400 to 600 feet above the forest canopy.

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Figure 1.--A severe Douglas-fir beetle infestation such as this can disrupt timber management plans.

Figure 2.--Method of sampling trees at the 10-foot level.

Results

Diameters of Sampled Trees

Diameters of the 142 trees sampled ranged between 10 and 29 inches at breast height. The 25-tree means ranged between 16.0 and 19.2 inches. Diameter of the sampled trees was not significantly correlated with attack density, egg gallery density, or brood density at the heights sampled.

Brood density

Brood density was high in 1959 and 1960, but declined thereafter (table 1). The high proportion of larvae to callow adults in 1961 and 1962 suggests that the downward trend of infestation in these years was associated with slow brood development. Furniss[2] found that a long-term infestation of D. pseudotsugae in southern Utah subsided because of slow brood development. Apparently the beetles which were larvae in late May failed to emerge in June at the time of the main flight. Only live adults were used, therefore, to associate preflight beetle densities with subsequent tree killing.

Live adult density varied greatly between trees during any one year. The variance was greater than the mean number of live adults in all but the 1960 and 1961 samples collected at 10 feet. Variance between trees was generally greater at 5 feet than at 10 feet. The differences in mean live adult densities between heights were significant in 1960, 1962, and 1964. This finding points out the importance of sampling at consistent heights above the ground.

[2]*Furniss, M. M. An instance of delayed emergence of the Douglas-fir beetle and its effect on an infestation in southern Utah. J. Econ. Entomol. 58: 440-442. 1965.*

Table 1.--Mean number of living Douglas-fir beetles per square foot of bark at 5 and 10 feet above the ground, Holy Ghost Canyon, Santa Fe National Forest, New Mexico

Year sampled	Larvae		Adults		Trees attacked upon emergence
	5 feet aboveground	10 feet aboveground	5 feet aboveground	10 feet aboveground	
	Number				
1958	--	--	--	--	[1]150
1959	--	0	--	39.5	205
1960	1.6	1.1	29.8 ± 7.6	60.4 ± 7.6	311
1961	2.6	6.4	12.8 ± 4.4	24.7 ± 3.0	129
1962	4.9	11.1	.6 ± .1	7.7 ± 2.8	27
[2]1963	.5	.6	13.8 ± 4.3	29.9 ± 8.0	36
1964	3.4	2.8	14.2 ± 4.5	17.6 ± 5.0	18

[1]Based on ground observations.
[2]Based on 17 sampled trees.

Despite the variation between trees, the mean number of live adults just prior to flight appears to be correlated with the number of trees attacked during the flight and subsequently killed. Table 1 shows that tree killing increased from the previous year when preemergence adult numbers at 10 feet were greater than 30 per square foot, but decreased when the average number was less than 25. Adult densities at 5 feet were not as well correlated with changes in the number of trees attacked and killed.

Attack, Egg Gallery, and Parasite Densities

The means for both inches of egg gallery and average number of attacks were consistently higher (significantly so in many cases) and their variances lower at 10 feet than at 5 feet (table 2). Numbers of entomophagous insects (mainly Coelodes brunneri Vier.) were extremely variable at both heights, but were consistently higher at 10 feet above the ground. On the basis of these data, neither attack density, inches of egg gallery, nor parasite densities appears to be an indicator of infestation trend.

Table 2.--Mean numbers of Douglas-fir beetle attacks, inches of egg gallery, and entomophagous insects per square foot of bark at 5 and 10 feet above the ground, Holy Ghost Canyon, Santa Fe National Forest, New Mexico

Year sampled	Attacks		Egg gallery		Entomophagous insects	
	5 feet aboveground	10 feet aboveground	5 feet aboveground	10 feet aboveground	5 feet aboveground	10 feet aboveground
	Number		Inches		Number	
1959	--	--	--	--	--	--
1960	7.5	7.7	34	42	0.8	5.6
1961	6.6	11.4	39	51	2.4	8.4
1962	5.8	7.5	20	38	0.3	6.2
1963	6.5	7.6	24	39	2.0	5.2
1964	5.8	6.7	28	40	2.2	2.7

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Composting Ponderosa Pine Bark--
Effects of Nitrogen Addition and Aeration

Vern P. Yerkes and Donald C. Markstrom[1]

Composting of ponderosa pine bark for 9 weeks resulted in a product with a disappearing bark structure, a darkened color, and an "earthy" odor. The addition of nitrogen and aeration speeded up the composting process.

Bark is a major component of the waste products developed by sawmills in the production of lumber. For example, it has been estimated that sawmills in the Black Hills of South Dakota and Wyoming that are sawing 20 to 60 MBF per day produce between 6 and 18 tons of ponderosa pine bark per day (Landt and Woodfin 1964). The potential annual production of bark for the area is estimated to be in excess of 20,000 tons. Currently, this material is disposed of by burning. This is not only a costly practice but public reaction to the accompanying air pollution is becoming increasingly unfavorable.

As a soil amendment, composted bark could increase soil friability, improve water infiltration and percolation characteristics, and ameliorate the physical condition of soils which have high clay contents. If additions of processed bark can be shown to be beneficial or at least not detrimental, the practice could prove of considerable value to the industry in many areas as a means of disposal. The economics of the processing was not determined in this study.

A few firms already are producing composted bark (Field 1958), and are marketing it to special markets or to local farmers.

The principles and economics of composting in other areas have been reported by others.[2] Probably the most important requirement, when making a soil additive from bark, is to reduce the carbon:nitrogen ratio to prevent depletion of soil nitrogen. This study was designed to determine whether composting of ponderosa pine bark requires either added nitrogen, aeration, or both.

Methods

The bark was collected at the Homestake Mining Company Sawmill at Spearfish, South Dakota. It was removed with a ring debarker

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[2]*Allison 1965, Bollen and Glennie 1961, Bollerslev 1968, Davey 1953, Field 1958, Jann et al. 1960, Lyon et al. 1952, Rao and Block 1963, Wilde 1958.*

Figure 1.--The bark was aerated by shoveling it out of and back into the wooden composting bins.

from logs that had been floated through a log pond. It was then ground with a farm-type hammermill with a 3/4-inch screen. This resulted in the following particle-size distribution, as measured by the amount retained on sieves with the indicated openings:

Sieve opening (Inches)	Bark retained (Percent)
0.500	6
0.263	21
0.065	42
0.039	13
Fines	18
Total	100

Bark was nitrogenated by mixing 312 pounds of liquid urea, (32 percent available nitrogen) with 387 cubic feet of bark in a livestock feed mixer.

The bark was composted for a period of 6 months in eight polyethylene-lined wooden bins, 4 feet square and 6 feet tall. Each bin contained about 92 cubic feet of bark. Four of the eight bins contained nitrogenated bark. Half of the bins—two with nitrogen and two without nitrogen—were aerated once a week by shoveling the bark out of the bins onto sheets of plywood and then back into bins (fig. 1). The remaining four bins were not disturbed during the composting period except for taking moisture samples. These samples were extracted weekly with a modified soil sampling tube.

Temperature-sensing elements were buried in the center of each bin; temperatures were recorded every morning, noon, and late afternoon.

Six samples of bark, totaling around 7,000 grams, were collected randomly throughout each bin before composting, and another six from the center of the pile after composting. Five of each group of samples were each divided into four subsamples for determination of ash, carbon, and nitrogen contents and pH.

The bark samples were first milled to pass a 20-mesh screen. Then the ash content was analyzed by ASTM method D 1102-56; total carbon by a technique described by Steward, et al. (1964); nitrogen by the Kjeldahl method; and pH by an electrometric glass electrode in a 1-to-20 aqueous suspension of bark.

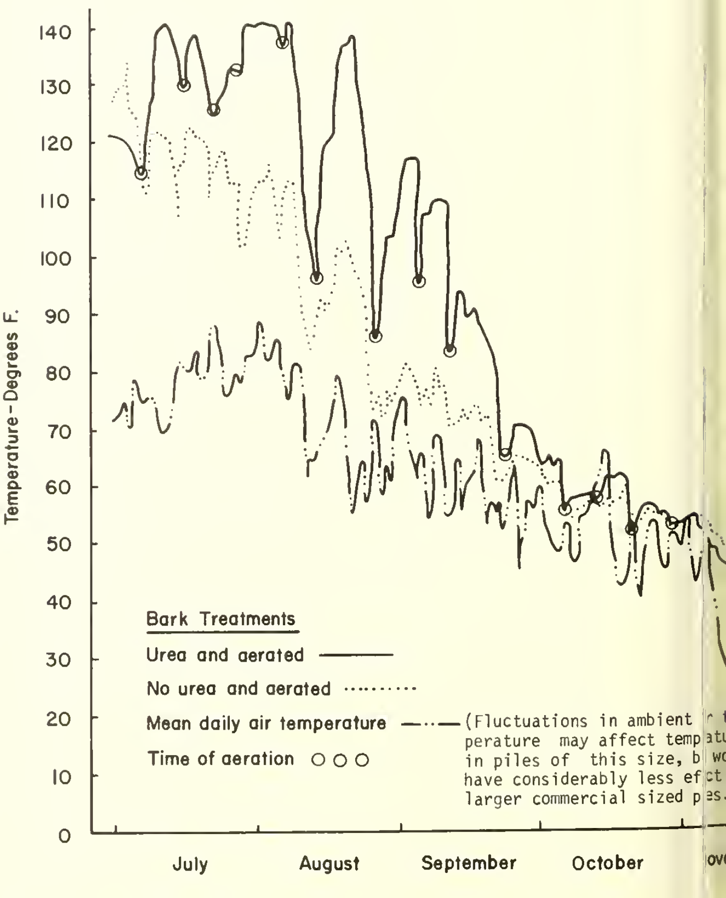
The data were subjected to a split-plot factorial statistical test to determine whether nitrogen addition and aeration significantly affected results.[3] Samples of bark taken before and after composting were also compared.

Results

As expected, the first indication of decomposition was high bark temperature (fig. 2). The aerated bark with urea added reached the highest temperature (140°+ F.). This temperature was recovered rapidly after each aeration. After the temperature of this bark began to drop, it took 4 weeks for it to drop to that of the bark without urea added.

The bark with urea added but not aerated maintained higher temperature (above 110° F.) for a longer period of time than any other bark. After September 1, the temperature of this bark dropped rapidly and was similar to the bark without urea added in about 5 weeks.

[3]Significance at 0.05 probability level used throughout this report.



The temperature of the aerated bark without urea began to drop after the first aeration. This temperature continued to drop steadily, and never completely recovered pre-aeration levels. The temperature of the bark without urea and not aerated was above 120° F. for about 5 weeks, then dropped rapidly until it matched that of both the aerated bark and ambient air temperature.

If we can assume that bark temperatures indicate the extent or rate of decomposition, the aerated bark with urea added was by far the most active. The urea-treated and non-aerated bark decomposed less rapidly but over a longer period of time, thus reaching nearly the same degree of decomposition as did the aerated bark with urea. Also the bark without urea added did not decompose as completely as the urea-treated bark.

The aerated bark with urea became darker after 2 weeks, the structure more obscure after 4 weeks, and the odor "earthy" after 9 weeks. A strong ammonia odor was sensed when this bark was aerated during the first 9 weeks. The color, structure, and odor of both the non-aerated and the aerated bark treated with urea were similar after the 5-month composting period. The bark without urea never lost its original color, structure, or odor.

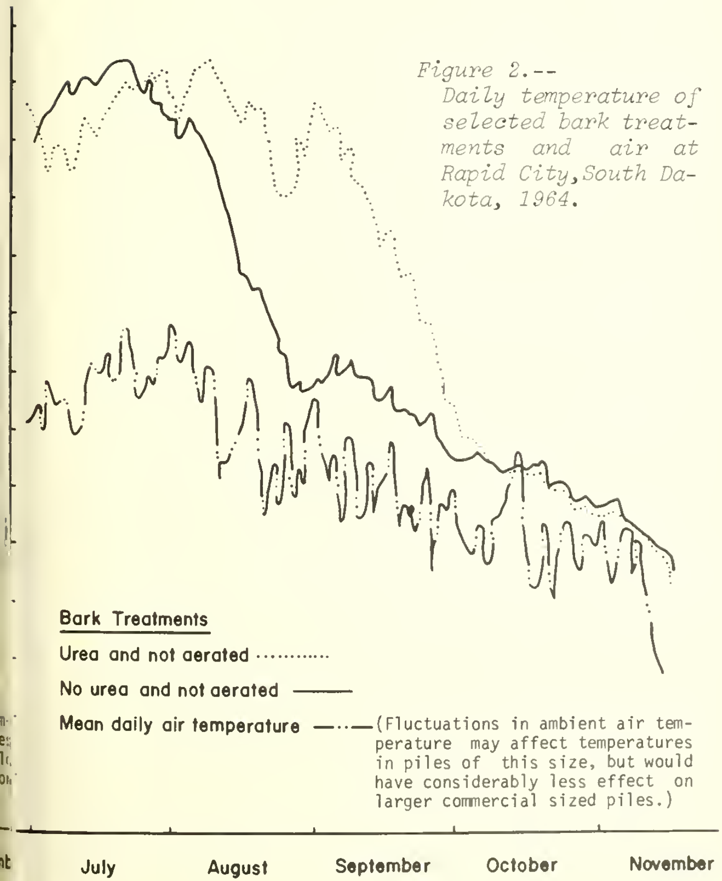


Figure 2.--Daily temperature of selected bark treatments and air at Rapid City, South Dakota, 1964.

Average percent nitrogen, carbon, and ash content, carbon-nitrogen ratio, and pH of the bark before composting, based on 20 observations, was as follows:

	Urea added	No urea added
Percent nitrogen	1.90	0.24
Percent carbon	46.61	48.99
Carbon-nitrogen ratio	25:1	200:1
Percent ash	8.39	5.44
pH	6.6	4.5

The only measured variable which changed significantly during composting was pH. The practical importance of this variable in measuring rate and/or extent of decomposition is questionable. This conclusion was reached because the pH of the bark not treated with urea increased more than that of the urea-treated bark. Overall changes were relatively small. The high pH of the urea-treated bark before composting was probably caused by urea hydrolyzing to highly basic ammonium carbonate (Lyon et al. 1952, p. 501). The role of pH as a measure of decomposition should be investigated further. All of the other variables—nitrogen, carbon, and ash contents— did not change significantly during composting.

Although the strong odor of ammonia from the urea-treated bark during aeration indicated some loss of nitrogen, no changes in relative amounts of carbon and nitrogen were detectable.

Before composting, the percent nitrogen content of the urea-treated bark was significantly higher and percent carbon content significantly lower than that of the bark without urea added. This is a result of the increased mass being made up entirely of nitrogen.

Conclusions

The addition of nitrogen speeds up the composting process. Nitrogen is also necessary to reduce the bark's carbon:nitrogen ratio and prevent depletion of soil nitrogen when applied. In this study the C:N ratio did not change throughout composting. If this holds true in practice, the desired C:N ratio of the final product could be established before composting.

Aeration was not found necessary for composting ponderosa pine bark. However, as indicated by the higher temperatures (fig. 2), the aerated bark decomposed faster than the nonaerated bark. Shortening processing time by aerating bark may be important for commercial operators. An economic analysis would be necessary to determine whether the additional benefits of shortening processing time per batch would justify the additional costs of aerating the bark.

Composting of ponderosa pine bark for 9 weeks resulted in a product with a disappearing bark structure, a darkened color, and an "earthy" odor similar to that of decomposed hardwood forest litter. The addition of 1.25 pounds of liquid urea containing 32 percent available nitrogen to 1 cubic foot of bark reduced the average carbon:nitrogen ratio from 200:1 to 24:1.

The most reliable practical indicators of the extent that the bark had decomposed were odor and color. The dark color and "earthy" odor of the bark with urea added are typical of composted materials. A continuous drop of bark temperature to that of ambient air indicates the completion of composting (Jann et al. 1960, Keller 1961). Therefore, temperature was considered a good indicator of the extent that the bark had decomposed. The pH did increase and may be a useful indicator. Because percent nitrogen, ash carbon, and carbon:nitrogen ratio did not change, they were unreliable indicators of the degree that the bark had decomposed.

The end of rapid decomposition for both the aerated and nonaerated bark with urea was indicated by the large drop in bark temperature during September. Bark temperatures dropped more rapidly than ambient air temperatures. This indicates that ambient air temperature itself was not the limiting factor in decomposition. Temperatures of all the bark after September paralleled ambient air temperatures and indicated little or no decomposition.

Further studies are planned to investigate bark composting requirements of Rocky Mountain species in more detail; to isolate more precisely, if possible, methods of determining the degree of decomposition; and also to see if composting is essential to produce a suitable soil additive.

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U.S.D.A. FOREST SERVI
RESEARCH NOTE RM-12

FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STA

Some Characteristics of the Forest Floor under Ponderosa Pine in Arizona

Peter F. Ffolliott, Warren P. Clary, and James R. Davis[1]

Timber basal area was the only stand or site variable tested that was significantly related to amounts of individual layers or total forest floor. Frequency distributions of forest floor depths were developed to be used as a management tool when critical ranges of depths affecting wildland products are defined.

The forest floor has an important influence on tree regeneration, herbage production, grazing patterns, and the hydrologic characteristics of a site. Also, it is an important forest fuel component. Forest floor is defined as the accumulation of dead organic plant matter above mineral soil. Three layers are distinguished: the **L** layer, consisting of unaltered organic matter; the **F** layer, consisting of partly decomposed matter; and the **H** layer, consisting of well decomposed matter. Only limited information has been available on the amounts and distributions of forest floor under southwestern forests.

The objectives of this study were to describe the depth and weight characteristics of ponderosa pine (Pinus ponderosa Laws.) forest floor, and to determine whether the amount of forest floor can be estimated from readily obtained stand and site variables.

[1]*Associate Silviculturist, Associate Range Scientist, and Associate Forest Fuels Specialist, respectively, located at Flagstaff in cooperation with Northern Arizona University; central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Ffolliott is currently Research Associate, Department of Watershed Management, University of Arizona, Tucson.*

Study Area

The study area was approximately 9,000 acres of selectively cutover ponderosa pine located on the Beaver Creek Watershed in north-central Arizona (Worley 1965). These stands are uneven-aged, with different age classes occurring as small even-aged groups. Gambel oak (Quercus gambelii Nutt.) and alligator juniper (Juniperus deppeana Steud.) occur as intermingling species, but were excluded from the sample.

Current timber volume averages 1,750 cubic feet and 4,000 board feet per acre. Site index ranges from 50 to 75 feet at 100 years (Meyer 1938). Timber was last harvested during a period from 1943 to 1950, when one-half of the merchantable volume of sawtimber was removed.

Annual precipitation averages 24 inches on the study area. Soils are developed from basalt and volcanic cinders, with surface textures ranging from clay loam to loam (Williams and Anderson 1967).

Methods

Depth of individual forest floor layers was measured at 1,042 permanent sample plots located on 10 small watersheds. Systematic sampling designs with multiple random starts were used (Shiue 1960). Depth was measured without compressing the layers, at four points within 2 feet of the plot center, one in each "quadrant." An average of the four depth measurements, recorded to the nearest 0.1 inch, was assumed representative of the forest floor at each sample plot.

The weight of individual forest floor layers was obtained from 1-square-foot samples taken in one "quadrant" at approximately every tenth plot; 113 samples were obtained. These samples were brought into the laboratory to determine ovendry weights. Corresponding depth measurements, taken at four sides of the 1-foot square samples, were also recorded.

Data necessary to develop the desired stand and site variables were obtained from timber inventory data taken at each sample plot. Basal area stocking conditions were determined by point sampling with an angle gage corresponding to a basal area factor of 25. Diameters of tallied trees were recorded to characterize size class distribution. Potential insolation in Langleys (gram-calorie/cm^2) was determined from slope - aspect measurements (Frank and Lee 1966). Soil management area designation, Brolliar or Siesta-Sponseller, was obtained from existing soil maps (Williams and Anderson 1967).

Results and Discussion

The individual forest floor layers were easily identified and separated. Means and standard errors of the means for depth, weight, and density are given in table 1.

Frequency distributions of forest floor depths under different timber size classes are illustrated in figure 1. When specific depths

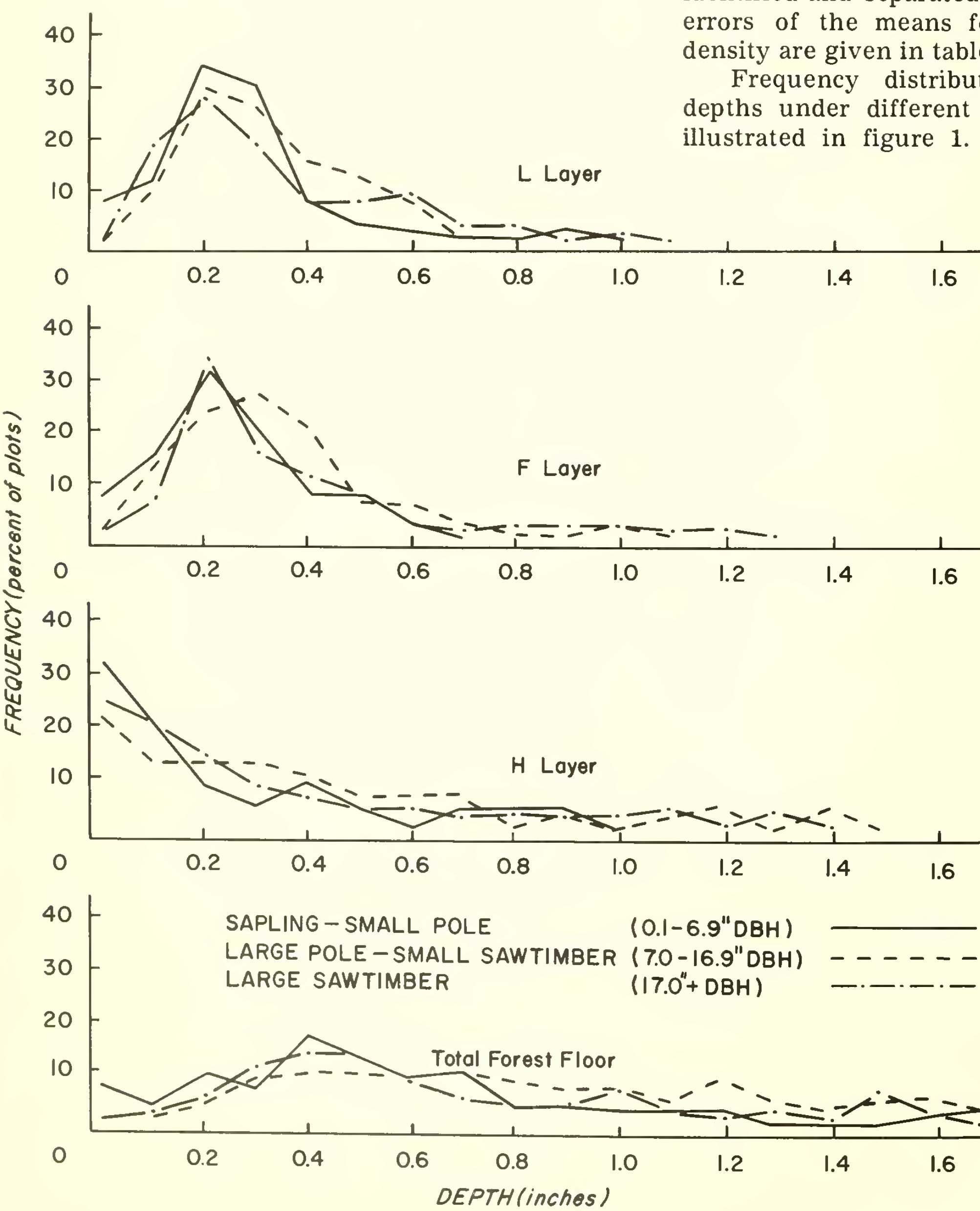


Figure 1.--Frequency dis[...] of forest floor depths [...] ferent timber size clas[...].

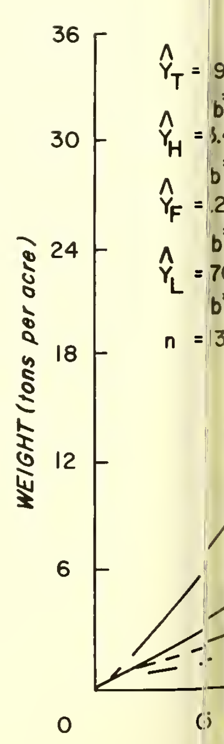


Table 1.--Means and standard deviation of the means for depth, weight, and density

Forest floor layers	Mean		Weight		Density	
	Mean	$S_{\bar{X}}$	Mean	$S_{\bar{X}}$	Mean	$S_{\bar{X}}$
	Inches		Tons per acre		Tons per acre-inch	
L layer	0.4	0.02	0.7	0.06	1.8	0.14
F layer	.4	.02	1.3	.11	3.3	0.27
H layer	.5	.04	7.3	.70	13.5	.80
Entire forest floor	1.3	.07	9.3	.77	6.0	.39

of forest floor are defined as affecting tree regeneration, grazing values, site hydrology, or forest fuels, these frequency distributions will provide estimates of the portion of Arizona ponderosa pine characterized by these critical amounts.

The relation of weights of forest floor layers to the corresponding depths are illustrated in figure 2. The model Y = bX, determined from the average of the ratios of weight and depth (Natrella 1963), was used to develop these relationships. The weight of the **H** layer per unit of depth far exceeds that of the **L** and **F** layers.

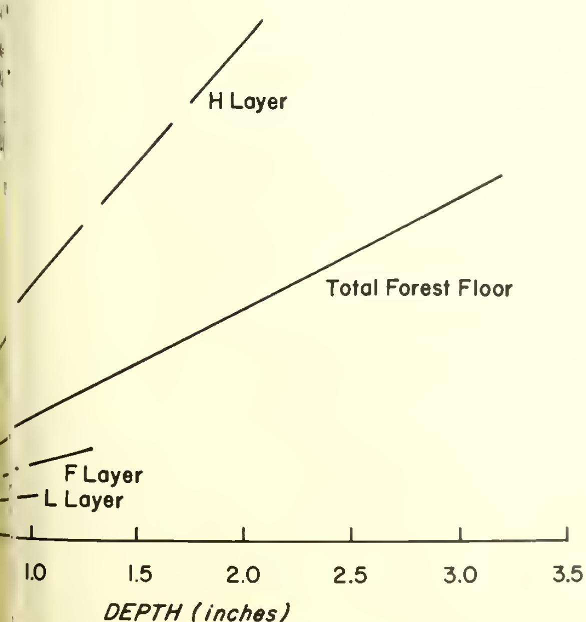
Theoretically, stand age, crown closure, temperature, and soils are among the factors that affect amounts of forest floor (Kittredge 1948, Lutz and Chandler 1951). Therefore, regression analyses were attempted to relate individual layer and total forest floor amounts to (1) stand age, indicated by size class distributions, (2) crown closure, estimated by basal area,[2] and (3) temperature, indicated by potential insolation. An analysis of variance was made to determine possible differences between soil management areas.

Timber basal area was the only tested stand or site variable that significantly predicted forest floor depth and weight. The prediction equations, when basal area is espressed in square feet per acre, are:

Forest floor depth (inches)	Forest floor weight (tons per acre)
$\hat{Y}_T = 0.528 + 0.0065X$, $r = 0.53$	$\hat{Y}_T = 2.026 + 0.0723X$, $r = 0.57$
$\hat{Y}_H = 0.096 + 0.0036X$, $r = 0.51$	$\hat{Y}_H = 1.570 + 0.0571X$, $r = 0.49$
$\hat{Y}_F = 0.199 + 0.0016X$, $r = 0.46$	$\hat{Y}_F = 0.202 + 0.0110X$, $r = 0.56$
$\hat{Y}_L = 0.235 + 0.0013X$, $r = 0.35$	$\hat{Y}_L = 0.250 + 0.0042X$, $r = 0.45$

[2]An unpublished study on the Beaver Creek watershed showed percent of overhead crown closure to be highly correlated with basal area measured by point sampling with a basal area factor of 25.

Figure 2.--Relationships between forest floor depth and weight. Lengths of regression lines indicate approximate range of data.



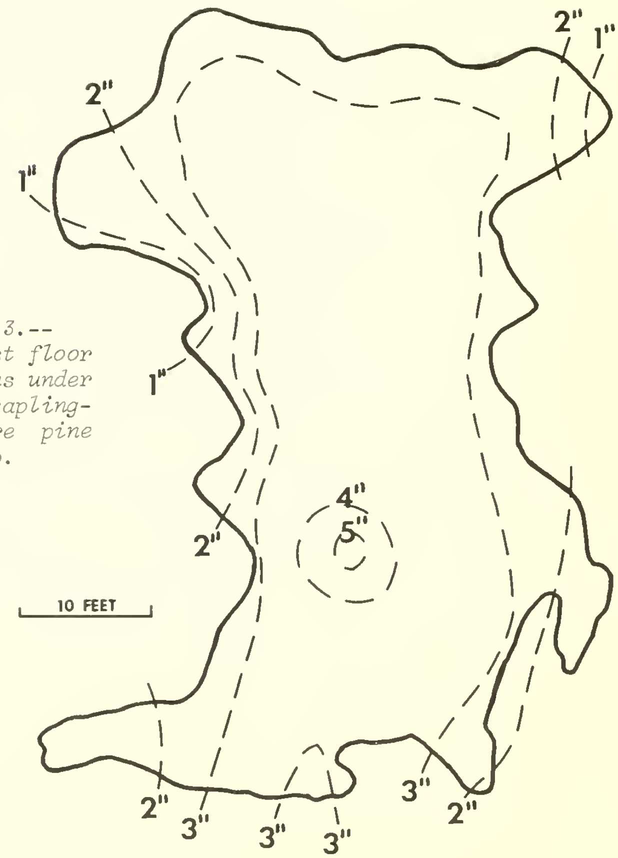


Figure 3.--Forest floor depths under a sapling-mature pine clump.

Analyses involving the indexes of stand age, temperature, and soils variables showed no significant relationship at the 0.05 level. Aldon (1968) found a high correlation between forest floor weight and stand age, but in the present situation with intermingling size and age classes, no truly meaningful expression of stand age was possible.

While they have some utility, even these basal area - forest floor relationships did not have high correlation. Aldon (1968) found a good correlation between basal area and weight of the forest floor, but his measurements were restricted to clumps of relatively uniform pole-sized ponderosa pine. The present study utilized data collected on an inventory basis, and therefore express the variability normally present in a cutover ponderosa pine stand. Total depth was examined in detail in a small (0.03 acre) clump to illustrate the variability of forest floor depths within short distances. A single mature pine dominated the clump; the remaining timber overstory was uneven-aged saplings. Depths increased from less than 1 inch near the edge of the clump to over 5 inches at the base of the mature pine (fig 3), and often increased 3 inches within a 2-foot distance.

Predictions of the amount of forest floor from stand and site characteristics are most dependable in stands with uniform structure and no history of fire (Brown 1966). These conditions did not exist on the study area.

Summary

1. The mean weight of the forest floor was 9.3 tons per acre (1.3 inches in depth), with the greatest accumulation in the **H** layer.
2. Frequency distributions of forest floor depths were developed to be used as a management tool when critical ranges of depth affecting wildland products are defined.
3. Timber basal area was the only tested stand or site variable significantly related to individual layer or total forest floor amounts. The correlations were low, but the regressions should prove useful in describing the forest floor characteristics under Arizona ponderosa pine.

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RESEARCH NOTE RM-128

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Soil Temperature Variations on a Semidesert Habitat in Southern Arizona

Dwight R. Cable[1]

Daily minimum soil temperatures were lowest at the surface and increased with depth; daily maximum soil temperatures were highest at the surface and decreased with depth. Diurnal variation was greatest (as much as 75° F.) at the surface and lowest (1° or 2° F.) at the 24-inch depth. Soil temperatures at the 3-, 12-, and 24-inch depths ranged mostly between 40° and 60° F. during the winter months, and between 70° and 90° F. during the summer months. Absolute maximum and minimum temperatures recorded were 141° and 29° F.

Soil temperature affects biological, chemical, and physical processes, including the rate of absorption of water and solutes, the germination of seeds, the rate of growth of roots, the geographic range of plant species, and the activities of microorganisms.[2] Thus, the temperature regime of the soil is an important dimension of the habitat. Soil temperature data collected from July 1961 to October 1963 on the Santa Rita Experimental Range, south of Tucson, Arizona, are presented here to characterize the soil temperature regime of this semidesert rangeland area.

Methods

The Study Area

The study area is in a semidesert grass-shrub type on a gently sloping northwest exposure at an elevation of about 3,900 feet. Annual precipitation averages 13.67 inches, with about 60 percent falling between July and September. The vegetation consists of rather sparse stands of annual grass, perennial grass, and burroweed, Haplopappus tenuisectus (Greene) Blake, (a half-shrub) in various combinations, with considerable exposed soil (fig. 1). The soil is a sandy loam of the Continental series, with sand varying from 75 percent in the 0- to 6-inch layer to 64 percent in the 12- to 18-inch layer, and clay varying from 8 percent in the 0- to 6-inch layer to 16 percent in the 12- to 18-inch layer. Bulk density is 1.64 gm/cm^3.

[1]*Range Scientist, located at Tucson, in cooperation with the University of Arizona; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*
[2]*Weaver, John E., and Clements, Frederic E. Plant ecology. Ed. 2, 601 pp. New York: McGraw-Hill Co. 1938.*

Figure 1.--Typical vegetation near study area: background, velvet mesquite; foreground, burroweed.

Soil Temperature Measurements

Soil temperatures were derived from thermistors in Colman soil moisture units buried in the soil at 3, 12, and 24 inches. Each depth was replicated 14 times. Readings were taken daily (within about 2 hours after sunrise) during periods of vegetation growth, and weekly at other times from July 1961 to October 1963. Starting on December 14, 1961, and continuing at intervals of about 2 months for 1 year, readings at 2-hour intervals from 6 a.m. to 10 p.m. were taken also from another series of seven units buried at depths of 0.5, 1, 2, 3, 6, 12, and 24 inches. Air temperatures were measured in the shade 0.5 inch above the ground surface. Weekly mean maximum and minimum air temperatures were also measured in a U. S. Weather Bureau shelter at the Santa Rita headquarters, 3 miles from the study area.

Results

Daily and Seasonal Fluctuations

Soil temperatures fluctuated daily in response to changes in air temperatures. Minimums at all depths down to 6 inches were recorded just before sunrise (fig. 2). The minimum at 12 inches was usually reached at noon, and daily fluctuations at 24 inches were very limited and apparently inconsistent. At 6 a.m., the 0.5-inch depth was the coldest on all dates, and the 24-inch depth the warmest (except on June 21). Rapid surface heating during the morning reversed this pattern, leaving the lowest temperatures at 12 and 24 inches and the highest temperature at the 0.5-inch depth. With the rapid cooling in late afternoon, the pattern reversed again. Thus, at all seasons the typical daily minimum and maximum were recorded at the soil surface, and daily temperature extremes decreased with depth. The absolute maximum and minimum soil temperatures recorded in the study were 141°F. and 29°F. Maximum and minimum soil temperatures reported by Shreve[3] for depths of 3 and 12 inches, measured under somewhat similar climatic conditions near Tucson, are roughly comparable to those reported in this study.

[3]*Shreve, Forrest. Physical conditions in sun and shade. Ecology 12: 96-104. 1931.*

Soil temperatures on sunny days varied less among the seven depths at 6 a.m. than at 2 p.m. Also, variations among depths were greater in summer than winter. For example, at 2 p.m. on the one sunny winter day sampled (February 15), the highest soil temperature measured was 84°F. at 0.5-inch depth, and the temperature varied 29° among depths. At 2 p.m. on the hottest summer day sampled (June 21), the highest soil temperature measured was 141°F. at 0.5-inch depth (air temperature, 109°F.), and the temperature varied 60° among depths. Just as the surface soil absorbs heat rapidly from sunrise until midafternoon, it also loses heat rapidly in the late afternoon as the sun approaches the horizon and air temperatures decline.

Diurnal temperature extremes were greatest on sunny summer days. For example, at 0.5 inch the spread between maximum and minimum on an overcast day (December 14, 1961) was 10°F.; on a sunny winter day (February 15, 1962) the spread was 40°F.; but on a sunny summer day (June 21, 1962) the spread was 75°F. The insulating effect of soil is apparent in the greatly reduced diurnal temperature extremes (only 2° spread) at 24 inches on the same summer day (table 1).

December 14, 1961, was unusual (for the Southwest) in that the sky was overcast all day, with several intermittent light showers. As a result, the normal daytime rise in temperatures was largely suppressed (fig. 2).

Temperature Lag

Daily and seasonal maximum soil temperatures usually occur sometime after maximum air temperatures are recorded. Maximum daily soil temperatures at the 0.5-, 1-, and 2-inch depths were recorded at 2 p.m., as were maximum air temperatures (time lags shorter than 2 hours were not measured). Maximum temperatures at the 3-, 6-, and 12-inch depths were recorded at 4, 6, and 8 to 10 p.m., respectively. The 24-inch depth exhibited no well-defined time lag, but morning temperatures generally averaged higher than afternoon temperatures, indicating a probably time lag of 12 to 18 hours.

Minimum daily temperatures within the surface 6 inches of soil coincided with minimum air temperatures, and were recorded just before sunrise. At 12 inches the minimum was usually recorded about noon, but diurnal variation at 24 inches was too small to show a consistent minimum.

Table 1. --Air temperatures[1] and soil temperature characteristics at seven depths in summer and winter

Weather conditions and date	Air temperatures	Soil temperatures by depths in inches							
		0.5	1	2	3	6	12	24	Range
	- - - -	- - - -	- - - -	- - - -	°F.	- - - -	- - - -	- - - -	- - - -
SUMMER (DRY, SUNNY)									
June 21, 1961									
Maximum	110	[2] 141	134	122	113	100	89	83	58
Minimum	66	66	68	73	79	82	82	81	16
Range	44	75	66	49	34	18	7	2	
WINTER (DRY, SUNNY)									
February 15, 1962									
Maximum	75	84	81	75	73	68	60	57	17
Minimum	41	44	44	46	49	52	54	56	12
Range	34	40	37	29	24	16	6	1	
WINTER (OVERCAST, WITH OCCASIONAL LIGHT RAIN)									
December 14, 1961									
Maximum	52	51	50	49	50	49	52	55	6
Minimum	40	41	41	41	44	46	50	54	13
Range	12	10	9	8	6	3	2	1	

[1] Measured in shade 0.5 inch above the ground surface.
[2] Highest soil temperature recorded during study period.

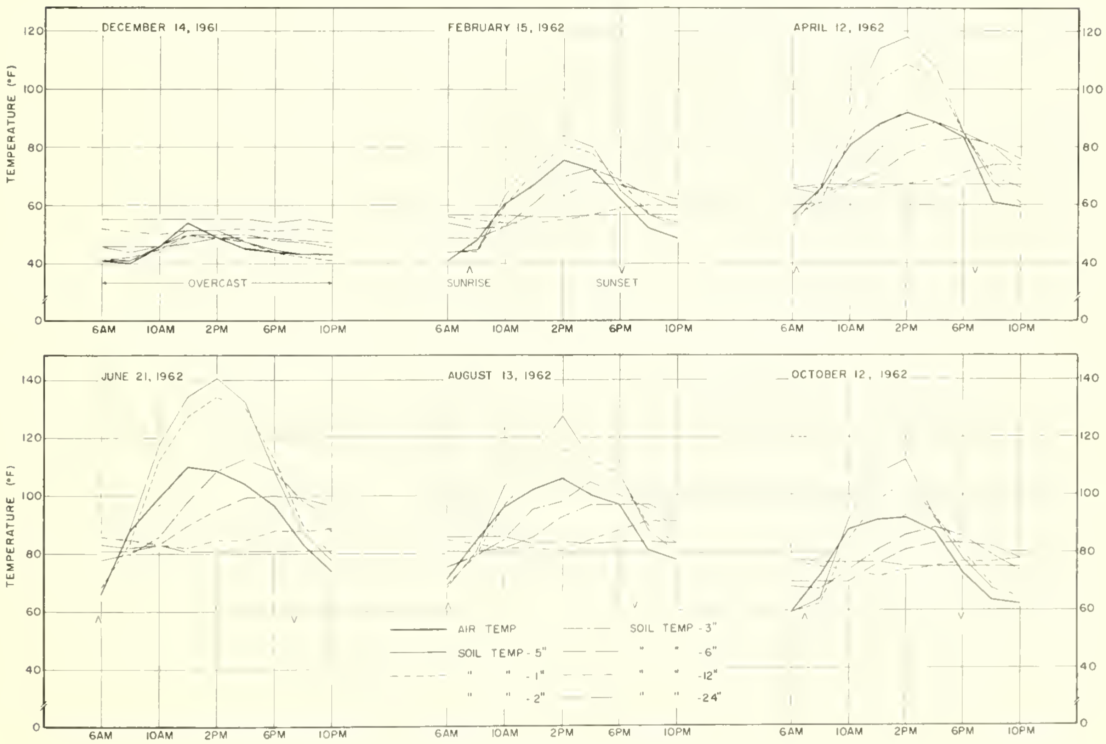

Figure 2.--Air temperature and soil temperatures at 7 depths, from 6 a.m. to 10 p.m. on 6 days from December 14, 1961 to October 12, 1962.

Seasonally, maximum insolation is received on June 21, and minimum insolation on December 21. But, seasonal minimum soil temperatures were reached about the middle of January, and seasonal maximums between mid-July and mid-August (fig. 3). Soil temperatures were well correlated with and usually fell within the range between weekly mean maximum and minimum air temperatures at the Santa Rita headquarters.

Summary

The data presented on soil temperature characteristics on semidesert rangeland in southern Arizona indicate:

1. Soil temperature varied in response to variations in atmospheric temperature and insolation, generally reaching a minimum just before sunrise and a maximum at about 2 p.m.
2. Daily minimum soil temperatures were lowest at the surface and increased with depth; daily maximum soil temperatures were highest at the surface and decreased with depth. The difference between the daily maximum and minimum soil temperatures at a given depth decreased rapidly with depth from as much as 75° at the surface to only 1° or 2° at the 24-inch depth.
3. The temperature in the top inch of soil rose as much as 32° higher than that of the air 0.5 inch above the soil surface.
4. Diurnal soil temperature changes on an overcast winter day were much smaller than on the usual sunny day because of restricted daytime soil heating.
5. Maximum soil temperatures at depths below 2 inches lagged increasingly behind those at the surface until at 24 inches the lag was 12 to 18 hours. Minimum soil temperatures lagged behind air temperature only at 12 and 24 inches.
6. Seasonal maximum and minimum soil temperatures were reached between mid-July and mid-August, and in mid-January, respectively.
7. Soil temperatures at the 3-, 12-, and 24-inch depths ranged mostly between 40° and 60°F. during the winter months, and between 70° and 90°F. during the summer months. Absolute maximum and minimum temperatures recorded during the study period were 141° and 29°F.

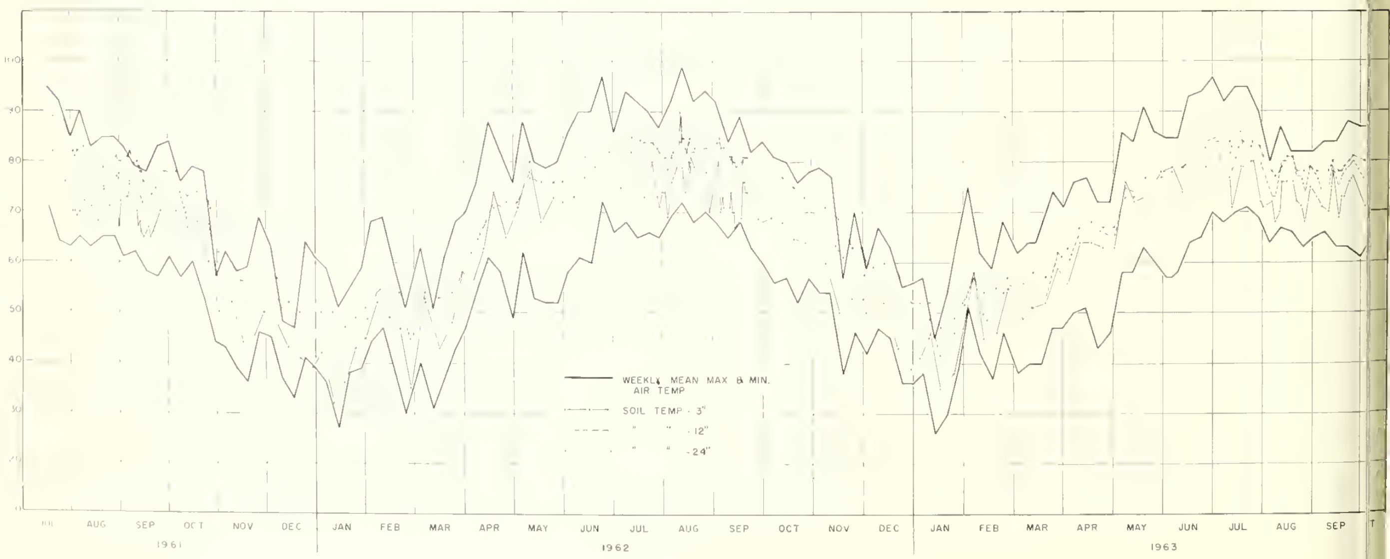

Figure 3.--Weekly mean maximum and minimum air temperatures, and soil temperatures at 3, 12, and 24 inches, measured within 2 hours after sunrise from July 1961 to October 1963.

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RESEARCH NOTE RM- 129

FOREST SERVICE
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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

The Relation of Precipitation to Flow From Little Leroux Spring on the San Francisco Peaks, Arizona

E. C. Martin[1]

Flow from Little Leroux Spring was affected by the combined influence of past and current precipitation. During a wet year spring flow was more responsive to rapid snowmelt and heavy summer storms than during a dry year.

This report summarizes the spring flow data collected at Little Leroux Spring on the Fort Valley Experimental Forest, Arizona, during two 4-year periods. Weekly discharge measurements were taken with a 1-gallon bucket at the discharge pipe and catchment. The spring discharge measurements were compared with precipitation records taken at the Fort Valley Experimental Forest headquarters. The precipitation data are reflected in the variation of discharge values recorded at the spring. Annual water yield from the drainage area was influenced by the current and preceding year's precipitation.

[1]*Forestry Research Technician, located at Flagstaff, in cooperation with Northern Arizona University; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

The San Francisco Peaks

Four peaks, Humphrey, Agassiz, Fremont, and Doyle, collectively, make up the main body of an eroding volcanic cone known as the San Francisco peaks. The tops of the peaks form the rim of a glaciated and eroded crater, locally called the "Inner Basin." The basin drains to the northeast through a wide breach in the crater wall.

Soils and Geologic Origin

Soils on the San Francisco Peaks are derived mainly from volcanic rocks of various forms, and are highly permeable. The rocks above 8,000 feet consist largely of the finer grained lavas. In contrast to this type are the basic basaltic rocks below 8,000 feet. Massive basalts underlie the surface and extend several miles out from the base of the moun-

Figure 1.--Location of Little Leroux Spring on the southwest slope of the San Francisco Peaks.

tain, overlying the earlier sedimentary layer of Kaibab limestone. Coconino sandstone underlies the limestone. These sedimentary layers probably maintained a horizontal attitude underneath great depths of lavas of various forms when the San Francisco Peaks were produced.

Forest Types

The main forest types on the mountain have the following approximate altitudinal arrangement:[2]

Predominant species:	Elevation (Feet)
Ponderosa pine (*Pinus ponderosa* Lawson)	7,300 (Base)-8,300
Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	8,300-9,500
Engelmann spruce (*Picea engelmannii* Parry)	9,500-11,500
Alpine type	Above 11,500

The forest types are indicators of increasing amounts of annual precipitation at higher elevations. The average annual precipitation increases 13 inches between the foot and top of the San Francisco Peaks. The Engelmann spruce and Douglas-fir types occupy zones of heavy precipitation. The dense cover associated with these types, porous soils, and heavy precipitation combine to make good conditions for water supply, and keep watershed values high.

Streams and Springs

There are no perennial streams in the area. Surface waterflow down drainages occurs only for short periods following rapid melt of the snowpack or a heavy rain.

There are about 20 springs on the mountain; they are found at all levels, on all sides, and in the Inner Basin. The springs range in elevation from 7,400 feet to 11,600 feet. 1,080 feet below the crest of Humphrey Peak. A few of them register fairly copious flows; others are comparatively small with flows fluctuating with melt of the snowpack or heavy rain.

[2] *Pearson, G. A. Factors controlling the distribution of forest types. Ecology 1: 139-159; 289-305. 1920.*

Little Leroux Spring

Little Leroux Spring is located in the ponderosa pine type, low on the southwest slope of Agassiz Peak, at an elevation of 7,605 feet (fig. 1). The area directly above the spring is deeply overlain with basalts. The basaltic rock terrain is moderately steep for about a mile above the spring before it blends with the finer grained volcanic rocks, and rises with increasing steepness for 2 more miles to the top of Agassiz Peak. A shallow drainage, in which the spring is located, traverses the foot of the overlying basaltic flow and is covered with a dense stand of ponderosa pine. Massive basalts underlie the surface on the downhill side of the spring.

The data presented are based on weekly volumetric discharge measurements taken at Little Leroux Spring during two 4-year periods, 1947 through 1950 and again in 1963 through 1966, to determine variability of flow. The discharge measurements were compared with precipitation recorded at the Fort Valley Experimental Forest headquarters, 2.7 miles southwest and 250 feet below the spring. The precipitation data presented are probably less than the amounts for the Little Leroux Spring watershed, but are representative and are reflected in the variation of discharge values recorded at the spring (fig. 2). The mean of the two 4-year periods of precipitation is 21.23 inches, compared to the 58-year mean of 22.58 inches.

Discharge varies with precipitation, and melt of a good snowpack induces a copious flow during the early spring months. In a dry year (1948) the discharge varied from a spring peak of 900 gallons per day to a fall trough of 200 gallons per day; in a wet year (1965) the corresponding extremes were 8,300 and 1,200 gallons per day (figs. 3 and 4). Weekly rainfall amounts in excess of 3 inches were followed by brief increases in discharge during the summer and fall (fig. 4).

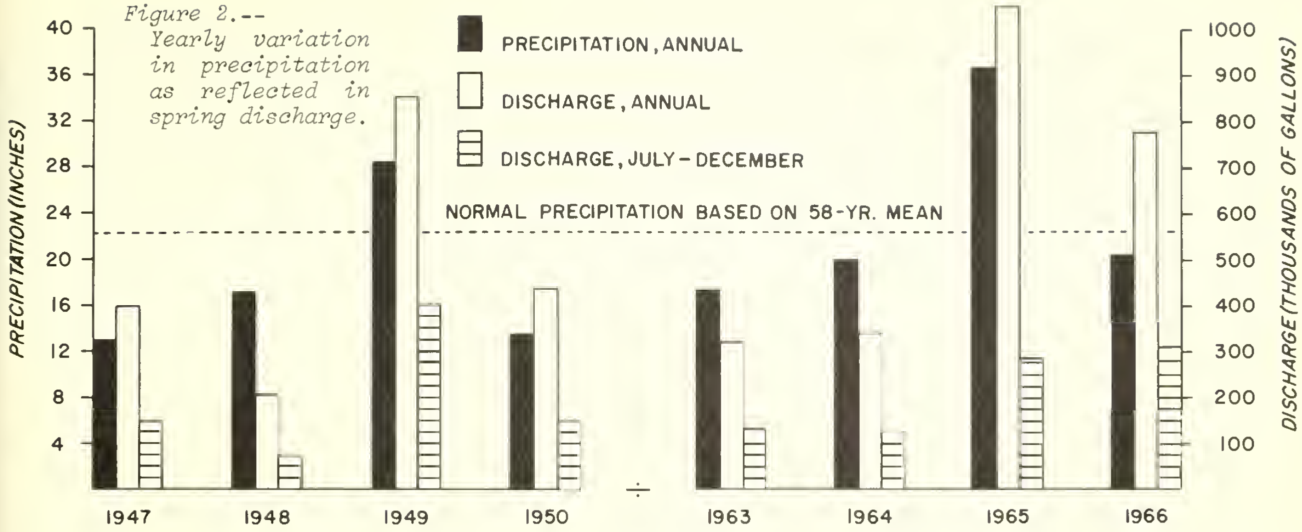

Figure 2.--Yearly variation in precipitation as reflected in spring discharge.

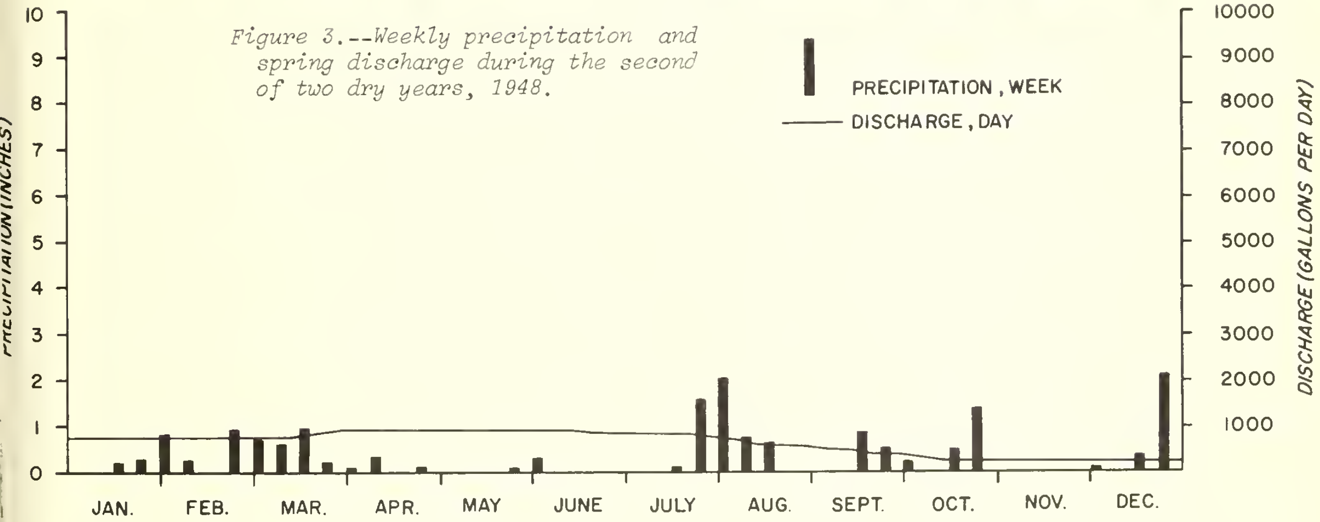

Figure 3.--Weekly precipitation and spring discharge during the second of two dry years, 1948.

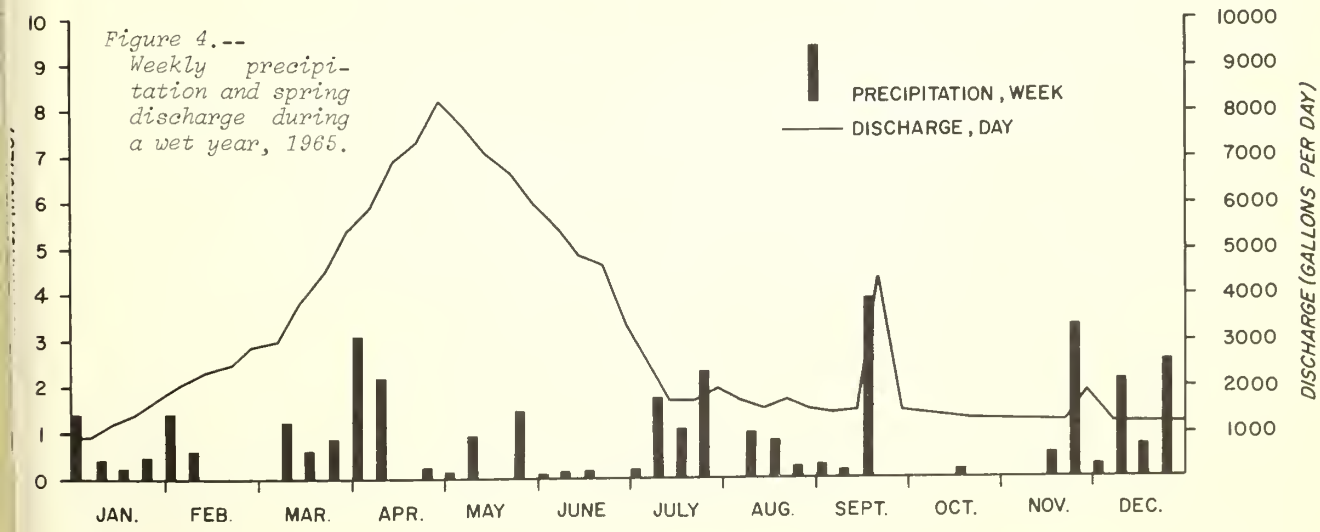

Figure 4.--Weekly precipitation and spring discharge during a wet year, 1965.

Big Leroux Spring

Big Leroux Spring is located in the ponderosa pine type, low on the southwest slope of Agassiz Peak, three-fourths mile northwest of Little Leroux Spring, but at the same elevation. It is high up on the west wall of a shallow canyon, in an outcrop of open-textured lava. A dry streambed in the bottom of the canyon forms the west fork of the head of Rio de Flag. The terrain directly above the spring is steep and overlain with massive basalts. A basalt cliff lies across the head of the drainage above the spring at 8,000 feet elevation. The basalts are replaced largely by the finer grained lavas above this level.

Big Leroux Spring, as its name implies, has much greater flow than Little Leroux Spring. Although intensive discharge data were not collected at Big Leroux, this brief report is based on occasional measurements taken during the two 4-year periods of intensive measurements at Little Leroux Spring. A daily flow of 40,000 gallons was indicated; no appreciable fluctuation was noted regardless of season or amount of precipitation. Although measurements were not intensive, they indicated a much more reliable flow than at Little Leroux Spring.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Modified Tree Pruner for Twig Sampling

John D. Stein[1]

The addition of a simple and inexpensive lever and push-rod to a standard pruner head makes it possible to cut and hold twig samples.

Entomologists often evaluate insect populations with counts of insects on whole or sections of branches. The counts may be inaccurate if some insects are dislodged and lost after the twig has been severed. Improvised collection baskets, mats, or aerial ladders used to reduce or prevent loss of insects often become inoperative in thick foliage or gusty winds.

With the addition of a lever and push-rod to a standard pruner head[2] (fig. 1), it is possible to cut and hold twig samples. The modification is simple and inexpensive. This innovation adds only a small amount of wind resistance and, under ordinary circumstances, no additional personnel or aerial equipment are needed. Once cut and secured, the twig sample can be lowered to the ground for examination.

Figures 2 and 3 demonstrate the basic details involved in modifying a standard pruner head to cut and hold the twig simultaneously.

[1]*Associate Entomologist, located at Bottineau, in cooperation with North Dakota School of Forestry; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*The basic pruner head was manufactured by Seymour Smith and Son, Oakville, Conn. Company name is mentioned for the benefit of the reader and does not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

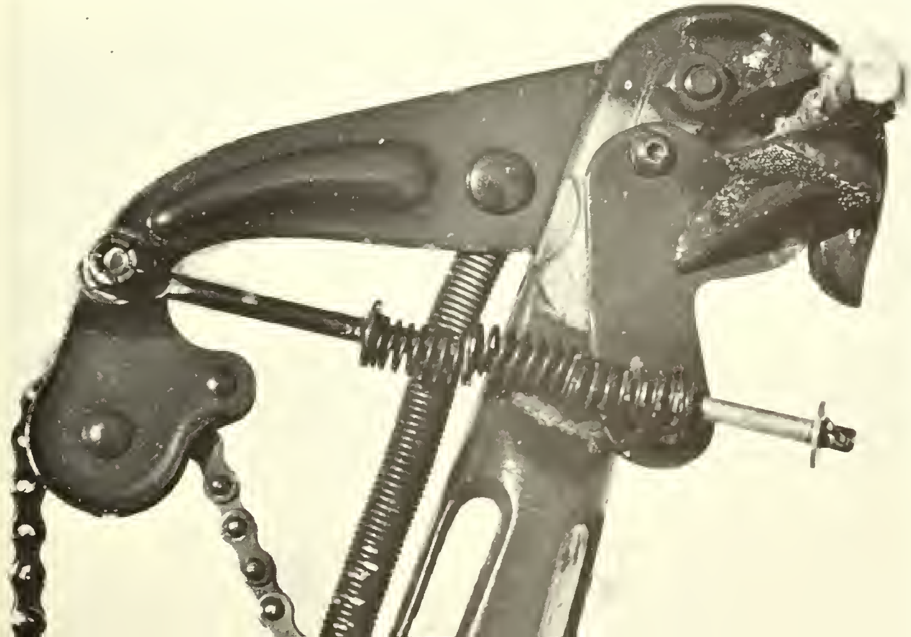
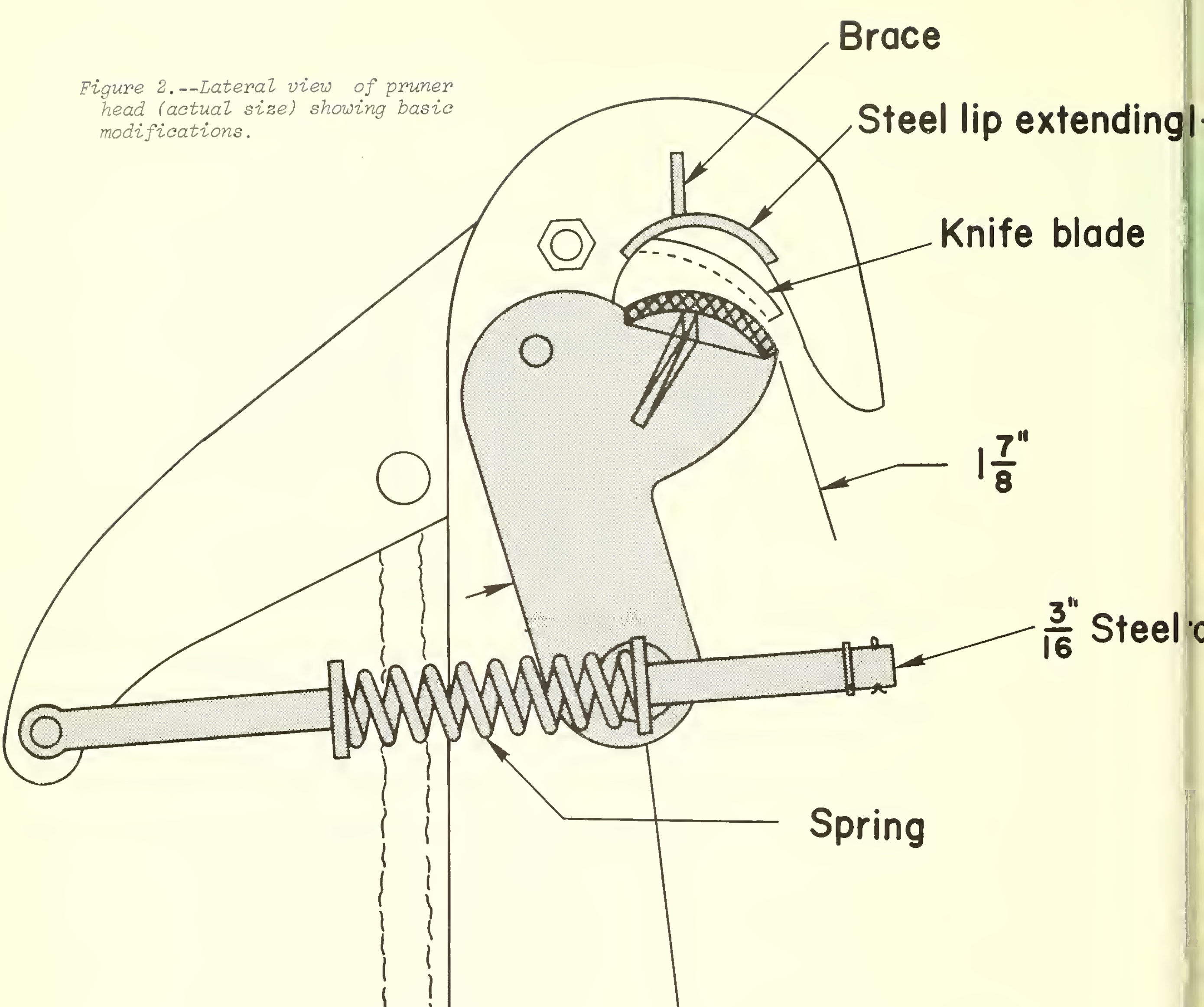


Figure 1.--Cut-and-hold action of modified pruner.

Figure 2.--Lateral view of pruner head (actual size) showing basic modifications.



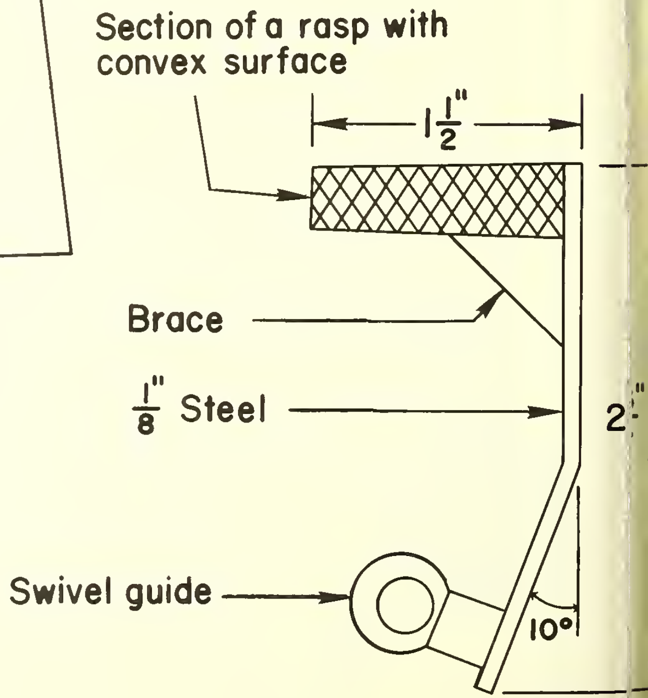


Figure 3.--Front view of movable lever with dimensions. The 10° angle of bend conforms to the contour of the pruner.

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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Herbage Production Differs with Soil[1] in the Pinyon-Juniper Type of Arizona

Donald A. Jameson[2] and J. D. Dodd[3]

Field observations and field data show that production on Springerville soils is similar to production on Gem and Tortugas soils where there are few pinyon and juniper trees, but that the Springerville soils produce much less perennial herbaceous vegetation than the other soils when there is appreciable tree cover. From the behavior of the species studied, the differences in the soils observed in the field did not appear to be due to soil moisture, nitrogen, or phosphorus.

One of the major problems of the pinyon-juniper type is the low herbage production as a result of tree overstory. Increased tree cover results in reduced understory production: tree covers of 10 percent and 30 percent have reduced herbage production 40 percent and 65 percent, respectively.[4] An examination of the Gem, Springerville, and Tortugas soils indicates that trees affect herbaceous vegetation differently on those soils. This Note presents results from an examination of nutrient status of these soils as a factor contributing to the differential responses of the soils to tree cover.

The Soils

About 32 percent of the pinyon-juniper type of Arizona is on soils formed from basalt parent material. Much of this parent material has developed into Gem and Springerville soils. An area of similar size (29 percent) is underlain by the Kaibab and Redwall limestones, much of which in turn has developed into Tortugas soils.

Gem.—This series is developed from basalt and other volcanic materials. It is the only soil in this study with a B horizon. In our samples, the average thickness of the solum (A and B horizons) was 15 inches, and the total soil depth 26 inches. The average texture was a clay loam on the surface layer and clay (49 percent clay) in the B horizon.

[1] *Soil profile descriptions in this study were made by George Wendt and Mack L. Miller, U. S. Soil Conservation Service, and Truman Anderson and W. R. Mitchell, U. S. Forest Service.*

[2] *Principal Plant Physiologist, located at Flagstaff, in cooperation with Northern Arizona University; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University. Jameson is currently Associate Professor of Range Science, Colorado State University.*

[3] *Associate Professor, Texas A & M University, College Station, Texas.*

[4] *Arnold, Joseph F., Jameson, Donald A., and Reid, Elbert H. The pinyon-juniper type of Arizona: Effects of grazing, fire, and tree control. U. S. Dep. Agr. Prod. Res. Rep. 84, 28 pp., illus. 1964.*

Nomenclature requirements may cause the name of this series to be changed to "Thunderbird."

Springerville.—These heavy clay soils have developed from parent materials that are, superficially at least, the same as the parent materials of the Gem series. The Springerville soil, however, is a vertisol, and soil churning is evident. Because of the churning effect, there is a lack of profile development. These soils have been described in detail by Johnson et al.[5] In our samples, the clay content below the surface averaged 55 percent, and soil depth averaged 34 inches.

Tortugas.—These are shallow, skeletal soils from limestone. In our samples the A horizon averaged 8 inches thick. Clay content on the surface averaged 24 percent, and this increased to 28 percent in the C horizon.

Soil chemicals were determined by "La Motte" soil tests (table 1). The major difference between these soils was the calcium content, ranging from 11,667 p.p.m. for the Tortugas soils to 4,650 for the Springerville soils.

[5] *Johnson, W. M., Cady, J. G., and James, M. S. Characteristics of some brown grunosols of Arizona. Soil Sci. Soc. Amer. Proc. 26: 389-393. 1962.*

Table 1.--Chemical analysis of three soils of the Arizona pinyon-juniper type

Soil series	Samples	Analysis								
		P_2O_5	K_2O	NO_3	NO_2	NH_3	Ca	Mn	Al	Fe
	Number	- - - Pounds per acre				- - -	p.p.m.			
Tortugas	4	183	177	9.3	[1]VL	VL	11,667	ML	ML	L
Gem	6	183	186	10.2	VL	VL	6,167	L	ML	L
Springerville	7	186	184	4.6	VL	VL	4,650	L	M	L

[1]VL = Very low; L = Low; ML = Medium to low; M = Medium.

Table 2.--Field production of three soils of the Arizona pinyon-juniper type

Soil series	Locations	Plots	Tree canopy	Herbage weight[1]		
				Perennials	Annuals	Total
	- - Number	- -	Percent	- - Pounds per acre - -		
Tortugas	2	6	[2]0	542	5	547
Gem	3	17	[2]3	457	0	457
Springerville	3	11	[2]3	517	22	539
Gem	1	48	[3]16	128	0	128
Springerville	2	92	[3]19	25	35	60
Tortugas	1	49	[3]31	80	6	86
Gem	1	49	[3]29	93	0	93

[1]Includes all herbage, but composition was primarily grasses.

[2]Tree canopy was from 50-foot line intercept transects (see Canfield, R. H., Application of the line interception method in sampling range vegetation. J. Forest. 39: 388-394. 1941.). Herbage weight was from corresponding 4-inch by 50-foot belts. Only total herbage weight was determined; the proportion of weight between annuals and perennials was estimated on the basis of relative basal area contribution.

[3]Tree canopy was from a spherical densiometer (see Lemmon, P. E., A spherical densiometer for estimating forest overstory density. Forest Sci. 2: 314-320. 1956.). Herbage was from corresponding 9.6-square-foot circular plot. Weights of annuals and perennials were determined separately.

Field Production

Field observations of these soils impress the observer with the lack of herbage production under pinyon-juniper stands on Springerville soils, although there is less difference between soils where there are few trees (fig. 1). Data from several study plots bear out these observations (table 2). These plots were selected for presentation here because the understory vegetation was primarily grasses and forbs. The production figures for grasses, therefore, are not confounded by competition from shrubs and half-shrubs. On plots with few or no pinyon or juniper trees, there was less than 20 percent difference in the herbage production on the three soils studied. Even with about 30 percent tree cover there was little difference in production between the Gem and Tortugas soils. With 19 percent tree cover, however, the Springerville soil produced only 47 percent as much as Gem soil with 16 percent cover. Much of the production on the Springerville plots with tree cover was from annuals, while on the other plots nearly all of the herbaceous production was from perennials.

Figure 1.--Study plots on three soils in Arizona, and related tree cover.

Springerville soil series, tree cover, 0.7 percent

Springerville soil series, tree cover, 19 percent

Gem soil series, tree cover, 29 percent

Tortugas soil series, tree cover, 31 percent

Greenhouse Production

To study the productivity of these soils under uniform conditions, soil samples from 17 locations were brought into the greenhouse for pot tests. Soil samples included the upper 10 inches of soil. The samples were screened through a 2 mm. screen, and 1,500 grams of air-dry soils were placed in polyethylene pots of about 3-quart capacity. All pots were brought to field capacity with distilled water, and twice weekly during the study soils were watered to restore the field capacity weight. Six pots of soil from each location were planted with corn, and six with side-oats grama (Bouteloua curtipendula (Michx.) Torr.). Side-oats grama was selected as a representative native plant, and corn was selected because some nutrient deficiencies are easily recognizable. After the seeds had germinated, the number of plants in each pot was reduced to one.

When the plants appeared to be well established, 75 mg. nitrogen (in NH_4NO_3) was added to one-third of the pots, and nitrogen plus 75 mg. P_2O_5 (in $Ca(H_2PO_4)2H_2O$) to another third. The pots were arranged in the greenhouse in two replications.

After 7 weeks, the corn plants were harvested, ovendried, and weighed (table 3). The side-oats grama was harvested at 9 weeks. In spite of the generally high phosphorus content of these soil samples, the corn plants commonly showed phosphorus deficiency symptoms; these symptoms were not altogether relieved by addition of phosphorus. There was, in fact, a significant negative correlation ($r = -0.683$, 15 df) between the calcium content of the individual samples and the increase of the NP treatment over the N treatment. This was apparently due to the high calcium content resulting in insoluble forms of phosphorus.

The Gem samples were the highest producers in all categories except for unfertilized corn. The Springerville samples were the lowest producers for corn, but the Tortugas samples were the lowest producers for side-oats grama. All soils showed response to nitrogen fertilizer. The greatest response to nitrogen fertilizer was on the Gem soils; additions of fertilizer to the other soils did not reduce the difference between these samples and the Gem samples.

Summary and Conclusion

Field observations and field data show that production on Springverville soils (vertisols) is similar to production on Gem and Tortugas soils when there are few pinyon and juniper trees, but that the Springerville soils produce much less perennial herbaceous vegetation than the other soils when there is appreciable tree cover. Production of corn and side-oats grama on samples of these soils kept at field capacity in the greenhouse showed differences between the series, with the Gem samples being the most productive. The difference between the soils was increased rather than reduced by addition of nitrogen and phosphorus fertilizer. From the behavior of the species studied, the differences in the soils observed in the field did not appear to be due to soil moisture, nitrogen, or phosphorus.

Table 3.--Corn and side-oats grama produced in greenhouse tests of three soils of the Arizona juniper type with three fertilizer treatments

Soil series	Corn				Side-oats grama			
	No fertilizer	N added	N+P added	Mean	No fertilizer	N added	N+P added	Mean
	- - - - - - - - - - Milligrams per pot				- - - - - - - - - -			
Tortugas	825	1,838	1,650	1,438	44	51	49	48
Gem	692	2,192	2,408	1,764	75	166	139	127
Springerville	442	1,142	1,464	1,016	52	59	90	67
Mean	653	1,724	1,841	1,406	57	92	93	81

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effect of Heavy Late-Fall Precipitation on Runoff From a Chaparral Watershed

Paul A. Ingebo[1]

Unseasonally high runoff resulted from extremely heavy late-fall precipitation in 1965 on an Arizona watershed. Streamflow during and following the rains was significantly regulated by the ability of the watershed to store and release water from its regolith.

The Three Bar experimental watersheds (fig. 1), a part of the Forest Service's water resource research program, received unusually heavy precipitation during November and December 1965. The storms caused December streamflow on the Verde, Salt, and Gila rivers to range from 11 to 16 times the 1948-62 average.[2]

The Three Bar watersheds lie within the Salt River drainage between 3,300 and 5,300 feet elevation on the easterly face of the Mazatzal Mountain range, some 3 miles northeast of Four Peaks and about 8 miles northwest of Roosevelt Dam. Wildfire swept over all four chaparral watersheds in 1959. By 1965 when the late-season storms occurred, watershed D (80.5 acres) had a returning natural brush cover of about 51 percent crown density. Prefire brush crown cover was 70 percent.

Most of the November-December precipitation in the 1965 storms came as rain to the Three Bar area. The rains, which started on November 17, were frequent but not intense. Rainfall was recorded at the gage at the lower end of watershed D on 19 of the 45 days during the period November 17 to December 31 (fig. 2). Intensities at the gage several times approached but never exceeded two-thirds of an inch in 1 hour. By January 1, a record 24.29 inches of precipitation had been measured at the gage since November 16 (about seven times the preceding 9-year average). Similar amounts probably fell throughout the watershed; the

[1]*Hydraulic Engineer, located at Tempe, in cooperation with Arizona State University; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Enz, Richard W. Water-supply outlook and Federal-State-Private cooperative snow surveys for Arizona. 10 pp., illus. U.S.D.A. Soil Conserv. Serv., Phoenix, Ariz. Jan. 15, 1966.*

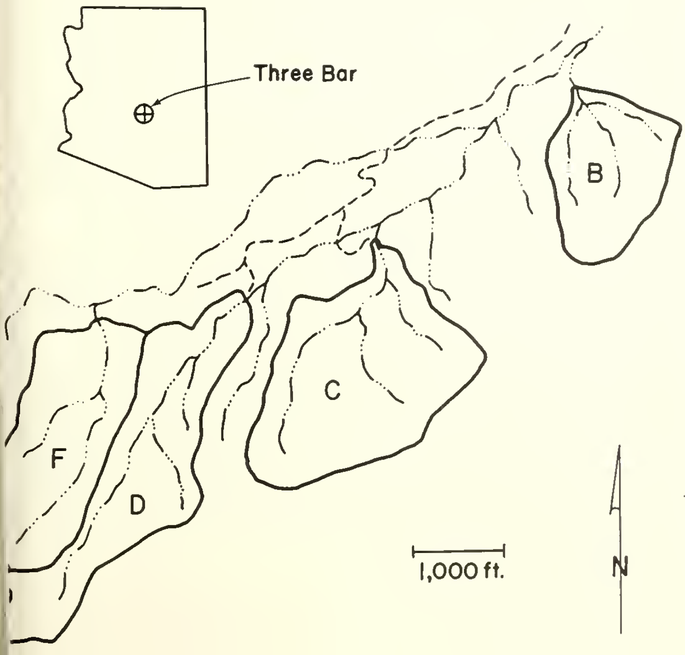

Figure 1.--The Three Bar experimental watersheds in central Arizona, tributary to Rock Creek and Roosevelt Lake on the Salt River.

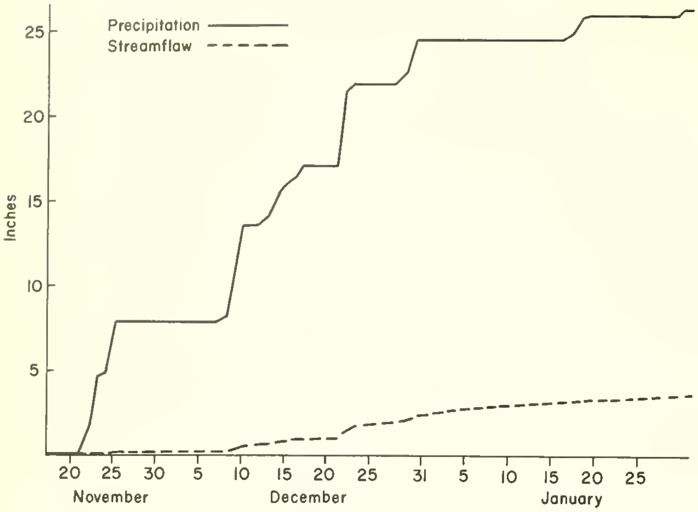

Figure 2.--Accumulated streamflow from Three Bar watershed D and precipitation at the gage near weir D, November 17, 1965-January 31, 1966.

higher elevation gages overflowed while access was interrupted due to flooding and washout of service roads. Streamflow for the period November 17 through December 31 was 2.4 area-inches.

The effect of precipitation on watershed runoff may be generally expressed in a simplified form of the water balance equation:

$$Q = P - (I+T+E) \pm X \pm S$$

where

Q = streamflow
P = precipitation
I = interception
T = transpiration
E = evaporation
X = seepage into or out of the watershed
S = changes in storage of water within the regolith of the watershed.

In this instance, the only known values are Q and P for the period November 17 to December 31. Because watershed D is generally north facing and the season cool, (I+T+E), which we will combine and call ET, is estimated at about 2.0 inches for the period. Seepage, if any, is thought to be negligible and, therefore, assumed to be zero. If we rearrange and substitute in the water balance equation:

$S = P - ET - Q$ or $S = 24.3 - 2.0 - 2.4 = 19.9$ inches

In this case, a 19.9-inch increase in stored water is indicated.

Seismographic exploration on and adjacent to watershed D suggests that it has an overburden of 30 to 40 feet of weathered and fractured rock which, along with the covering shallow soils, provides considerable space or potential for ground-water storage. Precipitation prior to November 17 was about 1.5 inches in 3 months. Streamflow immediately prior to November 17 averaged only 0.001 inch per day. Together, the two conditions suggest that ground-water levels were low at the beginning of the period, or that an appreciable portion of the ground-water storage potential in watershed D was available on November 17. It evidently provided storage for 19.9 inches of the precipitation by the end of December.

Streamflow responded little to the 8 inches of rainfall in November, presumably because soil-water deficits first had to be satisfied before an appreciable amount of water was released to the stream. With additional precipitation in early December (fig. 2) streamflow responded markedly, even though storage also increased. From early December to the end of the month, the more uniform rate of streamflow compared to the more sporadic rainfall suggests a continuing buffering action in movement of water through the watershed. Obviously, this action is influenced in large part by the ability of the regolith to accept and release the precipitation. After passing a peak daily rate in the latter part of the month, streamflow at the end of December was about 0.11 inch per day.

Streamflow did not end with the December rains, but continued a recession-type flow. By January 16 the daily rate of flow had receded to one-third that of the beginning of the month although it was still about 40 times higher than the flow immediately prior to November 17. Intermittent rains from January 17 to March 3 did little to interrupt the trend. It is reasonable to assume that the November-December rains were the major contributors to streamflow through January 16, and to a large extent through the period of light spring rains.

To arrive at a rational solution to the water-balance equation and to explain or determine some of the delays in streamflow resulting from storm events, it has been necessary to recognize the storage potential within the watershed. This storage potential is a peculiarity of the regolith; thus, the depth and characteristics of the overburden appear to be important considerations in studying water yields, storage, and flow behavior of watersheds.

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KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Volumeter for Estimating Quantity of Conifer Foliage

(for Expressing Photosynthesis on a Leaf-Volume Basis)

Frank Ronco[1]

Although many indices have been used to express photosynthesis on a leaf unit basis, volume appears to be the most satisfactory estimator of foliage quantity for conifers. Specifications and operational techniques for a simple but accurate volumeter are described.

There is no universally accepted method for determining the amount of foliage involved in photosynthesis. Kramer and Kozlowski[2], citing several investigators, showed that gaseous exchange in leaf tissue has been expressed on the basis of surface area, stomatal area, dry weight, fresh weight, chlorophyll content, and nitrogen content. While those methods are satisfactory for estimating foliage quantity of broadleaved species, Clark[3] indicated that they are generally not suitable for conifers. He considered needle volume to be the most consistent index of foliage quantity in spruces and firs.

Volumes of a few large needles may be computed from dimension measurements, but volumes of many small needles are best determined by water displacement. In photosynthetic studies of Engelmann spruce (Picea engelmannii Parry)[4], total foliage volume on 3-year-old seedlings was estimated with a volumeter (fig. 1) patterned after instruments described by Gibbs[5] and Clark.[3] It gave consistent results without breakage during handling when used with heavily foliaged spruce seedlings. Since component parts are common laboratory glassware, construction and repair costs are minimal.

Construction of Volumeter

Construction of the volumeter is described in the following paragraphs—letters in parentheses identify component parts in figure 1. The volumeter was constructed from the two sections of a 40/50 S/T ground-glass joint. The outer section (A) was fused across the open end to form a cylindrical receptacle 19 cm. long, and the inner section (B) was shortened and tapered to accommodate a pyrex-tubing stem, 9 cm. long and 7 mm. in diameter, fused to the tapered end. The volumeter was calibrated by filling the connected sections with 20°C water and etching a line on the stem at 185 ml.

[1] *Silviculturist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Kramer, P. J., and Kozlowski, T. T. Physiology of trees. 642 pp. New York: McGraw-Hill Co. 1960.*

[3] *Clark, J. Photosynthesis and respiration in white spruce and balsam fir. State Univ. Coll. Forest., [Syracuse, N. Y.], Univ. Tech. Pub. 85, 72 pp. 1961.*

[4] *Ronco, Frank. The influence of high light intensity on the survival of planted Engelmann spruce. D. F. dissertation, Duke Univ., Durham, N. C. 128 pp. 1967. (Diss. Abstr. 29: 429B-430B, 1968.)*

[5] *Gibbs, R. D. Sinkage studies. II. The seasonal distribution of water and gas in trees. Can. J. Res. 2: 425-439. 1930.*

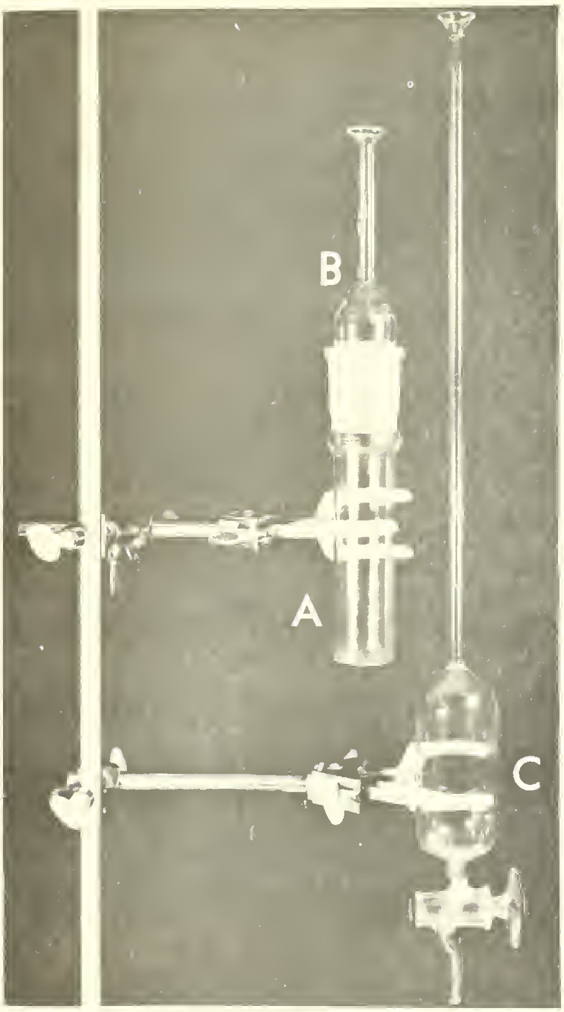

Figure 1.--Volumeter (A and B) and reservoir (C) used to measure foliage volume of conifer needles. (Parts identified by letters are described in the text.)

A reservoir (C), consisting of a pyrex-tubing stem, glass cylinder and stopcock, was also made to specifications by fusing the stopcock and tubing, 39 cm. long and 7 mm. in diameter, to the top of a glass cylinder, 5 cm. in diameter and 12 cm. long. The reservoir had a capacity slightly greater than 180 ml. and was calibrated with 20°C water so that etched lines on the stem would indicate a water discharge of 170, 175, or 180 ml. when completely drained by gravity. A standard 10 ml. burette (not shown in fig. 1) completed the apparatus.

Procedure for Measuring Volume

A seedling, severed at the root collar, was placed in the lower portion of the volumeter; the two sections were then lightly coated with stopcock grease and firmly joined. Water from the reservoir was then slowly and completely drained into the volumeter. Each gallon of water used to fill the reservoir and burette contained 6.0 ml. Kodak Photo-flo[6] wetting agent which prevented water droplet formation on glassware and reduced the formation of air bubbles trapped between needles when foliage was compressed in the volumeter. The level to which the reservoir was filled was determined by adding the estimated seedling volume to each of the three calibrated volumes of the reservoir, and selecting the level that gave the maximum total volume without exceeding the calibrated capacity of the volumeter. Finally, the volumeter was filled to the 185 ml. etched line with the 10 ml. burette. Volume of the seedling was determined by subtracting the total volume of water dispensed into the volumeter from the calibrated volume of the volumeter. Needle volume was determined by subtraction after making another volume determination of branches from which all needles had been removed.

Duplicate measurements, reproducible to within 0.01 or 0.02 ml., were obtained by the following technique:

1. Seedlings were kept in water containing wetting agent for the same length of time between duplicate measurements,
2. Each seedling was whiplashed four times to remove adhered water before being placed in the volumeter,
3. All air bubbles trapped between needles were removed by tilting the volumeter and tapping it vigorously,
4. The reservoir, burette, and volumeter were carefully filled and emptied to position the meniscus uniformly on calibration lines,
5. Glassware was kept clean,
6. The volumeter was dried between measurements by draining and rinsing with acetone,
7. The joint of the volumeter was lightly greased and firmly seated, and
8. The reservoir was completely drained into the volumeter.

[6] *Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effect of Photoperiod at Low Light Intensities on Growth of Four Sedges

W. M. Johnson[1]

The growth response of four species of Carex to light intensity and photoperiod was tested under greenhouse conditions at Laramie, Wyoming. Carex ebenea, C. tolmiei, C. phaeocephala, and C. egglestonii grew and developed normally under very low light intensities. Length of photoperiod affected only the time of flowering and the green weight of top growth.

Very little is known about the growth requirements of the high-altitude sedges (Carex spp). They grow in a wide variety of environmental conditions. Some species—C. brevipes W. Boott, for instance—will grow under dense shade in timber and also under maximum sunlight on open ridges, a rather wide range of adaptability. Preliminary investigations of factors affecting the growth of the sedges are underway. The purpose of this study was to determine the effect of length of photoperiod on the growth of four species of high-altitude sedges at low levels of light intensity.

[1]*Principal Plant Ecologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Research reported here was conducted in cooperation with the University of Wyoming at Laramie.*

Methods

The study involved four samples of four species of sedges with two levels of light intensity and three photoperiods.

Six growth cells were installed on a greenhouse bench in Laramie, Wyoming. Each cell was enclosed with heavy white muslin to exclude light from adjoining cells. The cells were left open on top to provide better temperature control. The greenhouse was heavily shaded to reduce outside light from above as much as possible. Due to limited physical facilities, treatments were not replicated and conclusions are based on comparison of the sample means.

For the lower level of light intensity, the growth cells were equipped with two 40-watt, cool white fluorescent bulbs plus one 40-watt incandescent bulb. For the higher level of light intensity, the light source was doubled. Minimum light intensity, as measured with a

Weston illumination meter, Model 756,[2] was 300 foot-candles (ft.-c.) at pot level for the high-intensity treatment and 200 ft.-c. for the low-intensity treatment. During daylight hours, light intensity in all cells was as high as 800 ft.-c. on bright, sunny days. For most of the study period, however, daytime light intensities averaged 450 ft.-c. for the high-intensity treatment and 375 ft.-c. for the low intensity treatment. Light intensities in the alpine zone on the Snowy Range in Wyoming often range from 9,000 ft.-c. to 10,000 ft.-c.[3]

Three photoperiods, 10, 14, and 18 hours, were established. All periods included the normal hours of daylight by starting before daybreak and ending after dark. The 10-hour treatment was closely equivalent to the normal period of daylight.

Temperatures were maintained at 60° to 63° F. at night and about 68° to 70° F. during the day. Spot checks of temperatures within the six cells were remarkably uniform; they never varied more than 3° F. between cells, but were always 1° to 2° F. above the recording thermometer in the center of the greenhouse. Humidity varied from 40 percent at night to 80-85 percent during the day. This unorthodox temperature-humidity relationship could be the result of moisture condensation at night on the cold walls of the greenhouse. Plants were watered from below with tap water so that the soil surface was always slightly moist.

Species tested in this study were C. ebenea Rydb., C. phaeocephala Piper, C. tolmiei Boott, and C. egglestonii Mack. Plant materials were 1-year-old plants grown from seed in pots in the greenhouse. The plants were set outside in late August and allowed to go dormant. When completely dormant (no evidence of green top growth), the old growth was cut off at 1.5 inches above the root crown. Each plant was then cut into four equal-sized clones, and each clone was planted in a 6-inch plastic pot. Clones were assigned at random to the six treatments.

[2]*Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

[3]*Billings, W. D., Clebsch, E. E., and Mooney, H. A. Photosynthesis and respiration rates of Rocky Mountain alpine plants under field conditions. Amer. Midl. Natur. 75: 34-44. 1966.*

Criteria used to evaluate the treatments were (1) number of days for the first inch of new growth to occur, (2) number of days until the first flower stalk appeared, (3) number of flower stalks per plant, (4) maximum length of leaves, and (5) green weight of top growth. The study started October 18, 1965, and ended December 12, 1965. At completion, all plants that were going to flower in a reasonable period of time had flowered, and most of the seeds were ripe.

Results

The average growth response of the test species was different for all criteria of evaluation: This response was expected. Furthermore, all four species responded to light intensities and photoperiod in the same way.

The level of light intensity had a significant effect only on the green weight of top growth. At the high level of intensity, average top growth was 5.4 grams per plant as compared with 4.5 grams per plant at the low level (table 1).

Photoperiod affected the green weight of top growth and the time required for the first seedstalk to appear. For both criteria, the longer photoperiods produced the best growth response. The average weight of tops was 5.6 grams per plant for the 18-hour period, 5.2 for the 14-hour period, and 4.1 for the 10-hour period. The number of days until the first flower stalk appeared was 13.3, 15.0, and 15.8 for the same photoperiods, respectively. C. tolmiei produced no flower stalks.

Discussion and Summary

The failure of light intensity to influence more of the measured growth criteria may have been due to the relatively poor control of light intensity during the study. On the other hand, it has been shown that sedges will grow and develop normally under very low light intensities.[4] Smith and Johnson[5] found that

[4]*Johnson, W. M. A comparison of the effect of two light sources on the growth of Carex. (In preparation for publication.)*

[5]*Smith, Dixie R., and Johnson, W. M. Vegetation characteristics on a high altitude sheep range in Wyoming. Wyo. Agr. Exp. Sta. Bull. 430, 14 pp. 1965.*

Table 1. --Summary of effects of light intensity and photoperiod on four Carex species

Species and photoperiod	Days, first inch		Days, first flower		Flower stalks		Average leaf height		Green weight of tops	
	High	Low	High	Low	High	Low	High	Low	High	Low
	Number		Number		Number		Centimeters		Grams	
C. ebenea										
18 hours	6.5	7.0	11.2	13.2	1.5	2.5	53.0	41.5	6.0	3.9
14 hours	7.2	7.5	14.2	14.0	3.8	2.2	42.8	55.5	6.6	5.5
10 hours	7.8	7.5	15.5	12.5	2.2	1.2	44.5	47.0	4.2	3.8
C. phaeocephala										
18 hours	7.0	7.0	10.8	11.2	12.0	7.2	21.8	29.5	3.4	2.5
14 hours	7.0	7.2	12.0	12.8	8.5	7.2	25.5	21.8	2.3	2.1
10 hours	7.5	7.0	14.2	12.0	5.2	6.2	26.2	19.8	2.0	1.2
C. tolmiei										
18 hours	7.8	7.8	--	--	0	0	39.2	36.2	9.0	7.4
14 hours	7.8	8.0	--	--	0	0	38.8	39.8	7.4	6.9
10 hours	7.0	7.5	--	--	0	0	38.2	39.5	7.4	4.9
C. egglestonii										
18 hours	8.8	8.0	16.8	.6.8	2.2	3.2	66.0	58.0	7.3	5.5
14 hours	9.0	10.2	19.5	17.5	2.0	3.5	55.8	54.5	5.6	5.2
10 hours	10.0	8.5	17.8	22.5	2.0	3.2	44.0	51.8	3.4	5.0

much of the growth of subalpine species occurs under snow cover.

The complete lack of flowering on C. tolmiei is somewhat unusual. Rhizomatous species such as C. tolmiei have never flowered as vigorously in the greenhouse as rootstock species such as C. ebenea, but C. tolmiei has flowered, although sparingly, under somewhat higher light intensities than were used in this study. Individual plants of the species do flower vigorously in their native habitat. It is quite possible that high light intensities may be needed to trigger flowering activity in the plant. For the other species tested, low light intensities do not inhibit flowering.

Photoperiod was positively controlled during the study, but it also affected only top growth and days until flowering. Although better growth was obtained with the longest photoperiod, growth still occurred with the shortest photoperiod tested.

Growth appeared normal under all conditions of light intensity and photoperiod. Leaves were a normal healthy green color. Seedstalks produced normal fruiting bodies, and the seeds appeared to be fully formed and viable. No morphological deformities were observed in any plant.

It is entirely possible that the results observed here are realistic, and simply indicate that the sedges are capable of adequate growth under a wide range of environmental conditions.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Ammonium Nitrate Encourages Decomposition of Ponderosa Pine Needles Under Laboratory Conditions

William H. Kruse[1]

Ammonium nitrate significantly affected litter decomposition; neither potassium phosphate nor Schubert's medium had an appreciable effect.

A heavy layer of litter is associated with low forage production in the ponderosa pine forests of the Southwest. More rapid decomposition of this litter may result in increased forage production of forested lands. The use of chemical treatments to accelerate pine needle decomposition was studied by applying the treatments under laboratory conditions.

Ponderosa pine (Pinus ponderosa Lawson) needles were gathered from branches of a single dead tree to insure uniformity and to eliminate possible contamination by soil. Ten grams of needles were placed in dacron sacks and closed with a numbered tag. Dacron is not readily decomposed.

The basic macronutrient treatments were a graded series of ammonium nitrate solutions from 1 to 1 x 10^{-5} molar (M). To one set of ammonium nitrate solutions, potassium phosphate was added at one-tenth the ammonium nitrate concentration (table 1). To another set, both potassium phosphate and Schubert's medium were added. Schubert's medium is designed to promote bacterial activity.

Four sacks of needles were soaked in each concentration of each treatment (table 1) for 75 minutes, and allowed to drain for 30 minutes. They were placed in a seed germinator and kept in a water-saturated environment at 80°F. After 2 months the sacks were ovendried and weighed. These weights were compared to pretreatment weights.

Analysis of variance showed a significant difference between chemicals, but differences between rates, or rates times chemical interaction, were not significant. Tukey's multiple range test was used to compare treatment means (table 1). Ammonium nitrate had the most significant effect, with the 0.01M solution being the most beneficial for decomposition. Neither the potassium phosphate nor the Schubert's medium had an appreciable effect.

It seems apparent from these observations that ammonium nitrate encourages pine needle decomposition in the laboratory. Further studies are necessary to determine how decomposition is affected by moisture and temperature, as well as the effect of these factors upon ammonium nitrate.

[1]*Range Research Technician, located at Flagstaff, in cooperation with the Northern Arizona University; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Table 1.--Decomposition of 10-gram pine needle samples as influenced by kind and amount of chemicals

Chemical and concentration	Mean weight loss	Significant differences[1]
	Grams	
Ammonium nitrate (NH_4NO_3)		
.01M	2.26	a
.001M	2.14	ab
.0001M	2.11	ab
1M	1.97	abc
.1M	1.87	bcd
Ammonium nitrate + Potassium phosphate (NH_4NO_3+ KH_2PO_4)		
.01M + .001M	2.01	abc
.1M + .01M	1.93	abc
.001M + .0001M	1.93	abc
.0001M + .00001M	1.82	bcd
1M + .1M	1.79	bcd
Ammonium nitrate + Potassium phosphate + "Schubert's medium"[2]		
.0001M + .00001M + 25 ml	1.97	abc
.01M + .001M + 25 ml	1.93	abc
.001M + .0001M + 25 ml	1.87	bcd
1M + .1M + 25 ml	1.83	bcd
.1M + .01M + 25 ml	1.76	cd
Checks	1.79	bcd

[1]Results from Tukey's multiple range test p. 251 from Snedecor, G. W. Statistical methods, Ed. 5, Ames: Iowa State Coll. Press. 1956. Letters indicate no significant difference from other treatments with the same letter. Difference of means greater than 0 = 0.36 were significantly different at the 5 percent level.

[2]In this study, Schubert's medium included 2.5 grams of $MgSO_4$, 5 grams of peptone, 7.5 grams of KH_2PO_4, and 10 milligrams of thiamin HCℓ, dissolved in 500 milliliters of tap water. Twenty-five milliliters of this medium were added to 500 milliliters of the graded ammonium nitrate solutions. See Ishikawa, H., Schubert, W. J., and Nord, F. F. Investigations on lignins and lignification. XXVII. The enzymic degradation of softwood lignin by white rot fungi. Arch. Biochem. Biophys. 100: 131-139. 1963.

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Alkali Sacaton Seedling Survival and Early Growth Under Temperature and Moisture Stress[1]

Earl F. Aldon[2]

The optimum growing conditions for alkali sacaton seedlings are 85°F. and soil moisture at field capacity. Seedlings seem to need rewatering after 5 or 10 days. If they received additional moisture during this time, survival was much better (91 percent to 99 percent) than if these young plants were forced to go longer before another wetting (survival dropped below 76 percent).

Flood plains on the Rio Puerco drainage in north-central New Mexico once grew thick stands of alkali sacaton (Sporobolus airoides Torr.) (Hickey and Springfield 1966). This plant is able to survive drought, excessive grazing, flooding, and sedimentation if managed properly (Aldon and Garcia 1967). Reestablishment of alkali sacaton would benefit many areas in need of soil stabilization.

The two studies reported here are part of a long-term cooperative study with the U. S. Bureau of Land Management to find ways to establish plants on eroding sites of the Rio Puerco to stabilize soils and increase their productivity. In the first study, alkali sacaton seedlings were subjected to several temperatures at two soil moisture levels to find optimum growing conditions; in the second, alkali sacaton seedlings were grown at the optimum temperature determined by the first study (85°F.), but subjected to 19 different watering schedules representative of the summer thundershower conditions that prevail in July and August. Alkali sacaton characteristically germinates during July and August, following the summer showers that often result in floods. Knipe (1968) found that germination of this plant is severely restricted with moisture tensions greater than 1 atmosphere (atm.).

We started our studies with wet conditions, allowed some soil drying, then rewet the soil at different time intervals, and measured seedling survival and root growth. Distilled water was used in all experiments.

Temperature and Moisture Stress Study

Methods

Two controlled-temperature water baths of the type described by Steele (1967) were used. In the first run, water temperature was maintained at 70°F. in one tank and 100°F. in the other tank. Other runs were made at 85°F. and 120°F., and 92°F. and 110°F. Water temperatures were monitored at 7 a.m., 2 p.m., and 7 p.m., daily during the runs, and never deviated more than 1°F. from the desired temperature.

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[1] *Study conducted in cooperation with U.S. Bureau of Land Management, Albuquerque, N. Mex.*

[2] *Principal Hydrologist, located at Albuquerque, in cooperation with the University of New Mexico; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

The experiment was designed as a split plot consisting of two water temperatures and two moisture levels (field capacity and one-half field capacity), with four replications per tank. To determine field capacity, a 5-quart pot was filled with 6,000 grams of air-dry soil, saturated, allowed to drain for 24 hours, and the water retained (800 grams, considered to be field capacity) determined by difference. Half of this amount (400 grams) was used as the one-half field capacity treatment.

Ten seeds were planted one-fourth inch deep in each pot. The pots were watered to prescribed levels and placed in the temperature tanks. One pot randomly selected in each treatment was wired with thermistors, at 2 inches and 5 inches below the soil surface, to monitor soil temperatures. Temperatures of soil and water were measured three times daily. Pots were weighed daily and watered to maintain moisture levels.

After 5, 10, and 15 days, seedlings were excavated by washing from two pots of each replication (one pot at each moisture level). Measurements were recorded for total length of root and longest shoot, oven-dry weight (24 hours at 140°F.) of roots and shoots, and number of seedlings surviving. Root length was determined by Newman's (1966) method.

Analyses were run to determine at which temperature and moisture level maximum growth, weight, and survival could be expected.

Results

Early in the study, results at the low 70°F. temperature and the very high temperatures of 110°F. and 120°F. indicated that not all combinations of analyses were warranted.

Seedlings grown at 85°F. survived significantly better and had larger and heavier roots and shoots (5 percent level) than those grown at other temperatures. Moisture levels proved nonsignificant in all 85°F. comparisons except at 120°F. Seedlings grown at 120°F. did poorly and needed high moisture levels to survive at all. Moisture levels had their greatest effect at these high temperatures. In tests of 100°, 110°, or 120°F., high moisture levels gave significantly better results (5 percent level) than low levels on 5- and 15-day-old seedling root length and seedling survival. All pot temperatures at 5 inches were within 2°F. of water bath levels throughout the study. Those at 2 inches were between 2° and 6°F. of water bath levels. It was harder to maintain high temperatures (100°, 110°, and 120°F.) at the 2-inch soil level than it was at lower temperatures (70°, 85°, and 92°F.).

Moisture Stress Study

Methods

The same controlled temperature tanks were used as in the first study, but the optimum temperature of 85°F. was maintained in both. Nineteen different watering schedules were tried (table 1). Seedlings were excavated at the end of each schedule.

To determine field capacity, a known weight of soil was placed in five 1-quart plastic milk cartons which were saturated, allowed to drain for 24 hours, and the weight of water retained determined by difference. This predetermined amount of distilled water was added to each pot initially after five seeds of alkali sacaton were planted at 1/4-inch depth. On the day rewatering was prescribed, the

Table 1.--Moisture stress treatment schedule

Treatment No.	Water: Daily	Water: Initially	Drying period	Rewater	Redrying period
	Days		Days		Days
1	5				
2	10				
3	15				
4	20				
5	25				
6		x	5		
7		x	10		
8		x	15		
9		x	20		
10		x	25		
11		x	5	x	5
12		x	10	x	5
13		x	15	x	5
14		x	20	x	5
15		x	5	x	10
16		x	10	x	10
17		x	15	x	10
18		x	5	x	15
19		x	10	x	15

pots were weighed and brought back up to their initial weight. Length of roots was determined after excavation as in the first study. Surviving seedlings were counted and the percent transformed to arc sin for analyses of variance.

A randomized, incomplete block with a balanced design was used. This design had 19 treatments, 9 units per block, and 9 replications (Cochran and Cox, 1957, p 526). Percent survival and root growth were compared to find the critical times when seedlings need moisture:

Treatments compared	Conditions
	(Age of seedlings, days)
1-6	5
2-7-11	10
3-8-12-15	15
4-9-13-16-18	20
5-10-14-17-19	25
	(After rewatering, plus days of growth)
11-12-13-14	5
15-16-17	10
18-19	15

Results

In general, survival was better after 5, 10, 15, and 20 days in those pots that were rewatered (treatments 11, 12, 13, 15, 16, 18). Survival dropped off in pots wetted at the study start and let dry for 15 days or longer (treatments 8, 9, 10). Daily watering yielded poor results in the first 15 days (treatments 1, 2, 3). In all eight comparisons, F values were significant at the 1 percent level. To test which treatments were best, a multiple range test was run on seedling survival (table 2).

Also, in treatments 11 to 19 where pots were rewatered, survival was better in the pots that received water 5 days after planting than those rewatered after 10, 15, or 20 days.

A pattern can be seen among the 90-percent-or-better survival figures (table 2). This group of treatments (6, 7, 11, 12, 15) are significantly better than all others. Treatments 6 and 7 showed good survival from 5 to 10 days without rewatering. After this time survival dropped off. Plants need rewatering after 5 or 10 days if they are to do well (treatments 11, 12, and 15). This would indicate that moisture during the first 10 days of a seedling's life is critical to survival. Kramer (1963) has noted

Table 2.--Survival of alkali sacaton seedlings

Treatment number	Adjusted mean (Percent)
7	[1]99.3a
12	98.7a
11	98.5a
6	93.3a
15	91.3a
9	75.9b
8	74.2b
13	72.2b
5	72.2b
18	66.1bc
16	61.3bcd
4	54.3bcde
17	44.5cdef
10	40.7def
14	38.6def
3	30.8ef
2	22.1f
1	20.3f
19	17.7f

[1]Any two means not followed by the same letter are significantly different (.05 level, Snedecor 1956, p. 253).

that the water content of plant tissues varies with the species, organ, age, season, and time of day, and that young plant tissues have high moisture contents. This need for more moisture in young plants may account for the better survival in those plants receiving additional water soon after they emerge.

Adjusted means for root length per pot show the expected pattern of longer mean root lengths for the older seedlings. When seedlings were subjected to long periods of drying, more of them died, but those that survived grew large root systems that reached down to the water that was available.

General Observations

Typical seedlings developed prominent lateral branches somewhere after the 5th but before the 10th day (fig. 1). Roots thickened after the seedling began manufacturing food from its leaves. On the 5th day after planting, primary roots were about 30 mm., shoots about 12 mm. long (just emerging from one-fourth inch), and lateral roots were about 0.5 mm. long—just starting to develop.

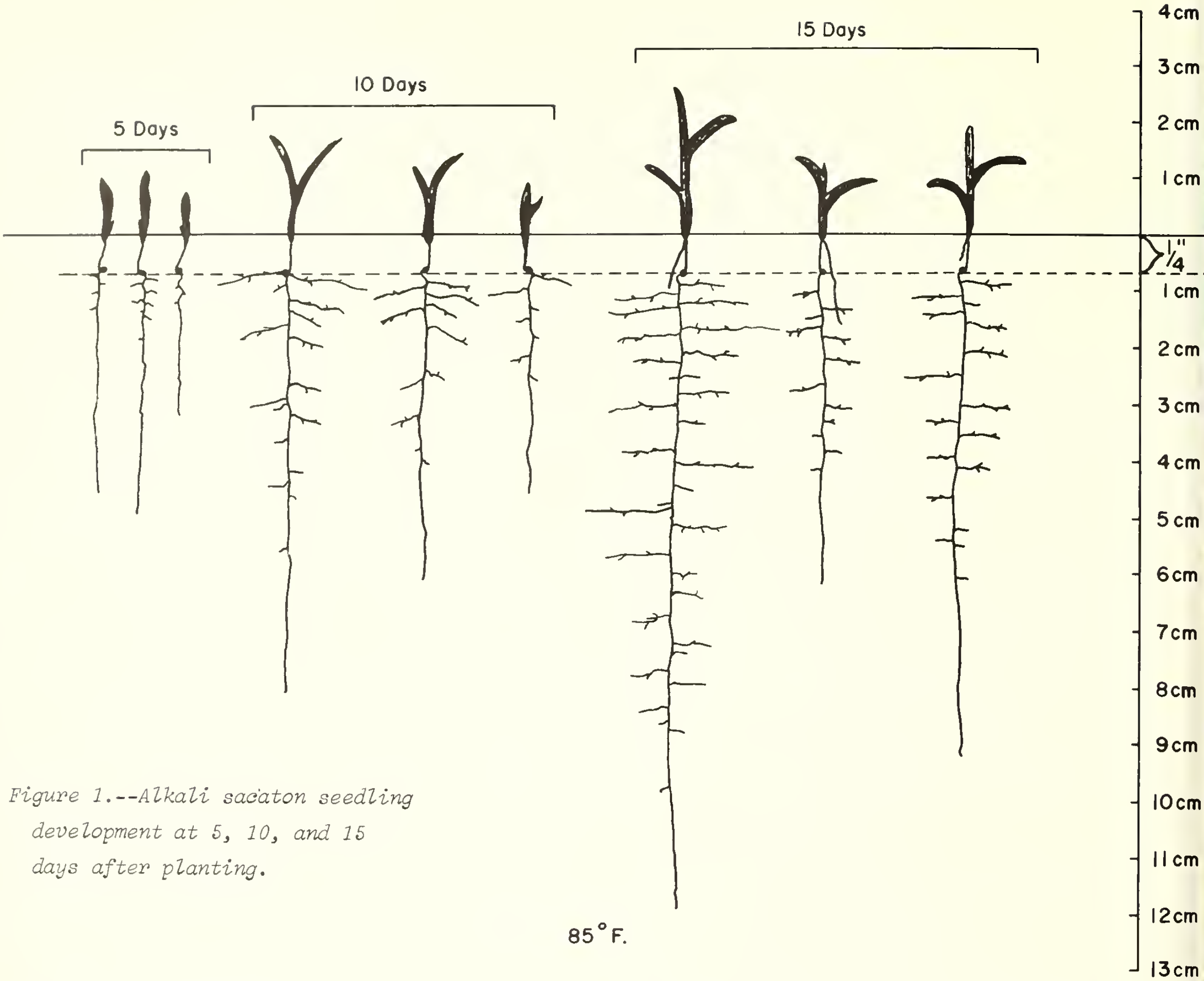

Figure 1.--Alkali sacaton seedling development at 5, 10, and 15 days after planting.

After 6 days, the second leaves usually appeared. By the 8th day, about 30 percent of the plants had two leaves, and shoots were about 20 mm. long.

By the 10th day, primary roots averaged 40 to 50 mm. long, and lateral branching averaged 12 per seedling with many up to 10 mm. long.

The 15-day-old seedlings had primary roots over 100 mm. long. Lateral roots were numerous and well developed. A heavy adventitious root was evident, which originated from the stem just below the soil surface. Most seedlings had three leaves.

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FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Incidence of Sperm in Emerging Female Mountain Pine Beetles

Dendroctonus ponderosae Hopkins (Coleoptera: Scolytidae)

William F. McCambridge[1]

Approximately 15 percent of female mountain pine beetles, Dendroctonus ponderosae Hopkins (Coleoptera: Scolytidae), examined during the normal brood emergence period from field-infested ponderosa pine contained spermatozoa. In laboratory tests where parent females were accounted for, less than 2 percent of brood females contained sperm.

The attraction of Dendroctonus bark beetles to specific trees is greatly enhanced by the pheromones produced by unmated females.[2] Pheromone production ceases soon after mating.[3] Reemerged mated females making their second attack also produce considerable attraction. This reemergence usually occurs within a month or two after the original attack, but a few parent females are known to emerge with the brood.

Recent examinations of female mountain pine beetles, D. ponderosae, showed that a fair percentage of those emerging and thought to be virgin brood could produce progeny of their own in the absence of males. (Parthenogenesis was dismissed based on investigations by Gibson[4] and Reid[5]) Since mated and virgin females may respond differently to attractants and thus affect the results of pheromone tests, the number of female "brood" containing sperm needed to be determined.

Procedure

Female beetles were collected periodically throughout the middle portion of the 1968 emergence

[1]*Entomologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Rudinsky, J. A. Response of Dendroctonus pseudotsugae Hopkins to volatile attractants. Contrib. Boyce Thompson Inst. 22: 23-38, illus. 1963.*

[3]*Jantz, O. K., and Rudinsky, J. A. Studies of the olfactory behavior of the Douglas-fir beetle, Dendroctonus pseudotsugae Hopkins. Oreg. Agr. Exp. Sta. Tech. Bull. 94, 38 pp., illus. 1966.*

[4]*Gibson, A. K. Parthenogenesis of Dendroctonus monticolae Hopk. 2 pp. 1927. (Unpublished report issued by Forest Insect Lab., U. S. Dep. Agr., Forest Serv., Coeur d'Alene, Idaho.)*

[5]*Reid, R. W. Biology of the mountain pine beetle, Dendroctonus monticolae Hopkins in the East Kootenay region of British Columbia. II. Behavior in the host, fecundity and internal changes in the female. Can. Entomol. 94: 605-613, illus. 1962.*

period from three naturally infested groups of trees near Redfeather Lakes, Colorado. A total of 400 females were examined for sperm from group I, 98 from group II, and 218 from group III. On the days of examination, all females that emerged were examined. Beetles were sexed according to the morphological characters of the abdomen described by Hopkins. [6]

The examination for sperm was made as follows: The live female was grasped venter upward, and the sides of the abdomen were firmly squeezed so that the vagina, accessory glands, spermatheca, and spermathecal pump were extruded (fig. 1). The pump and attached spermatheca, clearly visible under 40 magnifications, were removed with a teasing needle, placed in a drop of physiological saline solution on a microscope slide, and covered. The spermatheca was examined at 320 magnifications (fig. 2), and best results were obtained when dark field illumination was used.

As a check on the above dissections, a brood of mountain pine beetles was produced in the laboratory from parent stock from the Redfeather study area. On green pine bolts, 124 females were placed in isolated pairs with 124 males. After 4 days, the bark was removed, the males destroyed, and the presumably mated females forced to attack fresh bolts. Emerging parent females were destroyed as they emerged. Each of the 679 female brood emerging from the bolts after 45 days was examined for sperm.

[6]Hopkins, A. D. Contributions toward a monograph of the scolytid beetles. I. The genus Dendroctonus. U.S. Dep. Agr. Tech. Ser. 17, Part I, pp. 1-164, illus. 1909.

Figure 2.--Spermathecal pump (A) with attached spermatheca (B) and spermatozoa (C).

Results

Spermatozoa were found in 15 percent of 716 mountain pine beetle females sampled during the middle portion of the 1968 emergence period (fig. 3). These beetles emerged from bolts cut from three groups of naturally infested trees. Group I produced 12.8 percent sperm-carrying females; group II, 18.4 percent, and group III, 15.1 percent. The differences are believed due to sampling.

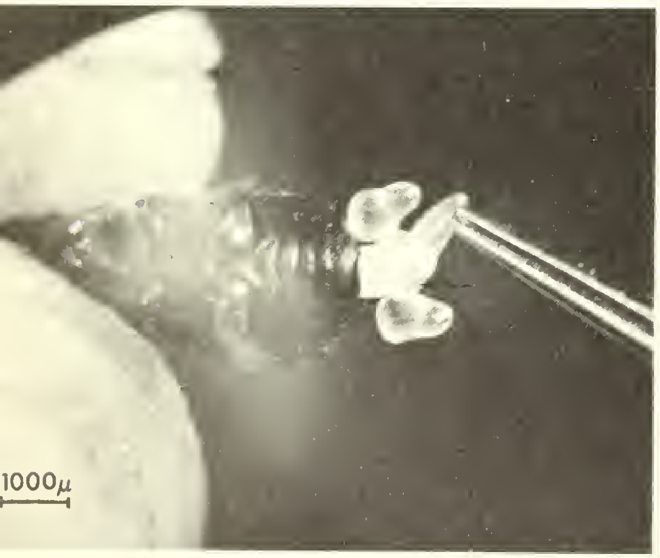

Figure 1.--Accessory glands, vagina, and spermathecal pump (arrow) of mountain pine beetle extruded by squeezing sides of the insect.

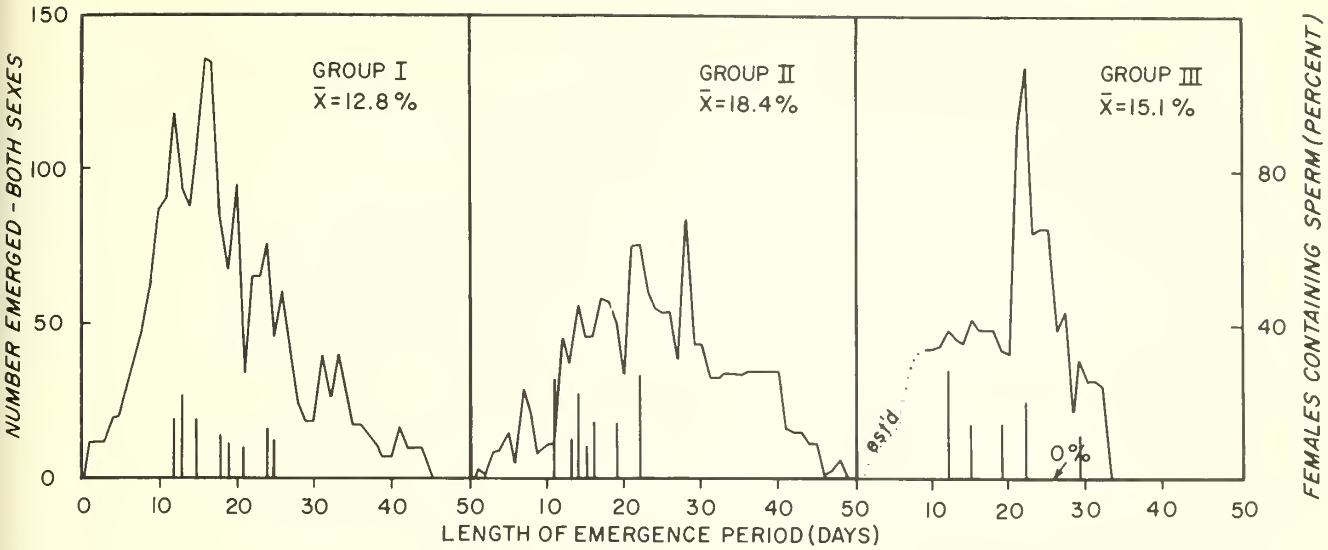

Figure 3.--Percent of emerging female mountain pine beetles containing sperm (vertical bar) in relation to emergence of three separate groups of beetles. Mean seasonal percentage from samples is shown above.

The laboratory rearings, on the other hand, produced a brood in which approximately 2 percent of the females contained sperm. A few of these were no doubt parent females. These data agree with Reid [7] who found for the mountain pine beetle that "...freshly emerged females showed that less than 1 percent had mated before they emerged. The mated females were the last to emerge..."

[7] *Reid, R. W. The behavior of the mountain pine beetle Dendroctonus monticolae Hopk. during mating, egg laying and gallery construction. Can. Entomol. 90: 505-509, illus. 1958.*

The data obtained from our field population of emerging females is at such variance with Reid [7] and our laboratory emerging female brood that one must suspect that the former contained about 14 percent parent females. Thus, persons testing attractant responses should bear in mind that a fair proportion of females collected throughout the emergence may contain spermatozoa, and this may influence their response to attractants. Adult D. ponderosae frequently cluster prior to emergence. This physical proximity would make mating a simple matter. Additional field and laboratory work are needed to clarify the situation.

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U.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Aspen Grove Use by Deer, Elk, and Cattle in Southwestern Coniferous Forests

Hudson G. Reynolds[1]

Aspen groves within mixed conifer forests produce more herbaceous understory than adjacent forest. Thinning aspen groves improves herbaceous understory and aspen regeneration. Higher deer and cattle use of aspen groves is associated with the greater abundance of understory vegetation.

Introduction

When mixed conifer forests of the Southwest are disturbed by fire, insect attacks, or logging, aspen sprouts are released. If forest growth is severely damaged, dense stands of aspen may subsequently develop. Normally, coniferous reproduction gradually establishes beneath aspen stands and eventually replaces them. Aspen stands in various stages of replacement are fairly common in coniferous forests of the Southwest (fig. 1A).

This report suggests the relative importance of aspen groves in mixed conifer forests to elk, deer, and cattle. Such knowledge should be helpful in designing habitat improvement measures for multiple use management of these lands.

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Figure 1.--Character of aspen groves studied:

ispersion of aspen groves n a mixed conifer forest.

Interior view of unthinned aspen grove, Apache National Forest.

Areas and Methods

The study was conducted on the Apache and Coconino National Forests in Arizona. On the Apache National Forest, five natural aspen groves from 15 to 22 acres in size were studied (fig. 1B). Aspen groves were checked against adjacent stands of mixed conifer forest at a distance of about one-fourth mile.

On the Coconino National Forest, three aspen groves were studied. About half of each grove had been thinned 2 growing seasons previous in an attempt to improve both aspen regeneration and understory forage production. Unthinned portions of these aspen stands were used as check plots.

From 8 to 11 sample plots were established at random in each natural or thinned aspen patch and in each adjacent check area, for a total of 54 plots on the Coconino Forest and 90 plots on the Apache Forest. Basal area of trees was determined with a wedge prism. Aspen sprouts were counted on 1/10-acre plots, pellet groups on 1/50-acre plots; weight of herbaceous plants was estimated by double-sampling on 96-square-foot plots. Significance of sampling differences was tested by a simple "t" statistic.

Although the same species of trees were found in aspen groves as in adjacent coniferous forests (table 1), there was lesser basal area of conifers and greater basal area of aspen in the aspen groves. Similarly, the same tree species were present on unthinned as on thinned aspen plots, with lesser basal area on the latter.

Understory Production

Apache National Forest.—Herbaceous vegetation beneath aspen groves differed from that beneath mixed conifer forests in both amount and variety of species (table 2). The most abundant herbaceous species associated with mixed conifer forests were: bromegrass and Arizona fescue among the grasses, the fleabanes, vetches, geraniums, and strawberries among the forbs. All of these species were found also in aspen groves. Bromegrasses, miscellaneous grasses, and vetch were outstandingly more abundant in aspen groves. Also, number of species was greater in the aspen groves, although these miscellaneous species were not individually important in the herbaceous composition. Aspen groves produced a statistically significant difference of about 14 times

Table 1.--Basal area of overstory trees on study areas on the Apache and Coconino National Forests

Tree species	Apache		Coconino	
	Unthinned aspen	Conifer forest	Unthinned aspen	Thinned aspen
	- - - - Square feet per acre - - - -			
Quaking aspen *Populus tremuloides* Michx.	156	21	299	42
Douglas-fir *Pseudotsuga menziesii* (Mirb.) Franco	7	44	--	--
Subalpine fir *Abies lasiocarpa* (Hook.) Nutt.	13	46	--	--
Engelmann spruce *Picea engelmannii* Parry	13	39	--	--
Ponderosa pine *Pinus ponderosa* Lawson	--	--	131	67
Gambel oak *Quercus gambelii* Nutt.	--	--	30	13
Total	189	150	460	122

Table 2.--Comparison of herbaceous understory in mixed conifer forests with included aspen groves on the Apache National Forest

Species	Aspen grove	Mixed conifer forest
	- - Pounds per acre - -	
PERENNIAL GRASSES AND SEDGES:		
Arizona fescue *Festuca arizonica* Vasey	15	5
Bromegrass *Bromus* spp.	95	10
Others	100	[1] T
Total	210	15
FORBS:		
Agoseris *Agoseris* spp.	T	T
Fleabane *Erigeron* spp.	35	25
Geranium *Geranium* spp.	5	5
RockyMountain iris *Iris missouriensis* Nutt.	5	0
Swertia *Swertia* spp.	5	T
Thistle *Cirsium* spp.	T	0
Vetch *Vicia* spp.	175	15
Western yarrow *Achillea lanulosa* Nutt.	T	T
Wild strawberry *Fragaria ovalis* (Lehm.) Rydb.	5	5
Others	15	10
Total	245	60
	- - Number per acre - -	
SPROUTS:		
Quaking aspen *Populus tremuloides* Michx.	94	219

[1] T = Trace.

the yield of grasses and about 4 times the yield of forbs as mixed conifer forests.

Aspen sprouts were more abundant beneath mixed conifers than within aspen groves. The greater abundance of sprouts under the forest may be the result of heavier grazing in aspen stands by both deer and cattle. Dropping groups of these animals were more numerous in aspen stands.

Coconino National Forest.—Thinned stands of aspen on the Coconino National Forest produced more herbaceous understory than unthinned stands. Bromegrass and Kentucky bluegrass (*Poa pratensis* L.) responded most to thinning among the grasses, and geraniums and swertia among the forbs. Compared to unthinned stands, thinned stands of aspen produced more than three times the yield of perennial grasses and about two times the yield of forbs. Production of aspen sprouts was stimulated by thinning, particularly where root systems were severed by soil disturbance (fig. 2).

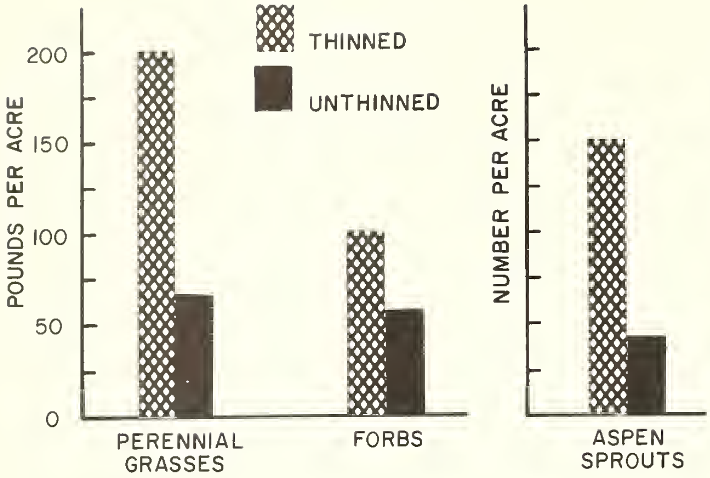

Figure 2.--Comparative production of perennial grasses, forbs, and aspen sprouts in thinned and unthinned aspen groves, Coconino National Forest, Arizona. (Differences are statistically significant.)

Game and Livestock Use

Estimates of comparative use of aspen groves by deer, elk, and cattle were based upon counts of accumulated dropping groups. Dropping groups of deer and cattle were more abundant in aspen groves on the Apache National Forest than in adjacent mixed conifer forests; differences in numbers of elk dropping groups were not significant statistically:

	Dropping groups per acre	
	Aspen	Mixed conifer
Deer	176	107
Cattle	129	31
Elk	38	33

The thinned plots of aspen were not utilized as much as unthinned plots, as measured by dropping groups, in spite of more forage. When the aspen plots were thinned, fallen trees created barriers to use by cattle. These barriers permitted aspen sprouts to develop without browsing, and allowed the herbaceous understory to recover without grazing. The fallen trees proved as effective barriers for deer and elk as for cattle. Comparative numbers of dropping groups on thinned and unthinned plots on the Coconino Forest, where elk populations exceeded those of the Apache Forest, were:

	Dropping groups per acre	
	Thinned plot	Unthinned plot
Deer	60	90
Cattle	90	130
Elk	140	290

Conclusions

1. Aspen groves within mixed conifer forests of Arizona yielded about six times more understory herbaceous plants than adjacent mixed conifer forests.
2. Thinning patches of aspen and associated coniferous reproduction in ponderosa pine forests to about three-fourths basal area produced about 2½ times as much herbaceous understory and increased production of aspen sprouts by 4 times.
3. Deer and cattle use, but not elk use, was greater within natural aspen groves, as measured by accumulated pellet group counts.
4. Fallen timber in the thinned aspen plots prevented deer, elk, and cattle from completely utilizing the more abundant forage therein.
5. Preserving or providing for an interspersion of aspen groves in a mixed conifer forest and encouraging existing aspen groves in ponderosa pine forests should effectively improve habitat for deer.

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FOREST SERVICE
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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Deer and Elk Use of a Ponderosa Pine Forest in Arizona Before and After Timber Harvest

David R. Patton[1]

Animal use increased to almost six deer and elk per section per year on the cut watershed. During the same period, use on an adjacent uncut forest changed little. The new environment provided additional food while maintaining sufficient vegetation for cover.

The ponderosa pine forest, comprising approximately 9 million acres, is a major wildlife habitat in Arizona and New Mexico. It is found between elevations of 5,500 to 8,500 feet, and is inhabited seasonally by deer and elk. Management practices that alter the plant communities in the pine forest also affect its animal life.

Wildlife managers need information on how timber harvesting affects the distribution and abundance of game animals. From information provided by research, administrative guidelines can be developed for multiple use coordination with timber management on wild lands. This Note reports the first 4 years of a long-term study designed to evaluate the effects of timber management on wildlife.

Literature Review

Timber harvesting has been recommended more than other techniques to create or maintain wildlife habitat. The cutting of timber does two things: First, herbage production is increased for several years after a reduction in overstory; and, second, a more diversified habitat is created.

Several examples suggest how overstory reduction increases herbage production. Browse in loblolly pine[2] varied from 90 pounds per acre under light thinning to 137 pounds with heavily thinned stands (Blair 1960). Herbage increased from 75 pounds with 100 percent tree cover to 425 pounds at 20 percent cover in the pine-hardwood forests of Texas

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[2]*Common and scientific names of plants and animals mentioned are listed on p. 7.*

(Halls and Schuster 1965). Other studies[3,4] (Cook 1939, Westell 1954, Pase and Hurd 1957) show a similar relation between overstory reduction and increased herbage production.

Some information is available on the time required for herbage production on logged areas to revert to prelogging conditions. On the Kaibab National Forest, production of herbage peaked at 6 years after cutting and then started to decline. After 15-20 years, it was about the same as on an uncut area (Reynolds 1962). In the redwood region of northern California, deer reached a high from 5 to 10 years after cutting, then declined until 20 years after cutting when the forest reached a tall shrub stage (Dasmann 1964).

Deer are considered a product of a subclimax forest, and plant succession can be manipulated to benefit them by rotational forest cutting (Leopold 1949). Large blocks of cutover land, while valuable for wildlife, do not have as great a value as smaller units that produce more miles of forest edge (Gabrielson 1936). In Arizona, deer and elk seem to prefer small openings of less than 20 acres in spruce-fir habitat (Reynolds 1966).

Study Watersheds

The Castle Creek watersheds (East and West Forks) are located at approximately 8,000-foot elevation, 12 miles southwest of Alpine, Arizona. The watersheds were designated as research areas in 1955 to determine how methods of harvesting ponderosa pine affect water and sediment yields. West Fork watershed (treatment) contains 900 acres and East Fork (control) has 1,163 acres.

Overstory vegetation in West Fork is principally ponderosa pine with an understory of Gambel oak. Douglas-fir, true firs, southwestern white pine, and quaking aspen are found on the cool, moist, north-facing slopes.

[3]McGinnies, B. S. The effects of forestry cutting practices on the production of deer browse in the Virginia pine (Pinus virginiana) type. 71 pp. 1949. (Unpublished master's thesis on file at Penn. State Coll., Univ. Park.)

[4]Patton, David R. The influence of forest cutting on browse availability. 57 pp. 1963. (Unpublished master's thesis on file at Va. Polytech. Inst., Blacksburg.)

Browse species include Gambel oak, quaking aspen, Fendler ceanothus, and New-Mexican locust. Mountain muhly, Junegrass, and bottlebrush squirreltail are the characteristic grasses. Common forbs present are horse cinquefoil, western yarrow, and RockyMountain iris.

Game species indigenous to the area are mule deer, white-tailed deer, Rocky Mountain elk, black bear, Merriam's turkey, Abert squirrel, red squirrel, and cottontail rabbit.

The watersheds are in Arizona Game Management Unit lA. Deer kill data from this unit indicate a steady decline in numbers from 1961 (42 percent hunter success) to 1967 (18 percent hunter success). Deer and elk move into or through Castle Creek in April and May. Snow conditions drive the animals onto the adjacent, but lower, Blue Range Primitive Area in late October or November. Only in very mild weather could Castle Creek be used as winter range.

Sampling Design

The forest was inventoried by watershed research in 1964 by means of a systematic sample with random starts. Sixteen transects were installed in each watershed with sample points spaced at 440-foot intervals. Each transect had from 25 to 50 points, for a total of 186 points in West Fork and 178 in East Fork.

The identification stake at each point was used as a center for different-sized circular plots to count browse plants and pellet groups, and to clip herbage. Browse was considered to be plants from 1 to 4.5 feet in height. Plants were counted (July 1964 and July 1968) on 69 square-foot plots. Herbage on one 9.6-square-foot plot was clipped at the same time.

Deer and elk pellets and cow chips were counted on 1/100-acre plots before and after the timber harvest. Pellets found in the first count (August 1964) were deposited over an unknown period, and were used only to delineate possible concentration areas.

Logging was begun in West Fork watershed in October 1966 and was completed by August 1967. The cutting method emphasized removal of poor risk and overmature trees. Trees over 11 inches d.b.h. were reduced from 45 to 12 per acre. One-sixth (150 acres) of the watershed was clearcut in patches from 2 to 32 acres (fig. 1). The remaining acreage is in thinned stands of saplings (1 to 3 inches d.b.h.) and poles (4 to 11 inches d.b.h.).

Two pellet counts were made after the timber harvest. One count was in October 1967. Deer pellet groups from this count were not over 6 months old, and were converted to a per-year basis. The elk pellet groups had been covered by snow and were considered to be 1 year old. The other count was in October 1968. Groups from both years were plotted as an isogram to delineate use areas. Any area over 50 acres with 6 days use per acre per year (78 pellet groups, 10.5 animals per section) was accepted as a concentration area.

Wildlife observations were recorded throughout each year by U. S. D. A. Forest Service personnel working in the watersheds. Intensive surveys were made in October of 1965, 1967, and 1968 by wildlife technicians working on the pellet transects.

Results

In 1964, before logging, one deer pellet accumulation area of approximately 80 acres (8.8 percent of the watershed) was found in West Fork on a south-facing slope where Gambel oak and New-Mexican locust were available as browse. An average of 561 pellet groups per acre were deposited at this site, compared to 83 pellet groups per acre for the surrounding area. Since the pellets had accumulated over an unknown period, the days use per acre was not estimated.

There was no large accumulation of elk pellets in either watershed before the timber harvest. From a topographic map and isogram, it was evident cow chips were concentrated on areas of less than 15 percent slope.

A pellet count, 2 months after logging was completed in August 1967, showed the most deer groups per acre to be on the same concentration area as in 1964. Days use per acre was estimated to be 2.05 as compared to 1.50 for the rest of the watershed.

Fourteen months after the timber harvest, days use per acre on the 80 acres increased from 2.05 to 7.69—a change of 5.64 days use or 9.9 deer per section per year. At the same time the surrounding 820 acres showed an increase from 1.50 to 2.60 days use per acre, or 1.9 deer per section. There were not enough cow chips after the timber harvest to form an isogram.

Average days use per acre for deer in West Fork watershed in October 1967 was 1.58 (table 1). Days use increased to 3.26 by October 1968—a change of 2.9 deer per section. The adjacent uncut watershed (East Fork) had 0.70 days use in 1967 and 0.67 days use in October 1968.

Elk days use increased from 0.28 in October 1967 to 1.93 days use per acre in 1968 for an increase of 2.7 elk per section in West Fork. East Fork showed an increase from 0.18 to 0.71 days use per acre—less than 1 animal per section.

Herbage production in July 1968 increased over 100 percent from pre-cut conditions, exclusive of forage consumed by wildlife:

	Herbage production	
	July 1964	July 1968
	(Pounds per acre)	
Forbs	30	90
Grass	50	70
Total	80	160

Grass production includes both native plants and those established by seeding logging roads and skid trails. The increase in forbs was all from native plants. After the timber harvest, the number of browse plants increased from 525 to 820 per acre:

	Browse plants	
	July 1964	July 1968
	(Number per acre)	
Fendler ceanothus	30	120
Gambel oak	305	540
New-Mexican locust	155	70
Quaking aspen	35	90
Total	525	820

The browse available was almost entirely from new plants or sprouts. Of the four species, only New-Mexican locust did not increase.

Wildlife observations indicate there are two main periods of use in Castle Creek. Deer and elk move through the watersheds on their way to summer range in May and June. Days use during this

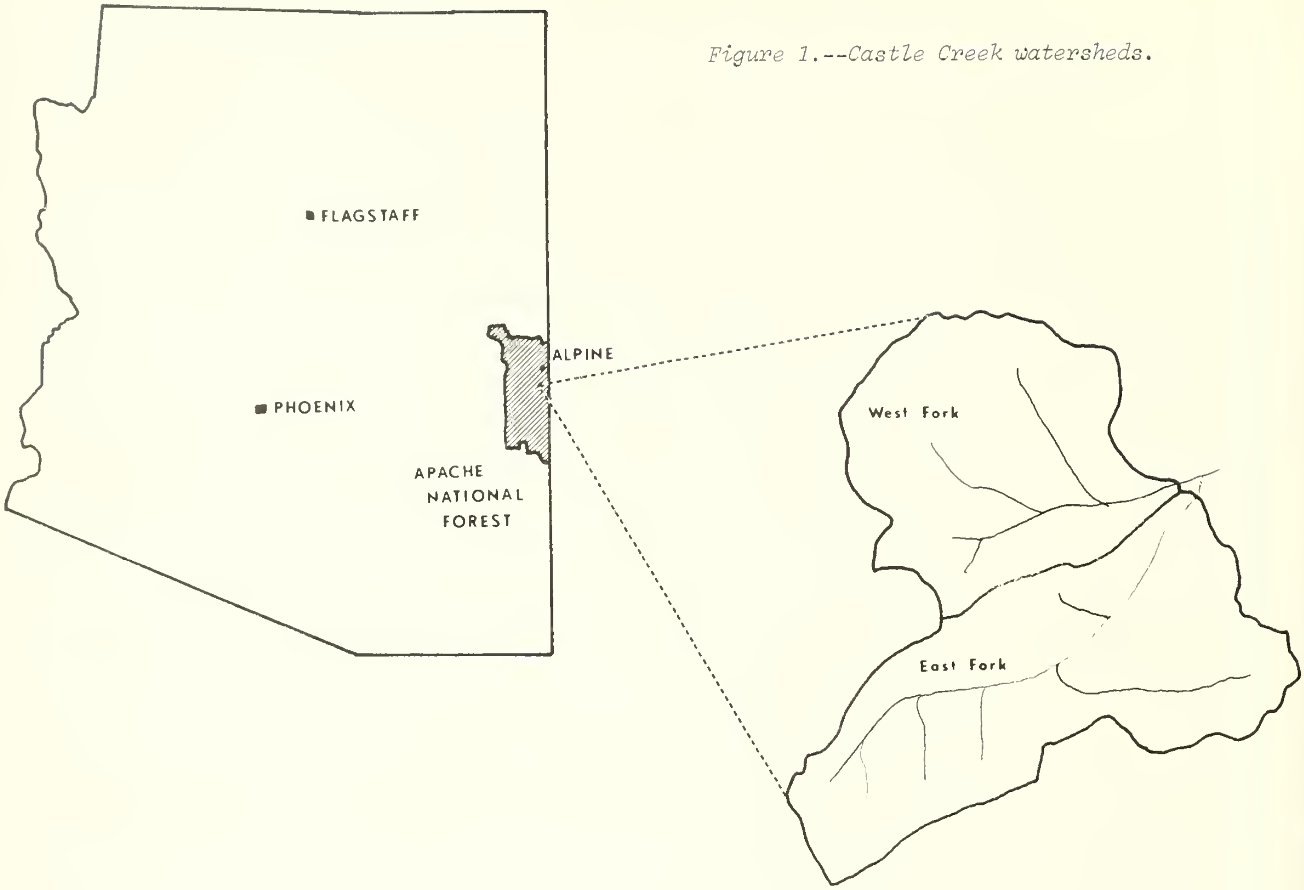

Figure 1.--Castle Creek watersheds.

AERIAL PHOTOGRAPHS OF WEST FORK WATERSHED

Prior to timber harvest

Following timber harvest

WEST FORK WATERSHED
(CAMERA POINT 3):

Prior to timber harvest

2 months following timber harvest

1 year following timber harvest

Table 1.--Deer and elk days use per acre on West (cut) and East Fork (uncut) watersheds

Date of pellet count and changes observed	West Fork (timber harvested August 1967)		East Fork (uncut)	
	Deer	Elk	Deer	Elk
	- - - Days use per acre per year - - -			
October 1967	1.58	0.28	0.70	0.18
October 1968	3.26	1.93	0.67	0.71
Difference	+1.68	+1.65	-0.03	+0.53
	- - - Number animals per section - - -			
Difference	+2.9	+2.7	-0.5	+0.8

period probably does not exceed one-half day per acre. A few animals remain in the watershed during the summer months. By October, deer and elk again move into Castle Creek, lingering there until the snow drives them onto lower winter range.

Discussion

The data from West Fork of Castle Creek indicate that timber harvesting has had a beneficial effect on deer and elk up to 14 months after cutting. An increase in days use per acre is associated with an overstory reduction followed by an increase in browse, forbs, and grasses.

Animal use increased to almost six deer and elk per section per year on the cut watershed. During the same period, use on an adjacent uncut forest changed little. Pellet accumulations on a south-facing slope increased to 10 deer per section on an 80-acre area. Observations in the watershed indicate that use is highest during October-November.

The timber harvest in West Fork has created a diverse environment from a monotonous habitat by separating the forest into small openings with scattered stands of saplings, poles, and sawtimber. The new environment has provided additional food while maintaining sufficient vegetation for cover.

The benefits also have been extended to hunters who have found easy access and good hunting conditions in the cut area. Even though the increased deer and elk use is for a short season, it coincides with the fall hunting. In 1967, four deer and one elk were harvested within the 900-acre, cut watershed.

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COMMON AND SCIENTIFIC NAMES OF PLANTS AND ANIMALS MENTIONED

Plants

Aspen, quaking	*Populus tremuloides* Michx.
Ceanothus, Fendler	*Ceanothus fendleri* A. Gray
Cinquefoil, horse	*Potentilla hippiana* Lehm.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Firs, true	*Abies* spp.
Iris, RockyMountain	*Iris missouriensis* Nutt.
Junegrass	*Koeleria cristata* (L.) Pers.
Locust, New-Mexican	*Robinia neomexicana* A. Gray
Muhly, mountain	*Muhlenbergia montana* (Nutt.) Hitchc.
Oak, Gambel	*Quercus gambelii* Nutt.
Pine, loblolly	*Pinus taeda* L.
Pine, ponderosa	*Pinus ponderosa* Lawson
Pine, southwestern white	*Pinus strobiformis* Engelm.
Squirreltail, bottlebrush	*Sitanion hystrix* (Nutt.) J. G. Smith
Yarrow, western	*Achillea lanulosa* Nutt.

Animals

Bear, black	*Ursus americanus amblyceps* Baird
Deer, mule	*Odocoileus hemionus crooki* (Mearns)
Deer, white-tailed	*Odocoileus virginianus couesi* (Coues & Yarrow)
Elk, Rocky Mountain	*Cervus canadensis nelsoni* V. Bailey
Rabbit, cottontail	*Sylvilagus nuttallii pinetis* (J. A. Allen)
Squirrel, Abert	*Sciurus aberti aberti* Woodhouse
Squirrel, red	*Tamiasciurus hudsonicus mogollonensis* (Mearns)
Turkey, Merriam's	*Meleagris gallopavo merriami* Nelson

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FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Selective Control of Brush on Chaparral Watersheds with Soil-Applied Fenuron and Picloram

Edwin A. Davis and Charles P. Pase[1]

Pelleted fenuron and picloram were applied by hand as spot treatments. Desirable browse species for big game can be retained by this method. Picloram, at half the application rate of fenuron, was less toxic than fenuron to the oaks, but more toxic to the other shrubs. Season of application, particularly as it relates to precipitation pattern, is important in the performance of soil-applied herbicides in Arizona.

The objective of watershed research in the chaparral type of Arizona is to improve water yield by reducing brush density. Since chaparral areas also produce big game, it is important to know the influence of vegetation management practices on game habitat potential. Hopefully, outputs of both water and game can be increased through manipulation of vegetation.

Until recently, the phenoxy herbicides—2,4,5-T (2,4,5-trichlorophenoxyacetic acid) and silvex(2-(2,4,5-trichlorophenoxy) propionic acid)-have provided the chief means of controlling chaparral brush (Schmutz and Whitham 1962, Lillie 1963, Pase 1967). However, because it has not been possible to eradicate the resistant sprouting species, even with repeated annual applications, other herbicides were sought. Soil applications of fenuron and picloram were effective in greenhouse tests on shrub live oak[2] (Davis 1961, 1964). Field tests also demonstrated the effectiveness of fenuron on shrub live oak (Davis and Lillie 1961, Lillie 1962) and prompted the use of soil-applied herbicides for the control of brush on chaparral watersheds.

[1]*Plant Physiologist and Plant Ecologist, respectively, located at Tempe, in cooperation with Arizona State University; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Common and botanical names for plants mentioned are listed on page 4.*

This is a report of the results of hand applications of pelleted fenuron (3-phenyl-1,1-dimethylurea) and picloram (4-amino-3,5,6-trichloropicolinic acid) on two experimental watersheds for the control of mixed chaparral brush. Although both herbicides were found to have weaknesses, they offer considerable promise for modifying chaparral vegetation. The extent of stream-water contamination by the picloram treatment was reported previously (Davis et al. 1968).

Materials and Methods

Study Area

The study area is located in the Mazatzal Mountains of central Arizona, between 3,300 and 4,500 feet elevation. Slopes are steep, ranging from about 25 to 70 percent. Soils are coarse textured and shallow to moderately deep, derived from deeply weathered and fractured Precambrian granites. The aspect is northerly.

In June 1959, an intense wildfire swept over the area killing all aboveground vegetation. Shrub live oak dominated the dense prefire chaparral cover, with lesser amounts of birchleaf cercocarpus, sugar sumac, Palmer oak, yellowleaf silktassel, Emory oak, pointleaf manzanita, and desert ceanothus. All shrubs except the last two mentioned sprouted vigorously after the fire.

After the wildfire, two previously calibrated experimental watersheds (C and B) were selected for herbicide treatment of sprout regrowth, and a third (D) was retained as an untreated control. The treated areas were successfully seeded to Lehmann, weeping, and Boer lovegrasses within 1 year after the fire.

The management objective for watershed C (95.3 acres) is complete conversion from brush to grassland. Following the wildfire, an annual spray program with 2,4,5-T was initiated in May 1960 to control the sprouting shrubs. After four annual applications, shrub live oak and birchleaf cercocarpus were the dominant shrubs remaining. Attempts to eliminate these shrubs were then shifted to the use of a soil application of fenuron.

The management objective for watershed B (46.5 acres) is selective eradication of undesirable shrubs among desirable deer browse species on northeast-facing slopes. Hand applications of fenuron and picloram were used for this purpose. Watershed B had not received the previous annual herbicide treatments, and contained a normal post-fire complement of shrubs.

Herbicide Treatments

The pelleted formulations of fenuron and the potassium salt of picloram[3] used in these studies contained 25 percent active ingredient and 10 percent acid equivalent, respectively. Both herbicides were spread by hand with crews of five to seven men. The herbicides were applied as spot treatments to individual bushes or clumps of bushes; intershrub spaces were not treated. The cross-sectional diameter of a bush or clump of bushes was estimated visually. A clear acrylic tumbler calibrated in shrub diameters (4 to 12 feet), for a given herbicide and rate of application, was filled with pellets to the appropriate graduation mark. Measured amounts of pellets were scattered on the ground beneath bushes with an erect habit of growth, or throughout the crowns of bushes with dense tops extending to the ground. In the latter case the pellets sifted through the bush to the ground. The minimum amount of chemical applied to any shrub, no matter how small, was the amount for a 4-foot-diameter bush. All application rates are on either an active ingredient or acid equivalent basis.

[3]*The picloram used in this study was donated by The Dow Chemical Company, Midland, Mich.*

Watershed C was treated with fenuron pellets in late summer, August 10-15, 1964, at an intended rate of 16 pounds per acre on the ground actually treated. The overall application rate on the watershed was 3.6 pounds per acre. Enough rain fell to dissolve the pellets and move the fenuron into the soil during late summer and early fall (4.6 inches from August 15 through October 17).

Northeast-facing slopes of watershed B were treated with fenuron and picloram in midwinter (January 25-February 1, 1965). Fenuron was applied on 16.4 acres at an intended rate of 16 pounds per acre on the ground actually treated. The overall application rate on the treated slopes was 18.3 pounds per acre. Thus, the intended rate was considerably exceeded. A 2.1-acre slope of a side drainage was treated with picloram at an intended rate of 8 pounds per acre on the ground actually treated. The overall application rate on the 2.1-acre slope was calculated to be 9.3 pounds per acre. Again, the application rate on the ground actually treated was higher than intended. Treatments are difficult to apply accurately with ground crews in dense brush.

Ample late-winter rainfall disintegrated the pellets and moved the herbicides into the soil prior to the start of spring growth and the dry spring and summer period. Picloram was tested at half the rate of fenuron on the basis of chemical activity and cost.

Evaluation of Treatments

The treatments were evaluated by observing the responses of tagged bushes over a 3-year period. Fifty bushes each of shrub live oak and birchleaf cercocarpus were tagged on watershed C; they were located in five areas across the watershed. Five major shrub species were evaluated on watershed B: shrub live oak, birchleaf cercocarpus, sugar sumac, yellowleaf silktassel, and Palmer oak. Fifty bushes each of the first two species and 30 each of the other species were tagged in both the picloram- and fenuron-treated areas. The tagged bushes were located in several representative areas across the watershed.

Shrub responses to the herbicides were evaluated during the fall or early winter months for 3 growing seasons following treatment. The grading system included a visual estimate of percent leaf injury, and a tally of living and dead bushes. Two or three years are necessary before mortality of sprouting species can be judged. The leaf injury rating is a measure of defoliation as well as leaf necrosis.

Records from rain gages at the base of each watershed showed the following amounts of precipitation during 3 years following treatments:

	Watershed C	Watershed B
First year	28.6	38.2
Second year	33.2	17.4
Third year	22.4	[1]13.8
Cumulative	[2]90.0	[3]69.4

[1]44 weeks [2]3 years 17 weeks [3]2 years 44 weeks

Results

The effect of the fenuron treatment on watershed C was less than anticipated. After 3 growing seasons, the mortality of shrub live oak was 48 percent, while that of birchleaf cercocarpus was only 26 percent (table 1). The action of fenuron was essentially complete after the second growing season. Leaf injury at the end of the first growing season was 77 percent for shrub live oak and 61 percent for birchleaf cercocarpus. Regrowth leaves developed less severe injury symptoms; by the end of 3 growing seasons the injury ratings had decreased to 62 percent for shrub live oak and 35 percent for birchleaf cercocarpus.

The fenuron treatment on watershed B was more effective than that on watershed C (table 1). Shrub mortality and leaf injury percentages after 3 growing seasons were highest for shrub live oak, intermediate for sugar sumac, birchleaf cercocarpus, and Palmer oak, and lowest for yellowleaf silktassel. It required 2 to 3 years to produce its maximum effect.

Effectiveness of picloram, at half the rate of fenuron, varied widely among the five shrubs (table 1). Its action was rapid and severe on birchleaf cercocarpus, sugar sumac, and yellowleaf silktassel. By the end of the first growing season its effect on these shrubs was nearly complete. Action of picloram on the oaks was slow and less severe; 2 to 3 growing seasons were required for maximum shrub response.

Discussion

Fenuron was less effective in controlling shrub live oak and birchleaf cercocarpus on watershed C than on watershed B because of several interrelated factors: season of application, amount and seasonal pattern of precipitation, and loss of fenuron from the shrub root zone of the soil by leaching and microbial decomposition. Watershed C was treated in August. It received 14.8 inches of rain prior to the treatment of watershed B in February. Also, during the remainder of the test period, watershed C received 5.8 inches more rain than watershed B. Since the shrubs were inactive during the late fall and winter months, it is likely that they largely escaped the effects of fenuron during this period of loss in the soil through leaching and decomposition. This suggests the advisability of mid- to late-winter applications in Arizona. The application should be timed to avoid the bulk of the winter rains, but to receive enough rain to disintegrate the pellets and move the herbicide into the soil before the late spring and summer dry period.

Picloram and fenuron exhibited different toxicity patterns toward chaparral shrubs. Picloram, at half the application rate of fenuron, was more effective than fenuron on birchleaf cercocarpus, sugar sumac, and yellowleaf silktassel, but less effective on the oaks (shrub live oak and Palmer oak). Fenuron was slower acting on all of the shrub species except Palmer oak.

Table 1.--Percent control of five shrub species, 3 growing seasons after spot treatments with pelleted fenuron and picloram at two seasons--late summer (August 10-15, 1964) and midwinter (January 25 - February 1, 1965)

Species	Treated with pelleted fenuron (16 pounds per acre) during--				Treated with picloram (8 pounds per acre) during midwinter (watershed B)	
	Late summer (watershed C)		Midwinter (watershed B)			
	Dead bushes	Leaf injury	Dead bushes	Leaf injury	Dead bushes	Leaf injury
	- - - - - - - - - - - - Percent - - - - - - - - - - - -					
Shrub live oak	48	62	82	94	56	66
Palmer oak	--	--	40	67	23	47
Birchleaf cercocarpus	26	35	54	71	94	99
Sugar sumac	--	--	57	83	100	100
Yellowleaf silktassel	--	--	20	43	100	100

The descending order of shrub susceptibility was:

Picloram	Fenuron
Sugar sumac	Shrub live oak
Yellowleaf silktassel	Sugar sumac
Birchleaf cercocarpus	Birchleaf cercocarpus
Shrub live oak	Palmer oak
Palmer oak	Yellowleaf silktassel

Although the spot-treatment application of picloram was probably heavier than necessary to control the picloram-sensitive species, it was marginal for the resistant oaks. The fenuron application was too low for all of the shrubs. Spot-treatment application rates of fenuron should be higher than 16 pounds per acre during years of high rainfall.

Hand applications of pelleted herbicides are more practical than aerial applications for treating open stands of brush; grass on intershrub spaces is spared and less chemical is required. As the density of brush increases, however, aerial applications become more practical. In relatively dense brush, aerial applications may be expected to be more effective than hand-applied spot treatments because of the added percentage of the root systems which will come in contact with the herbicide in the intershrub spaces. To control undesirable shrubs among desirable browse species with soil applications of fenuron or picloram, selective hand applications are necessary.

Because picloram is more toxic than fenuron to some shrubs and vice versa, and because the necessary rates of either herbicide to control all of the shrub species is excessive, a duo-herbicide treatment is an interesting possibility when hand applications are feasible. Picloram and fenuron could be applied singly to the shrubs most sensitive to each herbicide to achieve broad-spectrum brush control. Each herbicide could be used at the lowest rate commensurate with adequate control.

Two natural products of chaparral watersheds are water and big game. One way to approach a maximized balanced output of these products is to eliminate all but the desirable browse species. This necessitates a selective hand application, such as that described for watershed B. In addition to application problems, however, the end result may be less than desired from the standpoint of browse potential; the natural stand of browse shrubs may be undesirable in kind, or density, or both. Another approach might involve an aerial herbicide application for nonselective eradication of brush, followed, after appropriate periods of time, by grass and browse establishment programs. This approach would allow the establishment of specific browse shrubs in desired densities for a maximized balanced output of water and game.

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COMMON AND BOTANICAL NAMES OF PLANTS MENTIONED

Shrubs

Ceanothus, desert
Ceanothus greggii A. Gray
Cercocarpus, birchleaf
Cercocarpus betuloides Nutt.
Manzanita, pointleaf
Arctostaphylos pungens H.B.K.
Oak, Emory
Quercus emoryi Torr.
Oak, Palmer
Q. chrysolepis var. *palmeri* (Engelm.) Sarg.
Oak, shrub live
Q. turbinella Greene
Silktassel, yellowleaf
Garrya flavescens S. Wats.
Sumac, sugar
Rhus ovata S. Wats.

Grasses

Lovegrass, Boer
Eragrostis chloromelas Steud.
Lovegrass, Lehmann
E. lehmanniana Nees
Lovegrass, weeping
E. curvula (Schrad.) Nees

CAUTION: If you use herbicides, apply them only when needed and handle them with care. Follow the directions and heed all precautions on the container label. If herbicides are not handled or applied properly, or if unused portions are disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, honeybees and other pollinating insects, fish or wildlife, and may contaminate water supplies.

Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.

1969

U.S.D.A. FOREST SERVICE RESEARCH NOTE RM-141

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Response of Deer to Alternate-Strip Clearcutting of Lodgepole Pine and Spruce-Fir Timber in Colorado

O. C. Wallmo[1]

Pellet-group counts indicated that in Colorado clearcutting lodgepole pine and spruce-fir forest in strips 1, 2, 3, and 6 chains wide, with alternating uncut strips of the same widths, doubled the use by mule deer 10 years after logging. The increase in use was in the cut strips, where mean pellet-group densities were three times those on uncut strips and on adjacent virgin forest.

On the Fraser Experimental Forest in central Colorado, an area of lodgepole pine and spruce-fir timber[2] was logged in alternating clearcut and uncut strips as an experiment in watershed management. U. S. D. A. Forest Service scientists have evaluated the experiment in terms of hydrological,[3] silvicultural,[4,5,6] and wildlife influences. This paper reports some of the apparent responses of mule deer (Odocoileus hemionus hemionus (Rafinesque)) which use the area as summer range.

Study Area and Methods

The experimental treatment was applied to 550 acres of lodgepole pine and spruce-fir timber between 9,600 feet and timberline at about 11,200 feet on Fool Creek watershed (fig. 1). The adjacent East St. Louis Creek watershed was used as a control area. Both watersheds are north facing with predominantly northeast and northwest exposures.

The timber was harvested in 1954, 1955, and 1956 in clearcut strips 1, 2, 3, and 6 chains wide alternating with uncut strips of the same width. Strips ran across the contours, and their length, in most cases approximately 600 feet, was determined by access roads which ran on the contour. The area of merchantable timber was divided into four equal blocks, and the four strip widths were repeated in each block. All live trees 4 inches d.b.h. and larger were felled on the cut strips. Tops were lopped and scattered, but slash was not cleaned up.

Data were collected in 1966. Accumulated fecal pellet groups of deer were counted on continuous belt transects run through the center of each of the tiers of cut and uncut strips on Fool Creek and on

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[2]*Lodgepole pine = Pinus contorta Dougl., Engelmann spruce = Picea engelmannii Parry, subalpine fir = Abies lasiocarpa (Hook.) Nutt.*

[3]*Goodell, Bertram C. A preliminary report on the first year's effects of timber harvesting on water yield from a Colorado watershed. U. S. Forest Serv., Rocky Mountain Forest and Range Exp. Sta. Sta. Pap. 36, 12 pp., illus. 1958.*

[4]*Alexander, Robert R. Damage to advanced reproduction in clearcutting spruce-fir. U. S. Forest Serv., Rocky Mountain Forest and Range Exp. Sta. Res. Note 27, 3 pp. 1957.*

[5]*Alexander, Robert R. Windfall after clearcutting on Fool Creek, Fraser Experimental Forest, Colorado. U. S. Forest Serv. Res. Note RM-92, 11 pp., illus. 1967. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

[6]*Alexander, Robert R. Natural reproduction of spruce-fir after clearcutting in strips, Fraser Experimental Forest. U. S. Forest Serv. Res. Note RM-101, 4 pp., illus. 1968. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

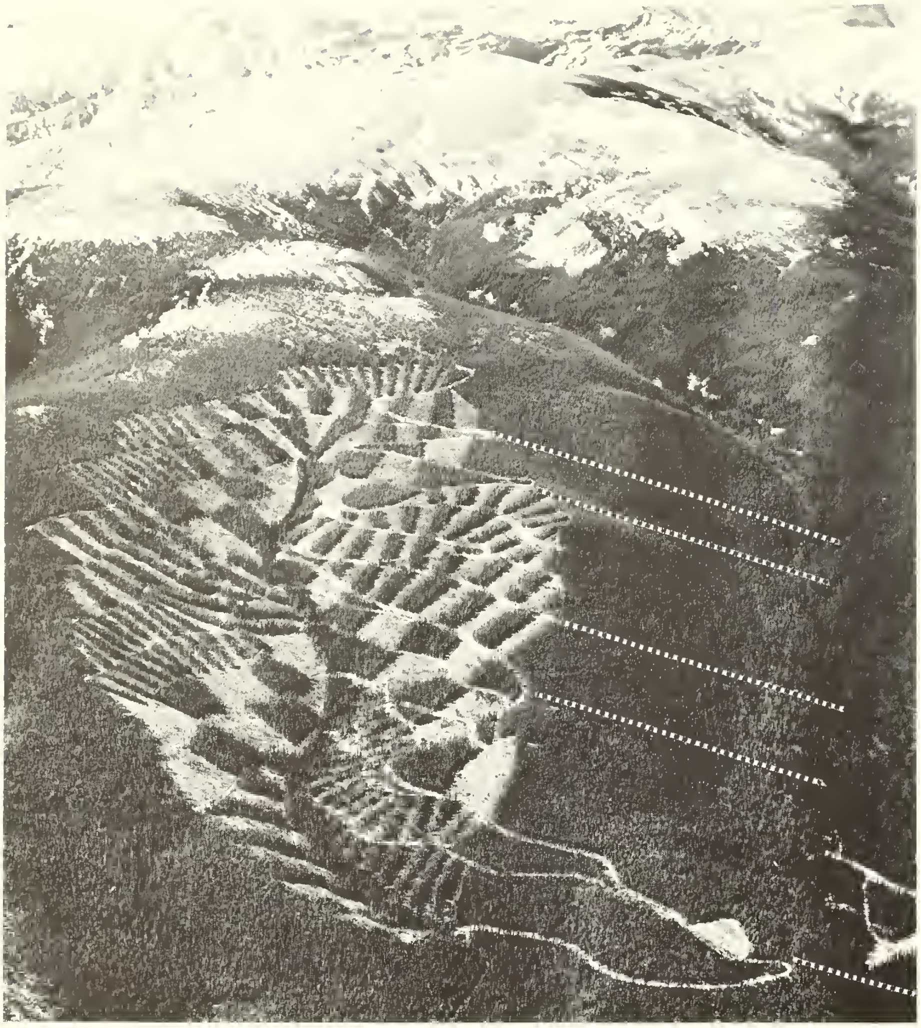


Figure 1.--Aerial view of Fool Creek (left) showing the pattern of clearcut strips, and East St. Louis Creek (right), the untreated comparison watershed, showing the approximate location of transects.

five straight-line belt transects at random intervals across East St. Louis Creek watershed. The transects were 5 feet wide and were divided into consecutive plots 9 feet long. Width was controlled with a measuring stick, but plot length was established by practicing pacing until paces averaged very close to 3 feet.

All recognizable deer pellet groups were counted in each plot. Plots were classified as to the treatment and timber type in which they occurred. Where a plot occurred at the boundary of a treatment or type, a subjective decision was made as to how it should be classified.

Prohibitively large plots would have been necessary for counts which would approximate continuous variables and have symmetrical frequency distributions. Consequently, small plots (5 x 9 feet; contiguous on transects) were used, and analysis was based on the number of plots with pellet groups present or absent. The frequencies of plots with pellet groups on treated and untreated areas were compared, using chi-square analyses to determine the magnitude of differences between areas. Mean density of pellet groups was obtained from the mean count per 45-square-foot plot.

A study by Porter[7] indicated that, 1 to 2 years after logging, deer were using the Fool Creek watershed less than the adjacent comparison watershed. Porter's original data and location records were no longer available, so his sampling could not be repeated.

[7]Porter, K. A. Effects of sub-alpine timber cutting on wildlife in Colorado. 1959. (Unpublished master's thesis on file at Colorado State Univ., Fort Collins.)

Results

Ten years after lodgepole pine and spruce-fir timber was logged in alternating clearcut and uncut strips, the use by mule deer, as indicated by accumulated pellet groups, was significantly higher than use of the adjacent untreated control area. The mean pellet-group density was nearly double that on the untreated area (table 1).

On uncut strips on Fool Creek, the density of pellet groups was approximately equal to that on the virgin forest on East St. Louis Creek (59 and 57 groups per acre). Also, the percentages of plots with pellet groups were about equal (5.62 and 5.65 percent). On cut strips, however, there was a significantly larger percentage of plots with pellet groups than on uncut strips (13.92 and 5.62 percent), and the mean density of pellet groups on all cut strips combined was nearly three times that on all uncut strips combined (158 and 59 per acre).

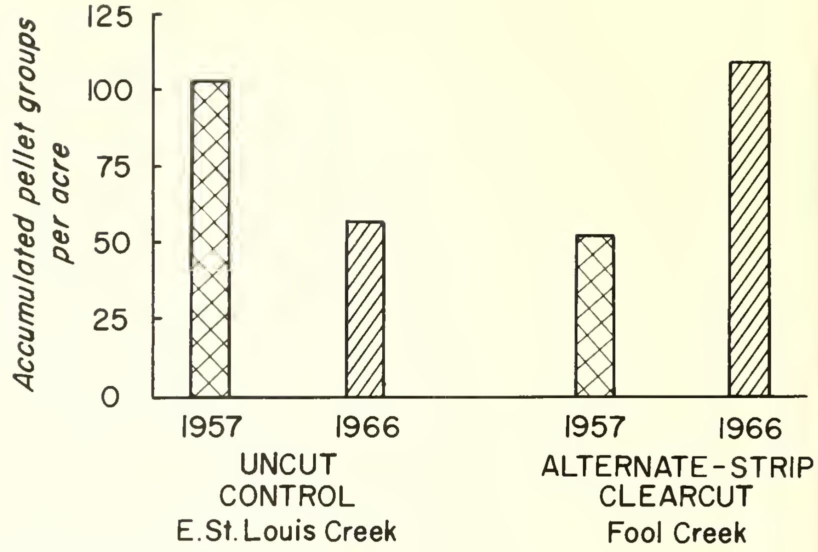
On cut strips of each width and in each timber type there was a larger percentage of plots with pellet groups than on uncut strips of the same width and type. The differences were statistically significant by chi-square test except in the comparison of cut with uncut strips 3 chains wide in the spruce-fir type.

The comparatively low use of Fool Creek 1 to 2 years after logging (fig. 2) suggests that the deep tangle of residual slash and possibly the disturbance from logging operations discouraged use of the area.[7] Whatever the deterrent factors, their in-

Table 1.--Frequency of occurrence of deer pellet groups and mean density per acre on Fool Creek strips and on the adjacent uncut watershed, East St. Louis Creek (each figure is derived from the sum of plots for that group)

Location, treatment, and forest type	Strip widths	Plots	Plots with pellet groups			Mean density of pellet groups		
	Chains	Number	- - - Percent - - -			Number per acre		
FOOL CREEK:								
Cut strips--								
Lodgepole pine	1	330	10.61	14.74	13.92	132	169	158
	2	393	16.28			183		
	3	259	22.01			246		
	6	504	12.50			140		
Spruce-fir	1	265	15.85	12.89		179	145	
	2	178	11.80			125		
	3	445	15.06			168		
	6	291	7.57			80		
Uncut strips--								
Lodgepole pine	1	384	1.56	4.51	5.62	15	46	59
	2	373	4.56			49		
	3	277	7.22			70		
	6	452	5.31			56		
Spruce-fir	1	234	9.40	7.09		95	73	
	2	130	3.85			37		
	3	360	11.95			99		
	6	390	2.31			22		
Total or average		5,265			9.82			109
EAST ST. LOUIS CREEK:								
No treatment (check)		1,168			5.65			57

Figure 2.--Deer use of virgin forest and adjacent alternate-strip clearcut forest 1 and 10 years after logging (1957 data from Porter, see footnote 7).



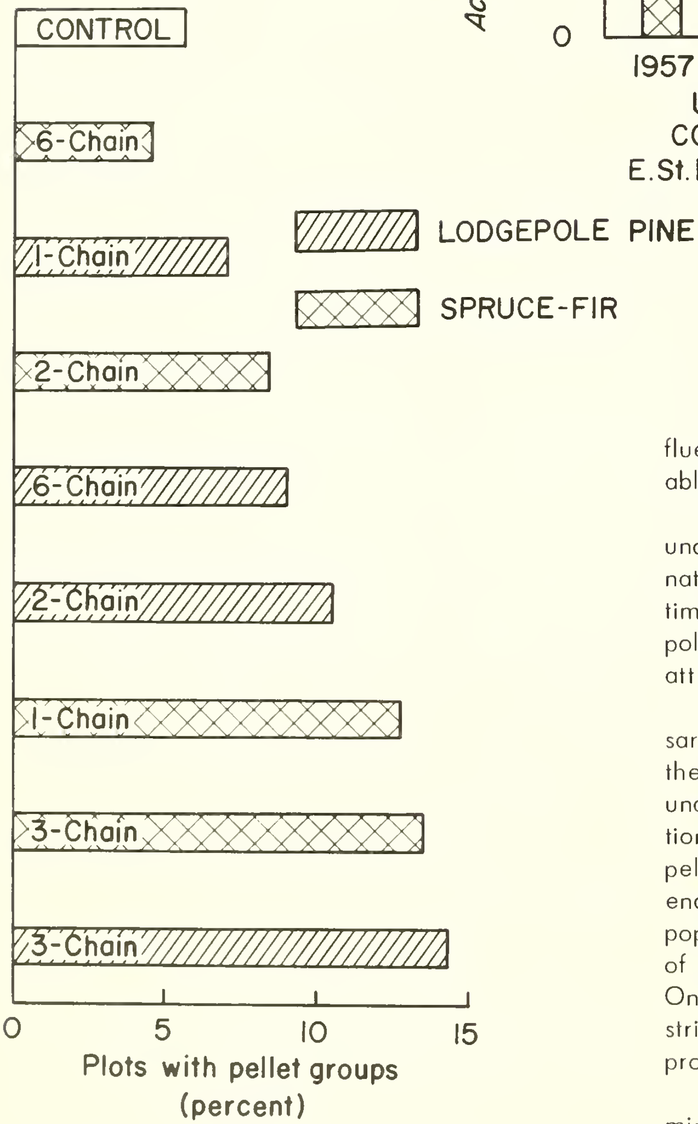


Figure 3.--Blocks of alternating cut and uncut strips of various widths rated according to frequency of deer pellet groups on sample plots. The control included both timber types.

fluence diminished over 10 years and deer were able to respond to factors that attracted them.

Comparison of blocks of alternating cut and uncut strips of the four widths indicates that alternate 3-chain strips attracted the most use in both timber types, while alternate 1-chain strips in lodgepole pine and alternate 6-chain strips in spruce-fir attracted the least use (fig. 3).

Local pellet-group concentrations do not necessarily reveal a net increase in carrying capacity, but they do indicate concentrations of some, so far undefined, kinds of deer activity. Since deer defecation rates are fairly constant,[8] differences in mean pellet-group densities, on areas large enough to encompass the activities of segments of a deer population, indicate that more of the requirements of deer are met on one area than on the other. On this basis, it can be assumed that alternate-strip clearcutting with strips 1 to 6 chains wide improved deer habitat.

Further studies are being conducted to determine what aspects of deer habitat are benefited.

[8] *Neff, D. J. The pellet-group count technique for big game trend, census, and distribution: a review. J. Wildl. Manage. 32: 597-614. 1968.*

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RESEARCH NOTE RM-142

FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Assimilation Chamber for Outdoor Measurements of Photosynthesis of Tree Seedlings

Frank Ronco[1]

Presents construction details for a simple, water-cooled plexiglass assimilation chamber, and a system for using several chambers simultaneously. Photosynthesis of spruce seedlings was measured satisfactorily at up to 16,000 foot-candles light intensity without excessive heating.

A number of chambers have been designed to measure photosynthesis by enclosing the entire plant or portions of the photosynthesizing organs in containers that transmit light. They have ranged from simple plastic buckets[2] and glass cylinders[3] to elaborate systems primarily suited for the laboratory where rigid controls are required.[4,5]

The chambers, generally used with infrared gas analyzers for detecting carbon dioxide concentration, may be employed in closed, open, or mixed systems.[6] In an open system, carbon dioxide concentration in air is measured before and after passing over photosynthesizing organs; in a closed system, the change in carbon dioxide concentration is measured over time. High chamber temperature, which must be lowered by heat filters or refrigeration, is the primary difficulty encountered in all systems. Excessive heating is less prevalent in an open system because of the cooling effect of a continuous stream of atmospheric air. Heat buildup is also

[1]*Silviculturist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Roberts, B. R., and Stipes, R. J. Plant chamber from a bucket. Agr. Res. 16(3): 14. 1967.*

[3]*Parker, J. Photosynthesis of Picea excelsa in winter. Ecology 34: 605-609. 1953.*

[4]*Clark, J. Photosynthesis and respiration in white spruce and balsam fir. State Univ. Coll. of Forest. at Syracuse, N.Y., Univ. Tech. Pub. 85, 72 pp. 1961.*

[5]*Decker, J. P. Effect of temperature on photosynthesis and respiration in red and loblolly pines. Plant Physiol. 19: 679-688. 1944.*

[6]*Bourdeau, P. F., and Woodwell, G. M. Measurements of plant carbon dioxide exchange by infra-red absorption under controlled conditions and in the field. pp. 283-289. In F. E. Eckardt (ed.), Arid Zone Research, XXV. Methodology of Plant Eco-Physiology. Proceedings of the Montpellier Symposium. United Nations, Educational, Scientific and Cultural Organization (UNESCO), Paris.*

less troublesome in natural than artificial light because the ratio of longwave radiation to visible light is considerably lower in the former. Consequently, the open system is better adapted to field measurements because temperatures can be maintained in the chamber without an elaborate cooling mechanism.

Photosynthesis of conifer seedlings was measured satisfactorily outdoors at high elevations in the Colorado Rocky Mountains with an open system and plexiglass chamber described here.[7] Temperatures inside the chamber were easily controlled, even though light intensities as high as 16,000 foot-candles were measured.

[7] *Conifers used for this study were Engelmann spruce (Picea engelmannii Parry) and lodgepole pine (Pinus contorta Dougl.).*

Chamber Construction

The plexiglass chamber could be made with hand tools, but power equipment is recommended to insure that adjoining surfaces are machined smooth enough to give tight, cemented joints. The only specialized equipment needed is a strip-heater to soften plastic in a narrow strip so it will bend easily.

Since other investigators may want chambers with dimensions suitable for their specific needs, only general construction techniques are presented. The chamber is approximately 3 inches wide by 5 inches high by 6 inches long (fig. 1). Letters in the figure identify the component parts discussed in the following paragraphs.

The chamber floor (A) was made from 0.150-inch sheet plastic, which was heated to 300°F. in an oven and shaped over a wooden mold to form a wide U-shaped trough. The curved bottom of the trough had a radius of 3 inches. The sides of the

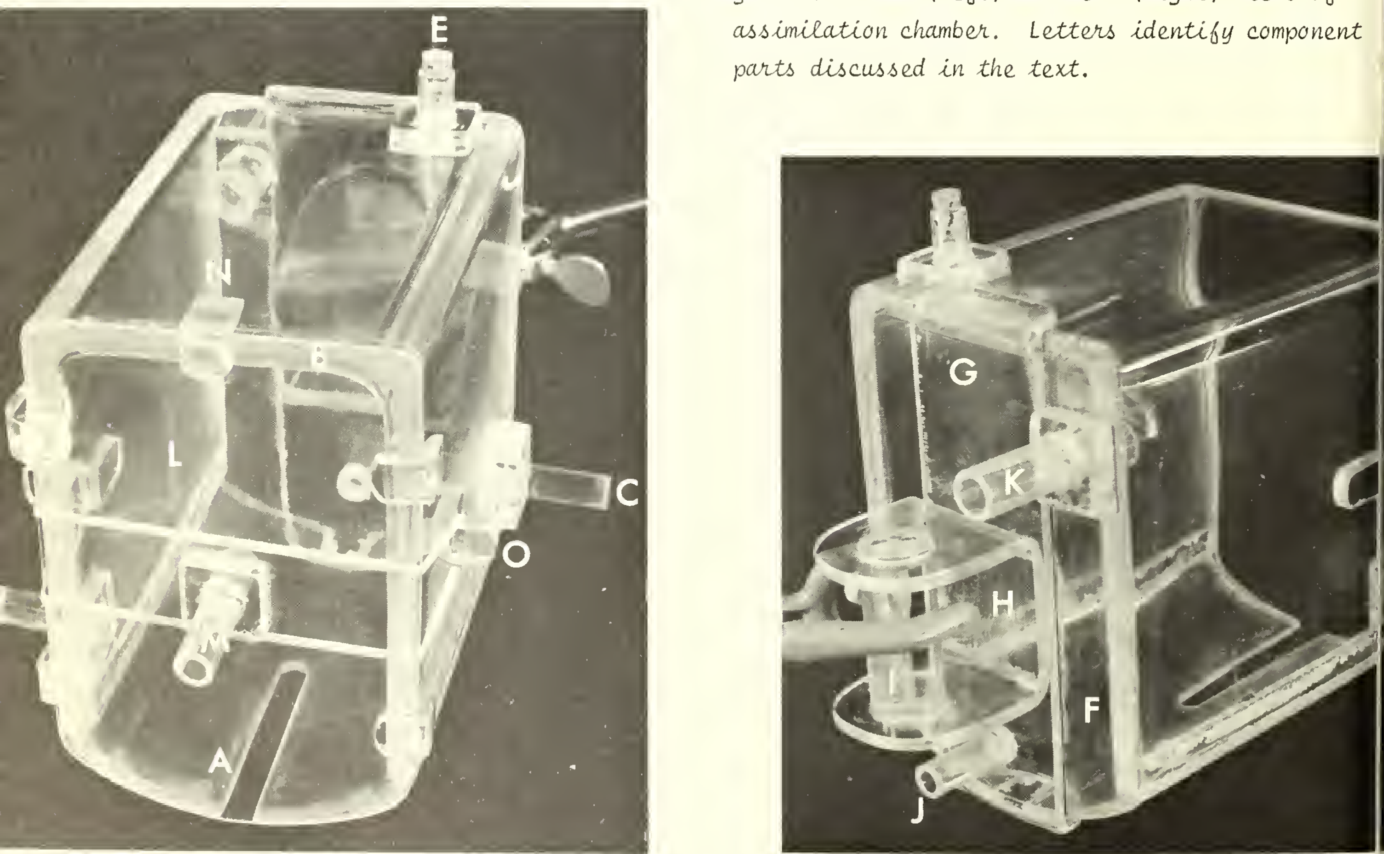

Figure 1.--Front (left) and rear (right) views of assimilation chamber. Letters identify component parts discussed in the text.

trough were trimmed to a height of 0.5 inch, and a slot 3 inches long and 0.375 inch wide was cut in the bottom to accommodate the stem of a tree seedling. Although the floor section can be made in the form of a flat-bottomed trough, a U-shaped curvature allows the chamber to be positioned more easily on potted seedlings.

The water jacket was formed by the double sidewalls and ceilings of the chamber. Flat-bottomed U-shaped troughs of 0.080-inch plastic were cemented to the inner and outer surfaces of the upturned edges of the floor section (fig. 2) to give an uninterrupted 0.150-inch space that extended up the sidewalls and across the top.

Before the outer portion of the water jacket was cemented to the floor section, it was drilled to accommodate 0.250-inch inside-diameter rigid plexiglass tubing for water-inlet (C) and water-outlet (D) ports. A third hole was drilled in a rear corner of the top of the water jacket for an air-bleed port (E). The area around each hole was reinforced with a small square piece of 0.250-inch plastic cemented to the wall of the water jacket. Flexible vinyl tubing was stretched over the water ports. The air-bleed port was closed with a small cork.

To seal off the water jacket at the end of the chamber with the stem slot, an 0.080-inch plastic sheet was cemented across the entire end of the box. After the cement dried, the plastic covering the door opening and the excess material outside the box were trimmed away, which left a permanent seal over the water jacket opening. The rear wall (F) of the chamber was similarly formed with an 0.080-inch plastic sheet, but only the excess material outside the box was trimmed.

The supporting brackets for the chamber were made from two strips of plastic, 0.150 inch thick by 1.75 inches wide. One strip was shaped to form the bracket (G) with the distance between the sides of the bracket equal to the outside height of the chamber. This piece was cemented so that the slightly longer bottom side supported the chamber and the shorter side extended over the top. The second piece was formed into the bracket (H). A solid plastic dowel (I), 0.750 inch in diameter, was cemented into holes drilled through both arms of the bracket. This bracket was then cemented to (G).

Air outlet (J) and thermometer (K) ports were placed in the rear wall of the chamber by the same technique as used for the water ports. The thermometer port was 0.375-inch inside-diameter plexiglass tubing; 0.250-inch plexiglass tubing was used for the air outlet.

The chamber door (L) was made from an 0.080-inch plastic sheet, cut to fit the outside dimensions of the chamber front. An air-inlet port (M) was placed in the center of the door. Five small tabs (N), narrow strips of 0.150-inch plastic bent at right angles, were cemented to the door to keep it positioned over the chamber opening. The door was held securely in place by a heavy rubber band stretched across the door face and looped over plastic hooks (O) cemented on each side of the chamber. An airtight gasket between the door and the chamber was made from modeling clay.

A completed chamber, with seedling in place for measurement, is shown in figure 3. Masking tape used to seal the stem slot is visible; modeling clay was formed around the seedling stem to complete the seal.

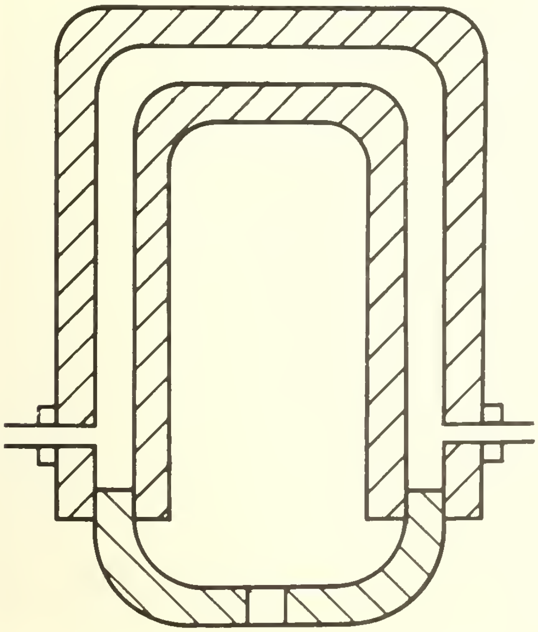

Figure 2.--
Construction details for water jacket of assimilation chamber.

Figure 3.--Engelmann spruce seedling enclosed in assimilation chamber during photosynthesis measurements.

Apparatus For Measuring Photosynthesis

Since the assimilation chamber is inexpensive, several can be built and operated simultaneously. Concurrent measurements would be especially advantageous for comparing photosynthesis of plants grown under different treatments. Consecutive measurements could be compared, but as the time interval between them increases, the comparisons become less reliable because of diurnal changes in photosynthesis.

An apparatus utilizing three of the chambers simultaneously is described in the following paragraphs; additional chambers could be easily added.

Atmospheric air was continuously drawn through each chamber by a separate aerator pump connected to the chamber by vinyl tubing. A fourth pump, also operating continuously, moved atmospheric air to the infrared gas analyzer. By using quick disconnects on the tubing, each pump could be quickly connected to the gas analyzer so that carbon dioxide concentration in each chamber or atmospheric air could be monitored within a few seconds. Before air reached the analyzer, it passed through a flow meter and a column of indicating drierite to remove moisture.

A centrifugal immersion pump recirculated water to the cooling jackets of the chambers from a reservoir cooled by a modified refrigerated drinking fountain. Chilled water was pumped from the reservoir to a three-valve manifold, which allowed the temperature in each chamber to be controlled independently over a range of several degrees above or below ambient air temperature.

Layers of cheesecloth were draped over the apparatus to control the intensity of light reaching the chambers.

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RESEARCH NOTE RM-143

FOREST SERVICE
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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Assimilation Chamber for Measuring Carbon Dioxide Exchange of Tree Seedlings in the Laboratory

Frank Ronco[1]

An apparatus to measure photosynthesis and respiration is described in sufficient detail to facilitate construction. Design features include portability, rapidity of measurement, and long-term reliability of the temperature control system. Since the temperature controls and other components are separate from the chamber, plants of different sizes can be measured simply by interchanging chambers of different dimensions.

An open system with a plexiglass assimilation chamber for measuring gaseous exchange of carbon dioxide (CO_2) in potted Engelmann spruce (Picea engelmannii Parry) and lodgepole pine (Pinus contorta Dougl.) seedlings under field conditions has been described.[2] Performance was satisfactory in the field, but not in the laboratory where experimental conditions required a different system and more elaborate equipment.

The water jacket in the plexiglass field chamber maintained acceptable temperatures under natural light, but could not filter and dissipate the heat from artificial lights with an intensity of 13,000 foot-candles—equivalent to natural light intensity during clear days at elevations where spruce grows. Secondly, reliable photosynthesis measurements are difficult to obtain in a laboratory with an open system, because CO_2 concentration can change from 300 to over 600 p.p.m. within a few minutes due to organic fuel combustion and CO_2 exhalation by persons in the laboratory area.

Since photosynthesis in an open system is determined by the reduction of CO_2 concentration of air after passing over a seedling, the difficulties encountered with a rapidly fluctuating CO_2 concentration are obvious. Consequently, a closed system—where gaseous exchange is measured by changes in CO_2 concentration over time—is more suitable for laboratory measurements. The apparatus described is a modification of units reported by Decker[3,4] and Brix.[5] Some of the desirable features of those units

[1]*Silviculturist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Ronco, Frank. Assimilation chamber for outdoor measurements of photosynthesis of tree seedlings. U.S.D.A. Forest Serv. Res. Note RM-142, 4 pp., illus. 1969. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

[3]*Decker, J. P. The effect of air supply on apparent photosynthesis. Plant Physiol. 22: 561-571. 1947.*

[4]*Decker, J. P. The effect of light intensity on photosynthetic rate in Scotch pine. Plant Physiol. 29: 305-306. 1954.*

[5]*Brix, H. The effect of water stress on the rates of photosynthesis and respiration in tomato plants and loblolly pine seedlings. Physiol. Plant. 15: 10-20. 1962.*

are incorporated, as well as innovations designed for versatility and operating convenience.

Advantages over similar devices are: compactness and portability; maintenance of a set temperature without overcompensation; reliability during continued operation; ease of plant insertion in the chamber; and interchangeability of chambers for different-sized plants.

Basically, the apparatus consists of an airtight plant chamber and systems for calibrating, cooling, drying and humidifying air, and measuring CO_2.

Carbon dioxide concentrations are most conveniently and accurately determined with an infrared gas analyzer; the other systems are easily fabricated or assembled from standard laboratory equipment.

Function of Component Systems

The various systems are described in the following paragraphs; letters in parentheses identify component parts shown in figure 1.

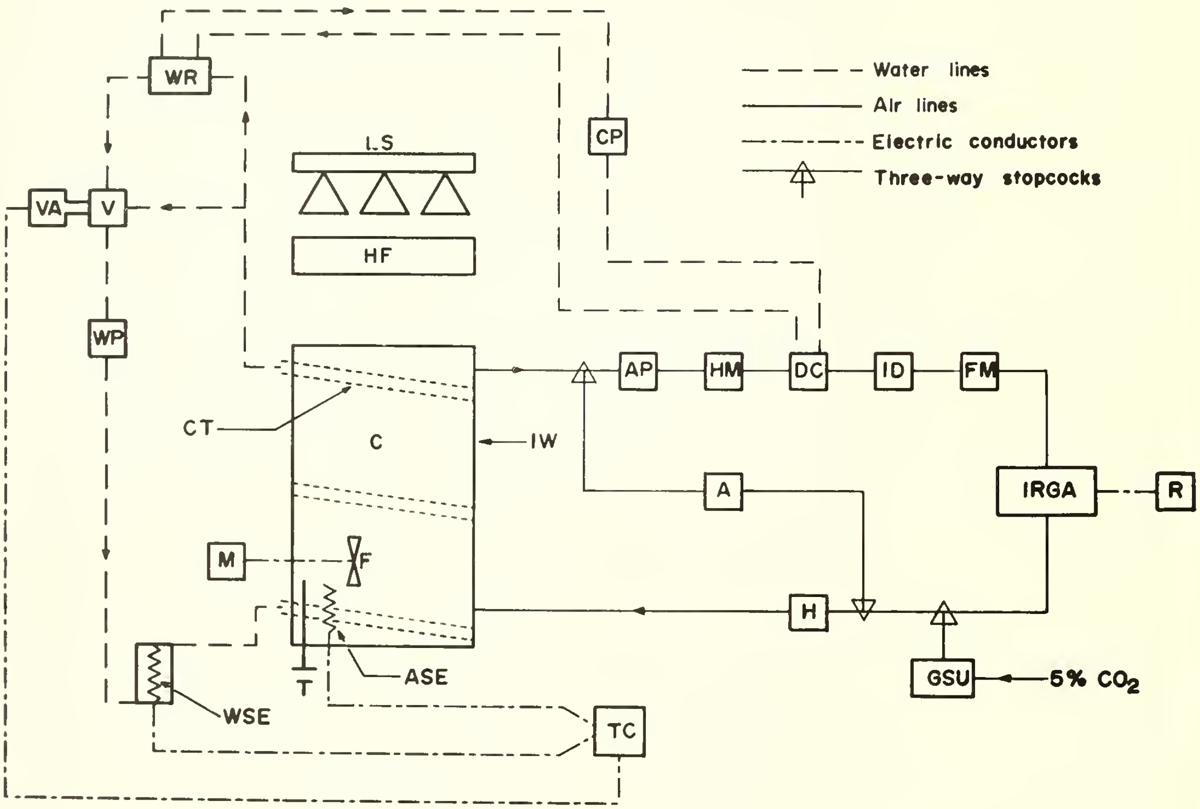

Figure 1.--Schematic diagram of closed-system apparatus for measuring photosynthesis.

A -	*ascarite column*	*IRGA* -	*infrared gas analyzer*
AP -	*air pump*	*IW* -	*internal copper wall of chamber*
ASE -	*air temperature sensing element*	*LS* -	*light source*
C -	*assimilation chamber*	*M* -	*fan motor*
CP -	*centrifugal water pump*	*R* -	*strip-chart recorder*
CT -	*copper tubing*	*T* -	*thermometer*
DC -	*water-cooled condenser*	*TC* -	*temperature controller*
F -	*fan*	*V* -	*3-way valve*
FM -	*flow meter*	*VA* -	*valve actuator*
GSU -	*gas sampling unit*	*HF* -	*heat filter*
H -	*humidifier*	*WP* -	*water pump*
HM -	*relative humidity meter*	*WR* -	*water reservoir and refrigerator*
ID -	*indicating drierite* ($CaSO_4$)	*WSE* -	*water temperature sensing element*

Air is drawn from a sealed chamber (C) by a Neptune Dyna-pump (AP),[6] and forced through a Serdex humidity meter (HM) to an air-drying system consisting of a water-cooled condenser (DC) and a cylinder filled with indicating drierite (ID). The drying condenser is cooled by recirculating chilled water with a centrifugal immersion pump (CP). Dried air moves through a flow meter (FM) into a Beckman 15A gas analyzer (IRGA) and returns to the chamber via a humidifier (H)—a gas-washing bottle. Carbon dioxide concentration and time are recorded on a Varian strip-chart recorder (R).

The light source (LS) is seven 300-watt spotlight bulbs, with a switch arrangement to illuminate bulbs in consecutive order. Most of the infrared radiation from the lights is removed by water in a heat filter (HF), and the portion not absorbed is dissipated by cold water flowing through copper tubing (CT) soldered to the inner wall (IW) of the chamber. An Eastern D-11 pump (WP) continuously recirculates the water in the copper tubing, which is maintained at a desired temperature by a regulated flow of chilled water from a refrigerated reservoir (WR). A fan (F) driven by a variable-speed stirrer motor (M), mounted outside the chamber, circulates air to increase cooling efficiency, and to prevent variable carbon dioxide concentrations. Air turbulence rates are variable from slow to rapid.

The temperature control system, manufactured by Johnson Service, is composed of five separate units: an air temperature sensing element (ASE), a water temperature sensing element (WSE), a temperature controller (TC), a proportional electro-hydraulic valve actuator (VA), and a 3-way valve (V). A low voltage signal—proportional to the temperature sensed by the air and water sensing elements—is transmitted by the electronic controller to the valve actuator mechanism, which positions the 3-way valve in proportion to the temperature sensed at the elements. When the controls are properly calibrated, the actuator will position the valve between its extreme limits of travel so that the valve-intake ports leading to the water reservoir and the copper tubing are partially open. As the valve slowly modulates in response to temperature deviations from the temperature set on the controller, a gradual change in the flow of chilled water from the reservoir will be accompanied by an equally gradual but inverse change in the flow of water already in the system. These gradual changes in flow rates prevent overcompensation in the heating-cooling cycle typical of relay-circuit controls, and make it possible to maintain chamber temperatures within 0.1°C. Chamber temperatures of 10° to 40°C. are possible under a full light load. Temperatures are recorded with a bimetallic dial thermometer (T), but the system should be calibrated by a sensitive thermocouple thermometer.

Valve movement is largely controlled by the air temperature sensing element, but somewhat finer control is obtained with the water sensing element. Since there is a time lag between chilled water entry into the copper tubing and its cooling effect inside the chamber, the latter element tends to reduce chilled water intake before such action is called for by the primary air sensor.

For photosynthesis determinations, the lights provide sufficient heat to raise chamber temperatures to commonly desired levels. Supplemental heat is required, however, to obtain temperatures above ambient when the chamber is darkened for respiratory determinations. That heat is obtained from an electric heating coil and relay activated by the temperature controller.

If duplicate photosynthesis measurements are desired, the CO_2 content of air in the chamber must be raised with a 5 percent CO_2 air mixture. That is accomplished by incorporating into the apparatus a gas sampling unit (GSU) composed of a gas sampling bulb with a 3-way stopcock at each end and a graduated 250-ml. separatory funnel used as a leveling bulb.

The calibrating system provides dry, CO_2-free air for the gas analyzer; two 3-way stopcocks bypass the chamber with a cylinder of Ascarite (A) that absorbs CO_2 from the air stream flowing through the analyzer.

Construction

This section presents general descriptions needed for understanding and constructing the apparatus, but fabrication techniques and assembly are left to craftsmen and researchers. Figures 2, 3, and 4 show the assembled apparatus, with the component parts lettered and identified in the figure captions.

The apparatus, except for the water reservoir, coolant pump, flow meter, and gas analyzer, is

[6] *Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

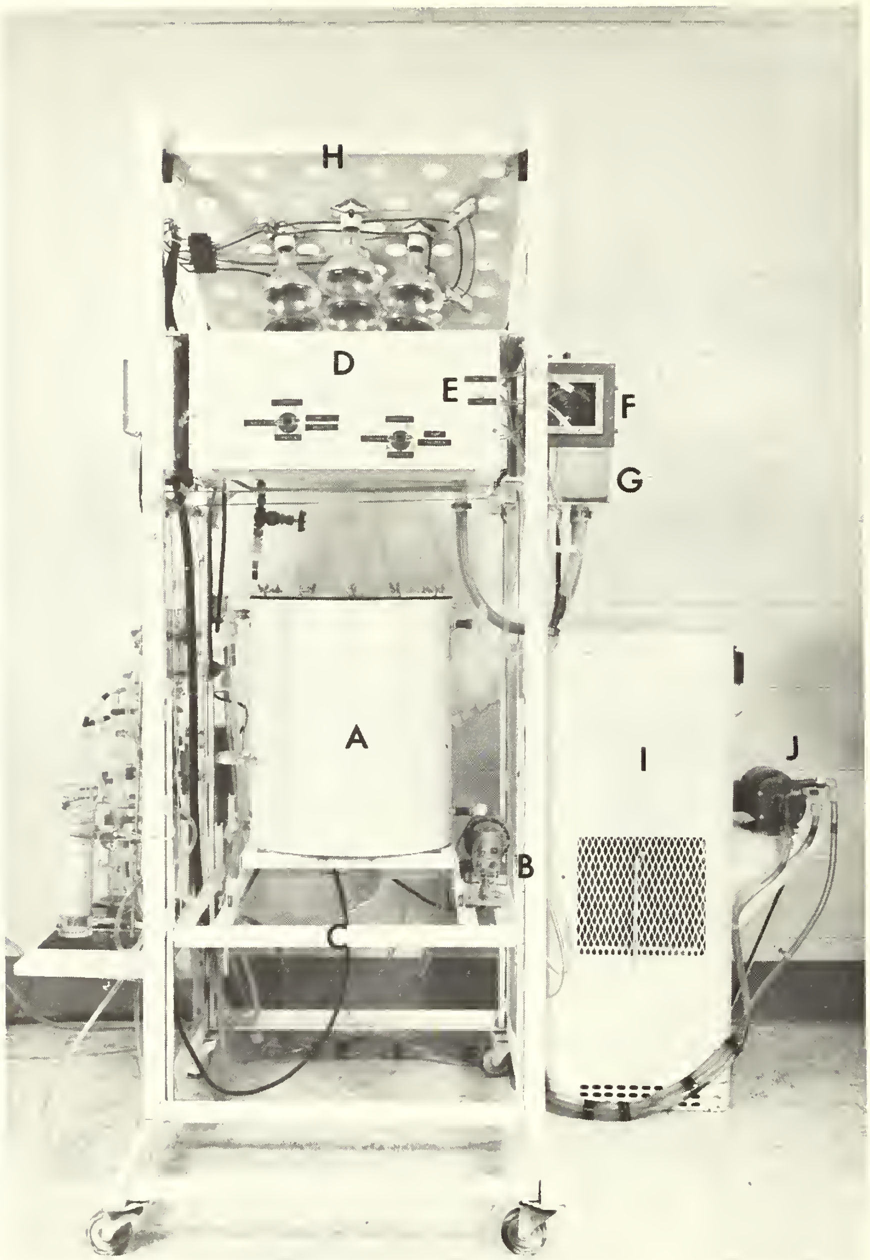

Figure 2.--Front view of closed-system apparatus for measuring carbon dioxide exchange of tree seedlings.

A - plant chamber
B - air pump
C - adjustable shelf
D - control panel with 3-way stopcocks of calibration system
E - inlet and outlet tubing to flow meter and gas analyzer
F - humidity meter
G - water-level control of heat filter
H - light bracket raised to show lamp arrangement
I - refrigeration unit and water reservoir
J - coolant circulating pump

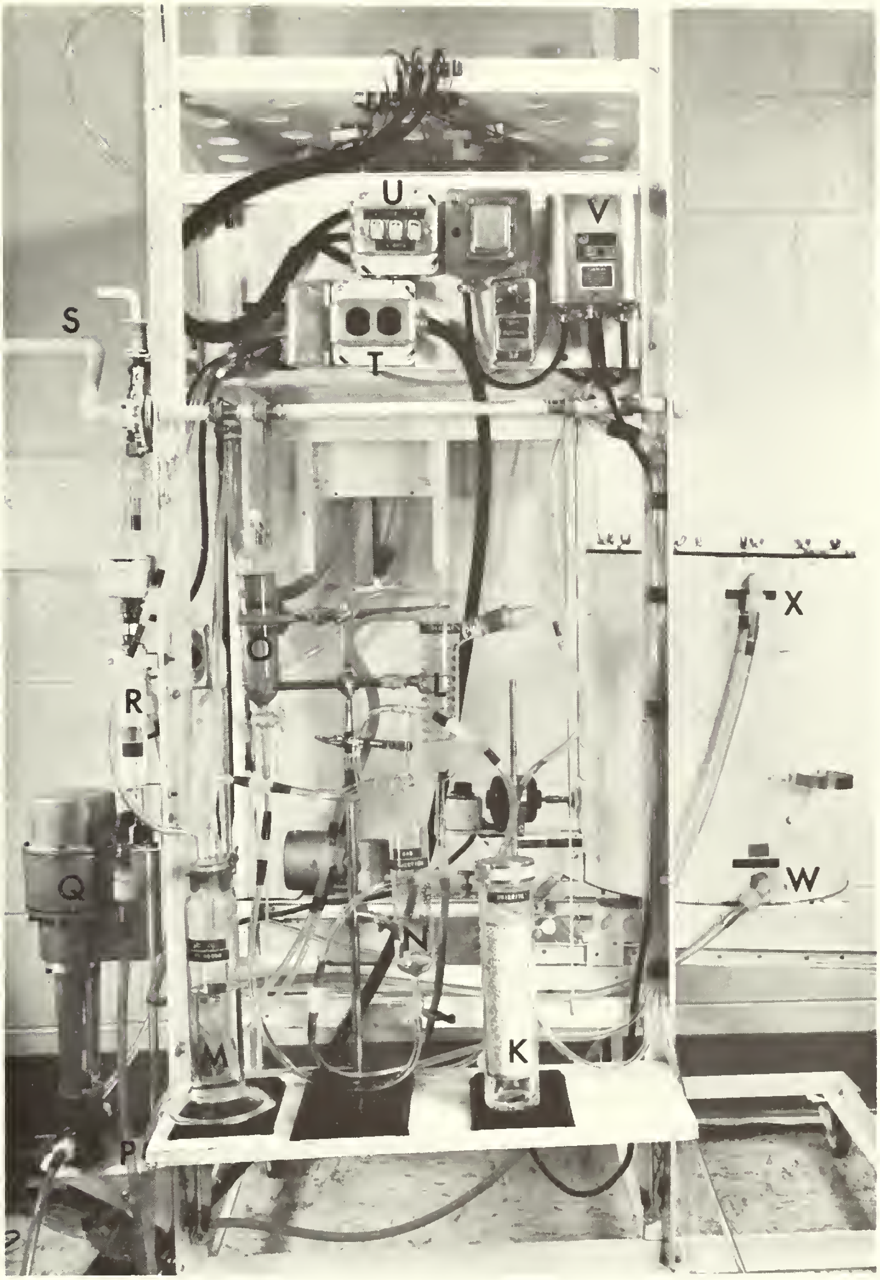

Figure 3.--Left side view of closed-system apparatus for measuring carbon dioxide exchange of tree seedlings.

K - drierite column
L - drying condenser
M - humidifier
N - bulb of gas sampling unit
O - separatory funnel of gas sampling unit
P - valve
Q - valve actuator
R - water temperature sensing element
S - lever and ratchet for vertical shelf adjustment
T - utility outlets
U - light switches
V - temperature controller
W - water inlet to chamber cooling coil
X - water outlet from chamber cooling coil

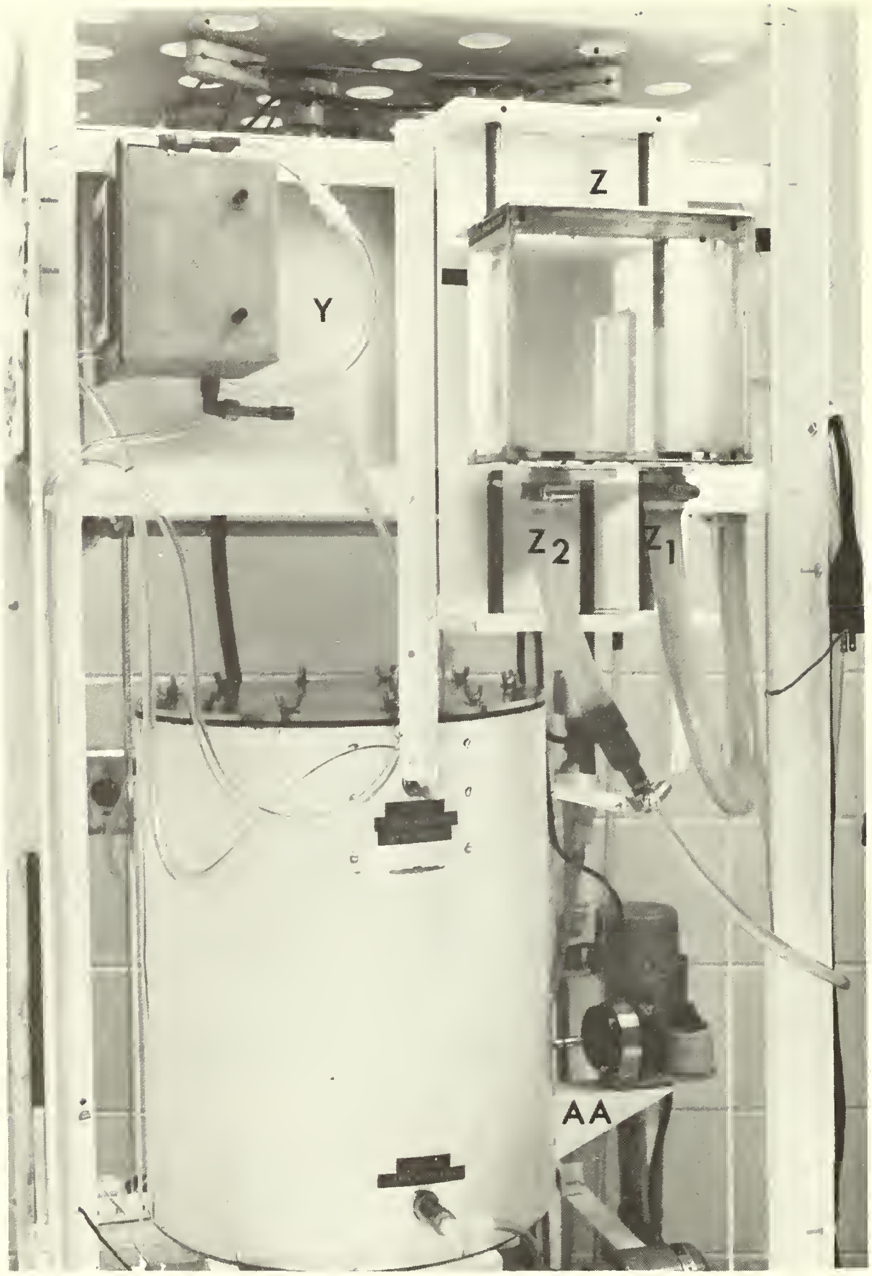

Figure 4.--Right side view of closed-system apparatus for measuring carbon dioxide exchange of tree seedlings.

- *Y - heat filter*
- *Z - water-level control for heat filter*
- *Z_1 - water inlet to water-level control*
- *Z_2 - water outlet from water-level control*
- *AA - fan motor and rheostat*

mounted on a welded angle-iron framework with rubber-tired casters. An estimate of the overall dimensions can be obtained from the upright supports, which are 6 feet high and spaced 3 feet apart.

The chamber is a double-walled cylinder, 22 inches long with an inside diameter of 12 inches; the inner cylinder wall is copper and the outer galvanized sheet metal. The 2-inch air space between the walls—filled with insulating vermiculite—is maintained by two flat rings, resembling washers, machined from 0.500-inch-thick aluminum plates. Each ring is fitted with 12 equally spaced 0.250-inch bolts which are capped with wing-nuts to hold the sheet-metal bottom and 0.250-inch-thick plexiglass top of the chamber in position. Rubber O-rings form an airtight seal between the aluminum rings and end covers of the chamber. One-half inch copper tubing is coiled and soldered around the outside of the copper cylinder at 1-inch intervals.

The seedling pot must be placed in the chamber because of the one-piece bottom. Consequently, the pot must be sealed to prevent CO_2 respired by soil organisms from entering the chamber atmosphere. A circular 0.150-inch-thick plexiglass disk—cut to a diameter slightly smaller than the diameter of the pot and slotted to accommodate the seedling stem—is placed over the soil. Masking tape and modeling clay seal the cover in place.

An open aluminum tank, 10 inches deep with a plate glass bottom, is mounted below the light source for a heat filter. Tap water flows continuously into the tank to replace evaporative loss. An overflow outlet acts as a water-level control.

The water-level control unit is an enclosed plexiglass box, partially divided into two compartments by a vertical plastic wall—with a sharp diagonal crest—that extends from the floor halfway up the sides of the box. Water entering one compartment through vinyl tubing from the tank flows over the crest into the other compartment, then to a floor drain via additional tubing. By adjusting the height of the control unit with a threaded rod, the water level in the tank can be maintained at any desired level.

A water reservoir is made from a refrigerated drinking fountain in which the internal water piping is replaced with a 2-gallon rustproof cylindrical tank containing a coil of copper tubing connected to the refrigeration unit. A continuous-duty water pump is mounted on the side of the fountain to circulate coolant to the chamber. An immersion pump, the type used in evaporative household coolers with an output of 2 gallons per minute, is placed in the tank to circulate water to the air-drying condenser.

To facilitate changing seedlings, the chamber is mounted on an adjustable shelf which can be positioned vertically with a ratchet and cable device, and moved horizontally on sliding-drawer guides.

The sheet-metal bracket holding the spotlights can be pivoted to a vertical position to replace bulbs and clean the heat filter.

Connections between vinyl tubing—0.375-inch inside-diameter water lines and 0.250-inch inside-diameter air lines—and pipe fittings are made with polypropylene tube fittings. Polyethylene quick disconnects are used in appropriate locations to join sections of air lines for ease of maintenance and operation.

Possible air leakage into the chamber through the fan-shaft opening can be eliminated by a machined shaft-housing—fitted with two ball bearing cones and two grease seals—which is kept filled with light grease applied through a grease fitting in the housing.

The chamber as described may not be suitable for photosynthesis measurements where experimental objectives of sizes and kinds of plants are different. Since the chamber is separate from most of the equipment, however, chambers of different designs can be interchanged to meet various requirements while utilizing all other components of the apparatus.

U.S.D.A. FOREST SERVICE
RESEARCH NOTE RM-144

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Estimating Defoliation of Douglas-fir and White Fir by the Western Budworm

M. E. McKnight[1]

A figure and a table are presented for estimating defoliation by the western budworm (Choristoneura occidentalis) from counts of undamaged shoots. The estimates are made on foliage samples taken for budworm egg mass surveys.

An adequate biological evaluation of an infestation of the western budworm (Choristoneura occidentalis Freeman) includes an assessment of tree defoliation.[2] Numbers of budworm eggs or larvae can be related to subsequent defoliation, and the information used to assist the land manager in determining whether suppression is needed.

Characteristically, budworm larvae feed from the shoot tip inward near the bases of the needles; they cut off the needle blades and leave the bases attached to the stems. By August, however, most of the dead needle bases have fallen, and only the bare shoot tips remain as evidence of budworm feeding.

Various methods have been used by other workers[3,4,5,6,7] to estimate current defoliation from foliage

[1]*Entomologist, located at Bottineau, in cooperation with the North Dakota School of Forestry; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*McKnight, Melvin E. Ecology of the western budworm, Choristoneura occidentalis Freeman (Lepidoptera: Torticidae), in Colorado. 206 pp. 1967. (Unpublished Ph. D. dissertation on file at Colo. State Univ., Fort Collins 80521.)*

[3]*Fettes, J. J. Investigations of sampling techniques for population studies of the spruce budworm on balsam fir in Ontario. 164 pp. 1951. (Unpublished Ph. D. dissertation on file at Univ. Toronto.)*

[4]*Terrell, Tom T. Estimating defoliation caused by spruce budworm from undamaged shoots. U.S.D.A. Forest Serv., Intermountain Forest and Range Exp. Sta. Res. Note 86, 2 pp., illus. 1961. (Ogden, Utah 84401)*

[5]*Carolin, V. M., and Coulter, W. K. Research findings relative to the biological evaluation of spruce budworm infestations in Oregon. U.S.D.A. Forest Serv., Pacific Northwest Forest and Range Exp. Sta. 39 pp. 1959. (Portland, Oreg. 97208)*

[6]*Silver, G. T. Individual differences in estimating defoliation. Can. Dep. Agr. Div. Forest Biol. Bi-mon. Progr. Rep. 15(3):3. 1959.*

[7]*Terrell, T. T. Spruce budworm survey methods in the northern region. U.S. Dep. Agr., Agr. Res. Serv., Plant Pest Contr. Div., Coop. Econ. Insect Rep 16: 1071-1072. 1966. (Hyattsville, Md. 20782)*

samples. Terrell's[4] method was used in this study to relate counts of undamaged shoots to estimates of percent defoliation of current growth on Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and white fir (Abies concolor (Gord. & Glend.) Lindl.).

Foliage was collected from each species in August 1965 and 1966 for egg mass surveys. To estimate the percentage of defoliation, undamaged and total shoots were counted from 111 Douglas-fir samples and 15 white fir samples. Each sample contained 100 or more new shoots.

The percentage of defoliation was assumed to be related to the percentage of undamaged shoots as
$Y = a + bX + cX^2$
where
Y = percent defoliation, and
X = percent undamaged shoots.

The equation for the relationship (fig. 1) was
$Y = 88.8028 - 1.6449X + 0.0076X^2$ ($r^2 = 0.95$)
for Douglas-fir, and
$Y = 76.3400 - 1.5468X + 0.0079X^2$ ($r^2 = 0.95$)
for white fir.

These equations were used to develop table 1. The percentage defoliation in a given area can be estimated from any unbiased foliage sample. It will usually be most convenient to use the foliage collected for egg mass counts. Take at random 100 new shoots from the entire sample and count those undamaged by feeding of budworm larvae. Estimated defoliation is then read from table 1.

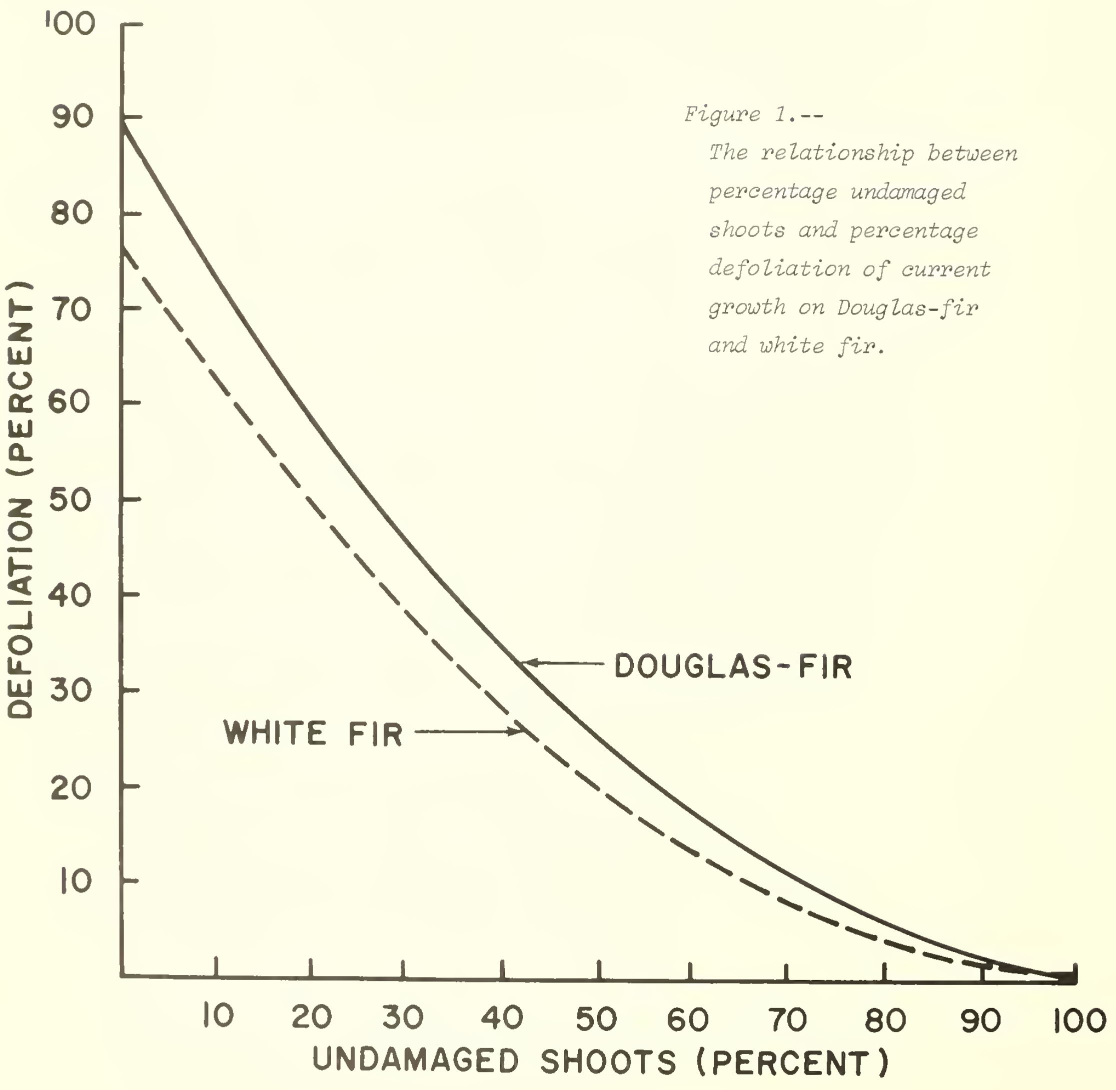

Figure 1.--
The relationship between percentage undamaged shoots and percentage defoliation of current growth on Douglas-fir and white fir.

Table 1.--Estimation of percent defoliation of current growth on Douglas-fir and white fir from counts of undamaged shoots

Percent undamaged shoots	Percent defoliation		Percent undamaged shoots	Percent defoliation	
	Douglas-fir	white fir		Douglas-fir	white fir
0	89	76	51	25	18
1	87	75	52	24	17
2	86	73	53	23	17
3	84	72	54	22	16
4	82	70	55	21	15
5	81	69	56	21	14
6	79	67	57	20	14
7	78	66	58	19	13
8	76	64	59	18	13
9	75	63	60	17	12
10	73	62	61	17	11
11	72	60	62	16	11
12	70	59	63	15	10
13	69	58	64	15	10
14	67	56	65	14	9
15	66	55	66	13	9
16	64	54	67	13	8
17	63	52	68	12	8
18	62	51	69	11	7
19	60	50	70	11	7
20	59	49	71	10	6
21	58	47	72	10	6
22	56	46	73	9	6
23	55	45	74	9	5
24	54	44	75	8	5
25	52	43	76	8	4
26	51	41	77	7	4
27	50	40	78	7	4
28	49	39	79	6	3
29	47	38	80	6	3
30	46	37	81	5	3
31	45	36	82	5	3
32	44	35	83	5	2
33	43	34	84	4	2
34	42	33	85	4	2
35	41	32	86	4	2
36	39	31	87	3	2
37	38	30	88	3	1
38	37	29	89	3	1
39	36	28	90	2	1
40	35	27	91	2	1
41	34	26	92	2	1
42	33	25	93	2	1
43	32	24	94	1	1
44	31	24	95	1	1
45	30	23	96	1	1
46	29	22	97	1	1
47	28	21	98	1	1
48	27	20	99	0	1
49	26	20	100	0	1
50	26	19			

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U.S.D.A. FOREST SERVI
RESEARCH NOTE RM-14

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATI

In Vitro Digestibility of Alpine Forages in Wyoming

Dixie R. Smith[1]

At the time of maximum standing crop, 54 species of alpine plants formed a spectrum of digestibility ranging from 35 to 78 percent. The primary forage species were intermediate in the digestibility spectrum. Carex elynoides, red fescue, and American bistort were the most digestible of the primary forage species.

Over 300 sheep allotments and 40 cattle allotments in Colorado and Wyoming include some alpine range (Wasser and Retzer 1966). These alpine ranges also furnish forage for elk, deer, and bighorn sheep.

The quality of alpine forages is not well known. Smith and Johnson (1965) reported the seasonal variation in crude protein content of eight species in the alpine zone of the Medicine Bow Mountains. They found that crude protein content was normally adequate for lactating ewes during the summer grazing season. Average energy values of alpine plants are reported (Golley 1961) to be higher than values of plants at lower elevations. Bliss (1962) associated the high energy content of alpine plants with their high lipid content.

Johnston et al. (1968) described the chemical composition and cellulose digestibility of several alpine plants in southwestern Alberta. Those species, some of which occur in the alpine zone of the central Rocky Mountains, provided a nutritious forage for bighorn sheep during the summer.

[1]*Principal Plant Ecologist, located at Laramie, in cooperation with the University of Wyoming; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

This paper reports the in vitro digestibility of dry matter in 54 species of alpine plants (table 1).

The study area consisted of 6 square miles of alpine range in the Absaroka Mountains near Cody, Wyoming. Elevations in the area ranged from about 10,000 to 11,500 feet.

Plant materials were obtained by clipping herbage to ground level in a two-stage sample (Hansen et al. 1953). The first stage consisted of 29 units, each containing 36 square yards. The second stage consisted of 20 units each 1 x 1 foot.

Plant material was harvested over a period of 17 days--July 18-August 3--the approximate period of maximum standing crop for alpine species (Smith and Johnson 1965).

Plant materials were dried at 105°C. and composited by species. Digestible dry matter was determined in triplicate samples by the in vitro technique of Tilley and Terry (1963). Inoculum was obtained from a fistulated steer on a diet of good quality alfalfa hay. Because of the inoculum source, the digestion coefficients may be inexact. However, the coefficients establish the relative digestibility of the various species.

Results

The 54 species formed a broad spectrum of digestibility (table 1): Coefficients ranged from 78 percent for spikefescue to 35 percent for alpine forget-me-not.

The primary forage species, those most abundant in the diet of sheep in this area, were Carex elynoides, red fescue, American bistort, bluegrasses, dwarf clover, whiproot clover, and golden avens. These species were of intermediate digestibility.

There were, however, considerable differences in digestibility among the primary forage species. Digestion coefficients for red fescue, American bistort, and Carex elynoides were equal and relatively high (65 percent). Bluegrasses were only slightly less digestible. Digestibilities of dwarf and whiproot clovers were rather low (56 and 49 percent respectively), despite the fact that proximate, mineral, and vitamin analyses emphasize their nutritional adequacy for livestock and game animals (Hamilton 1961). The digestion coefficient for alpine avens, an abundant species of relatively low palatability, was only 42 percent.

These results include no measure of seasonal or annual variation. They are reported, however, because of the lack of specific information on quality of alpine forages.

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Table 1.--Percent in vitro digestible dry matter in compos

Species	Mean ± standard error	Species
Spikefescue *Hesperochloa kingii* (S. Wats.) Rydb.	78 ± 1.8	Scribner wheatgrass *Agropyron scribneri*
Larkspur *Delphinium* sp.	77 ± 2.3	Sedge *Carex obtusata* Lil
Paintbrush *Castilleja* sp.	73 ± 3.5	Southern shootingstar *Dodecatheon radica*
Western yarrow *Achillea lanulosa* Nutt.	70 ± 2.9	Ebony sedge *Carex ebenea* Rydb.
Kittentails *Besseya cinerea* (Raf.) Pennell	70 ± 2.4	Fleabane *Erigeron simplex* Gr
Lomatium *Lomatium montanum* Coult. & Rose	70 ± 2.9	Lupine *Lupinus greenii* A.
Spike trisetum *Trisetum spicatum* (L.) Richt.	70 ± 3.5	Spike woodrush *Luzula spicata* (L.)
Fremont groundsel *Senecio fremontii* (Torr. & Gray)	69 ± 2.0	Bluegrass *Poa* spp.
Dandelion hawksbeard *Crepis runcinata* Torr. & Gray	68 ± 1.4	Blackhead sedge *Carex albo-nigra* Ma
Crazyweed *Oxytropis parryi* A. Gray	68 ± 0.7	Varileaf cinquefoil *Potentilla diversif*
Parry lousewort *Pedicularis parryi* A. Gray	68 ± 1.8	Parry clover *Trifolium parryi* A.
Littleflower penstemon *Penstemon procerus* Dougl.	68 ± 1.4	Alpine sagebrush *Artemisia scopuloru*
Sedge *Carex elynoides* Holm	66 ± 1.8	Tufted hairgrass *Deschampsia caespit*
Sticky polemonium *Polemonium viscosum* Nutt.	66 ± 1.4	Diamondleaf saxifrage *Saxifraga rhomboide*
Red fescue *Festuca rubra* L.	65 ± 2.3	Bluebells *Mertensia alpina* (T
Prairie junegrass *Koeleria cristata* (L.) Pers.	65 ± 2.3	Goldenrod *Solidago ciliosa* Gr
Slender wheatgrass *Agropyron trachycaulum* (Link) Maite	64 ± 1.8	Dwarf clover *Trifolium nanum* Tor
American bistort *Polygonum bistortoides* Pursh	63 ± 2.0	Pale agoseris *Agoseris glauca* (Pu

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1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassland Soc. 18: 104-111.

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1966. Ecology and utility of the central Rocky Mountain alpine zone. Ninth Int. Grassland Cong. [Sao Paulo, Brazil], Proc. 9: 357-361.

...amples of alpine herbage harvested July 18-August 3, 1967

	Mean ± standard error	Species	Mean ± standard error
	62 ± 0.7	Fernleaf fleabane *Erigeron compositus* Pursh	52 ± 0.7
	62 ± 1.8	Sedge *Carex limnophila*	51 ± 3.5
...ene	62 ± 1.4	Starry cerastium *Cerastium arvense* L.	50 ± 2.4
	61 ± 2.3	Whiproot clover *Trifolium dasyphyllum* Torr. & Gray	49 ± 3.4
	61 ± 2.3	Flowery phlox *Phlox multiflora* A. Nels.	48 ± 0.7
	61 ± 1.2	Sheep fescue *Festuca ovina* L.	47 ± 2.0
	61 ±<0.1	Snow willow *Salix nivalis* Hook.	46 ± 1.8
	61 ± 2.0	Arctic sandwort *Arenaria obtusiloba* Rydb.	45 ± 3.5
	60 ± 0.7	Phlox *Phlox pulvinata*	44 ± 2.4
...ehm.	60 ± 1.8	Ballhead sandwort *Arenaria congesta* Nutt.	43 ± 2.3
	59 ± 1.2	Golden avens *Geum rossii* (R. Br.) Ser.	42 ± 2.4
...ray	58 ± 0.7	Alpine forgetmenot *Myosotis alpestris* Schmidt	42 ± 2.4
...) Beauv.	58 ± 0.7	Wormleaf stonecrop *Sedum stenopetalum* Pursh	42 ± 3.5
...ene	57 ± 3.1	Alpine pussytoes *Antennaria alpina*	40 ± 2.7
...). Don	56 ± 1.4	Alpine willowweed *Epilobium alpinum* L.	39 ± 1.2
	56 ± 0.7	Boreal sandwort *Arenaria rubella* (Wahl.) Smith	38 ± 1.8
	56 ± 1.4	BearRiver fleabane *Erigeron ursinus* D. C. Eaton	36 ± 1.4
...) Dietr.	54 ± 2.9	Alpine forget-me-not *Eritrichium elongatum* (Rydb.) Wight	35 ± 2.0

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U.S.D.A. FOREST SERVICE
RESEARCH NOTE RM-146

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Estimating Numbers of Eggs In Western Budworm Egg Masses

M. E. McKnight[1]

Describes a rapid method of estimating egg numbers, laid on Douglas-fir and white fir, based on number of rows of eggs, length of the egg mass, and a conversion table.

Population trends of the western budworm, Choristoneura occidentalis Freeman, in Colorado have been followed by means of egg mass surveys (biological evaluations)[2] since 1959. The number of eggs per new egg mass was estimated for each sample each year prior to 1966. Counts of new egg masses probably are adequate to show trends unless the numbers of eggs per mass vary considerably from year to year. McKnight[3] suggested that an adequate biological evaluation should include counts of budworm eggs in August and counts of instar IV larvae the following spring so that the degree of survival during the intervening period can be computed. This Note provides a means of estimating accurately the numbers of eggs in each budworm egg mass.

[1]*Entomologist, located at Bottineau, in cooperation with the North Dakota School of Forestry; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2]*Conducted and reported by the Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo., in 1959 and 1960; and by the U.S. Forest Serv., Reg. 2, Div. Timber Manage., Br. of Forest Pest Contr., Denver, Colo., beginning in 1961.*

[3]*McKnight, Melvin E. Ecology of the western budworm, Choristoneura occidentalis Freeman (Lepidoptera: Tortricidae), in Colorado. 206 pp. 1967. (Unpublished Ph. D. dissertation on file at Colo. State Univ., Fort Collins 80521.)*

Terrell[4] presented regressions for estimating numbers of eggs of the western budworm in Montana from the measured lengths of egg masses, and Miller[5] and Bean[6] presented similar data for the spruce budworm, Choristoneura fumiferana (Clem.).

Trends Observed in Egg Mass Size

The biological evaluation reports from all plots in the Rocky Mountain Region, 1959-65, show that egg mass sizes fluctuated widely: The average number of eggs per mass declined from 25.3 in 1959 to 23.6 in 1961 when egg mass densities were increasing; rose sharply to 31.9 in 1962 when egg mass densities were low; and fluctuated between 24.0 and 29.7 in 1963, 1964, and 1965, when egg mass densities were generally low but variable.

[4]*Terrell, Tom T. Techniques of spruce budworm surveys in the northern Rocky Mountain Region, 1960. Progr. Rep. U. S. Forest Serv. Intermountain Forest and Range Exp. Sta. Mimeo. 14 pp. 1961. (Ogden, Utah 84401)*

[5]*Miller, C. A. A technique for estimating the fecundity of natural populations of the spruce budworm. Can. J. Zool. 35: 1-13. 1957.*

[6]*Bean, James L. A method for estimating the number of spruce budworm eggs per mass. J. Econ. Entomol. 54: 1064. 1961.*

Trends in densities of new egg masses and numbers of eggs per mass on nine plots on the San Juan National Forest are shown in figure 1. Data were used only for years when Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) trees were sampled; all plots were sampled at least 4 years and some plots were sampled for the entire period 1959-66. The egg masses were significantly larger in 1963 and 1964 than in 1959 and 1960 as shown by Duncan's Multiple Range Test. Mean number of eggs per mass also differed significantly between plots. Although density of new egg masses was not significantly correlated with size of egg masses, the data show a tendency toward an inverse relationship between trends in egg mass size and egg mass density.

Miller[5] stated that the mean number of spruce budworm (C. fumiferana (Clem.)) eggs per mass is dependent on the degree of infestation. When food supplies are meager and densities of larvae are high, the resultant moths are small and lay smaller egg masses.

Relationships Between Egg Numbers and Egg Mass Size

In the course of extensive fecundity trials[3] more than 3,300 unhatched egg masses laid on Douglas-fir and white fir (Abies concolor (Gord. & Glend.) Lindl.) needles were measured for length, number of eggs, and number of rows. The relationship between the number of eggs in a mass (Y) and its length (X) is linear (Y= a + bX) for masses of one, two, three, or four rows. The means and regression statistics are presented in table 1; the relationships, in figure 2.

When they hatch, the egg masses shrink to a degree depending on their length. Egg counts and measurements were taken from about 120 two-row and three-row egg masses that hatched in

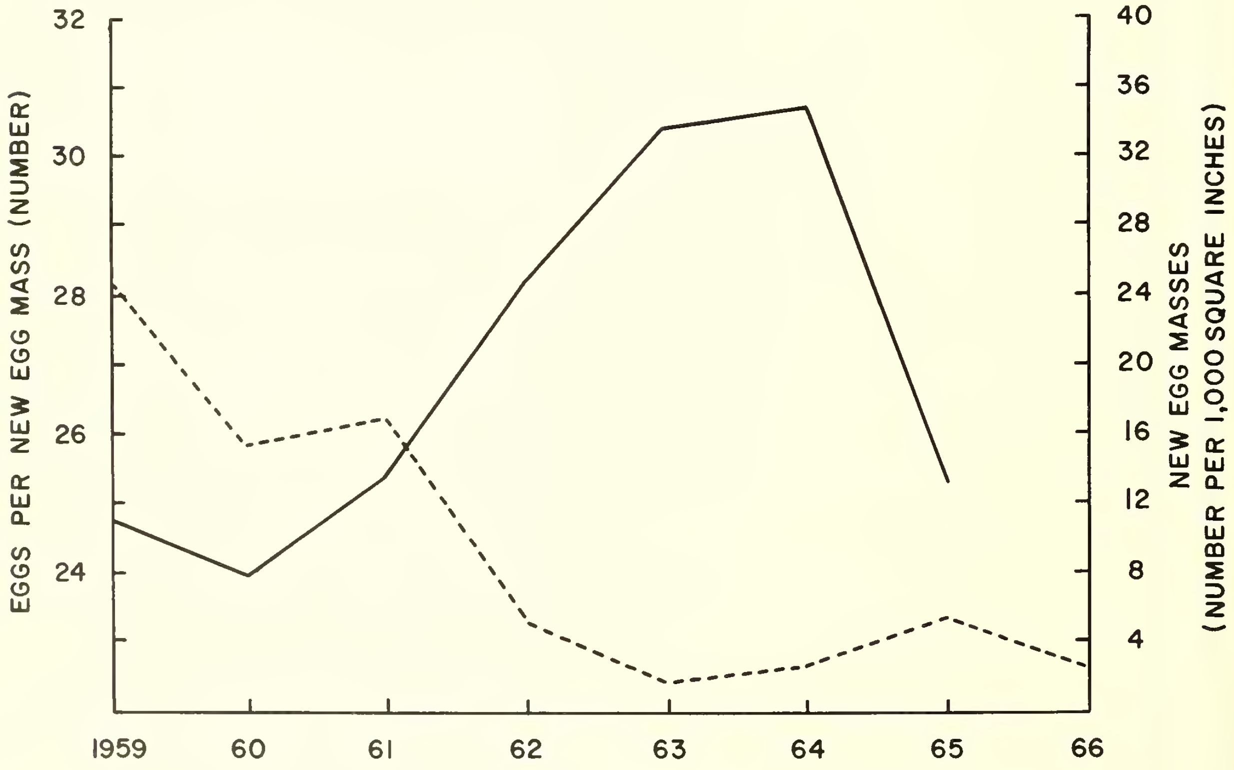

Figure 1.--Trends in the size of egg masses (solid line) and the density of new egg masses (dashed line) on nine survey plots on the San Juan National Forest, Colorado.

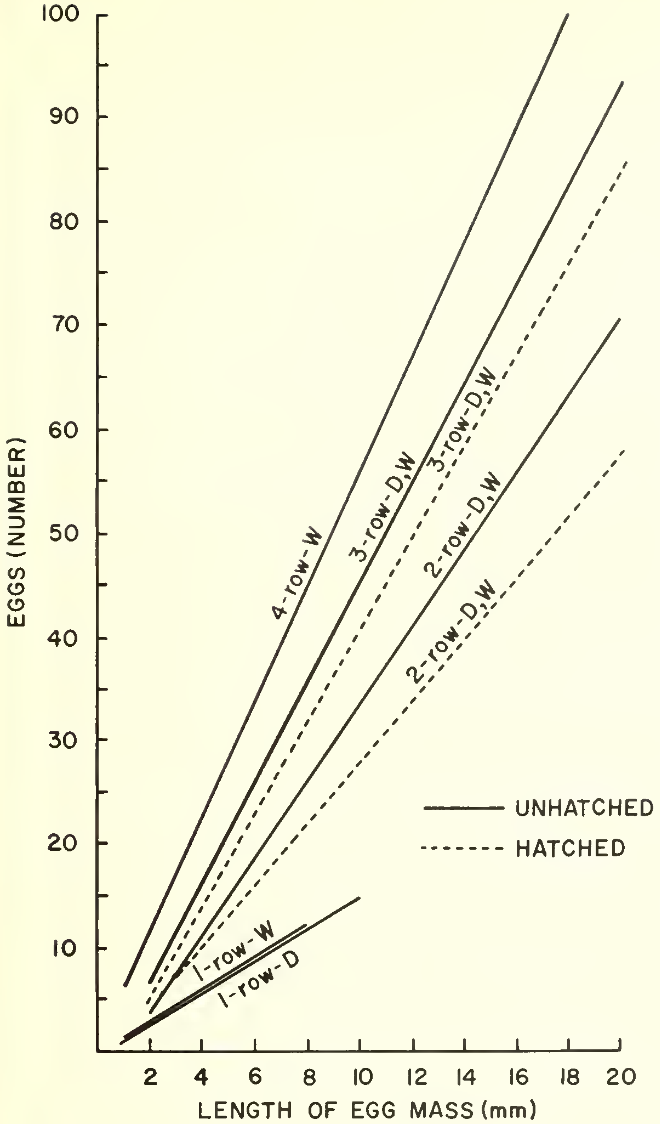

Figure 2.--
The relationship between the length of egg masses and the number of eggs in masses of 1, 2, 3, or 4 rows on Douglas-fir (D) and white fir (W).

Table 1.--Means and regression statistics from analyses of relationship of egg mass size and egg numbers in unhatched masses on needles from Douglas-fir and white fir

Number of egg rows, and species	N	Mean egg mass length	Mean number of eggs	a	b
		mm.			
One row:					
Douglas-fir	443	2.32	[1]2.88	-0.78	1.58
White fir	139	2.32	[1]3.42	- .24	1.58
Two rows:					
Either species	1,589	6.02	18.58	-4.26	3.79
Three rows:					
Either species	1,159	7.49	32.82	-3.01	4.78
Four rows:					
Douglas-fir	43	8.31	46.72	.24	5.59

[1]Adjusted mean number of eggs estimated from the mean egg mass length of 2.32 millimeters.

the field. The length-egg numbers relationships (dashed lines in fig.2) for these masses were obviously different from the relationships for unhatched masses. Egg numbers are therefore underestimated when the regressions from table 1 are applied to hatched egg masses. An accurate adjustment can be made for two-row and three-row masses by increasing the estimated number by 13 percent and 12 percent, respectively. For one-row and four-row masses, increases of 14 percent and 11 percent, respectively, probably would be satisfactory.

In egg mass surveys, examiners collect needles bearing budworm egg masses from foliage samples. An entomologist separates the egg masses into two categories: new egg masses, laid the year of the survey; and old egg masses, laid in prior years. Usually, the eggs are counted in 25 new egg masses from each plot. The more rapid method of using the number of rows of eggs, the length of the egg mass (measured with a calibrated micrometer eyepiece in a binocular microscope), and a conversion table will allow observers to make estimates for all egg masses in the sample. Table 2 is a summary of a more complete table which can be calculated from the regressions in table 1.

Observers should have little trouble distinguishing between one-, two-, or four-row egg masses. They should be cautioned that "three-row" egg masses have three definite rows, with the middle row at least one-half as long as the lateral rows.

Table 2.--Number of western budworm eggs in unhatched masses[1] of one, two, three or four rows of eggs on Douglas-fir or white fir needles

Length of egg mass (mm.)	Number of eggs in--				
	One row on--		Two rows on either species	Three rows on either species	Four rows on white fir
	Douglas-fir	White fir			
1	0.8	1.3	--	1.8	5.8
2	2.4	2.9	3.3	6.5	11.4
3	4.0	4.5	7.1	11.3	17.0
4	5.5	6.1	10.9	16.1	22.6
5	7.1	7.7	14.7	20.9	28.2
6	8.7	9.2	18.5	25.7	33.8
7	10.3	10.8	22.3	30.4	39.4
8	11.9	12.4	26.1	35.2	45.0
9	13.4	14.0	29.8	40.0	50.5
10	15.0	15.6	33.6	44.8	56.1
11	16.6	17.1	37.4	49.6	61.7
12	18.2	18.7	41.2	54.3	67.3
13	19.8	20.3	45.0	59.1	72.9
14	21.3	21.9	48.8	63.9	78.5
15	22.9	23.5	52.6	68.7	84.1
16	24.5	25.0	56.4	73.5	89.7
17	26.1	26.6	60.2	78.2	95.3
18	27.7	28.2	64.0	83.0	100.9
19	29.2	29.8	67.8	87.8	106.4
20	30.8	31.4	71.5	92.6	112.0
21	32.4	32.9	75.3	97.4	117.6
22	34.0	34.5	79.1	102.1	123.2
23	35.6	36.1	82.9	106.9	128.8
24	37.1	37.7	86.7	111.7	134.4
25	38.7	39.3	90.5	116.5	140.0

[1]For hatched masses, multiply indicated number of eggs by:
1.14 for one-row masses, 1.12 for three-row masses,
1.13 for two-row masses, 1.11 for four-row masses.

Agriculture --- CSU, Ft. Collins

U.S.D.A. FOREST SERVICE
RESEARCH NOTE RM-147

FOREST SERVICE
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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Heated Thermopile Anemometer Compared With Sensitive-Cup Anemometer in Natural Airflow

James D. Bergen[1]

Comparison of twenty 5-minute average speeds showed discrepancies of as much as ±50 percent with windspeeds ranging from 2.8 to 6.6 miles per hour. The magnitude and sense of the deviations did not vary systematically with turbulence intensity or speed. Measurements were made at an air temperature of about 20°C.

In a recent study involving the measurement of vertical wind profiles, a heated thermopile anemometer was compared with an array of standard sensitive-cup anemometers. The large differences between the values of windspeed indicated by the thermopile instrument and those estimated by extrapolation of the cup anemometer readings raised a question about the compatibility of the two types of instrument under conditions of natural turbulent flow, and led to direct comparison of the two instruments.

[1]*Meteorologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

The thermopile anemometer[2] consists of a circle of thermocouple junctions exposed to the ambient airflow; the sensor is supposed to be nondirectional with regard to flow in the plane of the circle, and is furnished by the manufacturer with a single calibration on the instrument scale. The output is recorded by a stylus pressed against a logarithmically graduated pressure-sensitive strip chart. A typical record is shown in figure 1.

[2]*Hastings RA-I air meter with an N-7 probe. (Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.)*

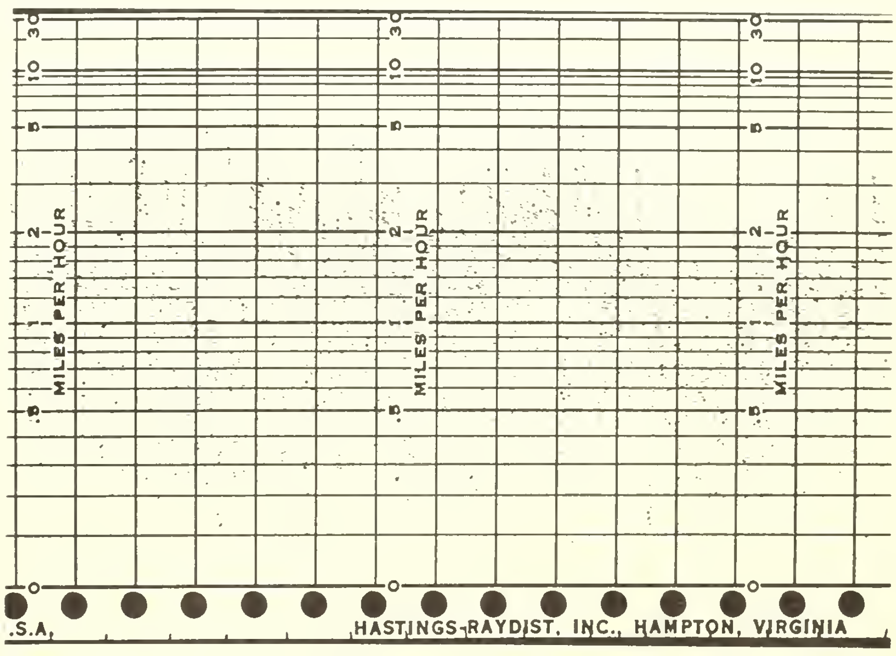

Figure 1.--Sample thermopile anemometer record (full scale--at a speed of one inch per hour).

The cup anemometers have tapered, plastic cups with beaded edges, mounted on a shaft which illuminates a photo cell with each rotation. The resulting electrical current pulses drive a mechanical counter. A threshold velocity of 0.26 m.p.h. and counting circuit accuracy of one count per timing interval is claimed by the manufacturer. For 5-minute intervals and speeds of the order of 5 m.p.h., this would amount to an error less than ±0.05 m.p.h. The major source of error in fluctuating natural winds, however, is the "overshoot" effect common with all cup anemometers. An order of magnitude estimate,[3] based on the cup dimensions and weight, indicates that for turbulence intensities of 1.00 at 5 m.p.h., overshoot could cause an 8 percent overestimate of average windspeed.

[3]*Meteorology Office. Handbook of meteorological instruments. I. Instruments for surface observations. M. O. 577, 458 pp., illus. 1956. London: Her Majesty's Stationery Office. (Reprinted 1961.)*

The two instruments were compared in a slightly sloping open field with a sparse grass cover. The thermopile anemometer and a Thornthwaite sensitive-cup anemometer were mounted 2 feet apart at a height of 5 feet.

The cup anemometer was mounted on a staff and tubular arm assembly provided by the manufacturer. The staff has a square cross section of 1.5 inch on a side. The arm is about 1 foot long and consists of tubing 0.5 inch in diameter. The staff was kept downwind from the cup assembly. The thermopile sensor was mounted in a burette clamp at its base, which was in turn clamped to a ring stand downwind from the sensor.

The average wind for 5-minute intervals, indicated by the cup anemometer ($\bar{U}_c$), was compared to the average computed from the trace of the thermopile anemometer.

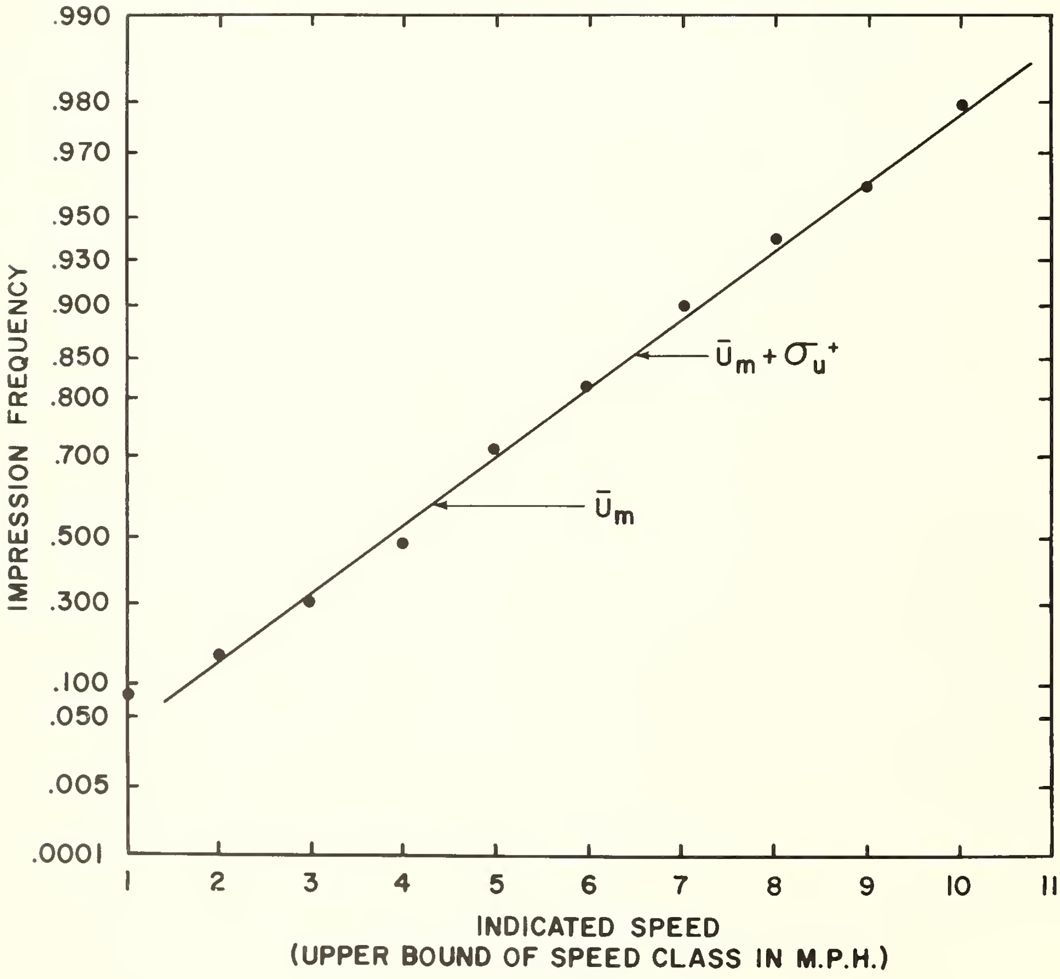

Figure 2.--Example of graphical estimate.

Table 1.--Comparison of 5-minute cup anemometer speeds with speeds computed from heated thermopile anemometer recording

Average speed $\bar{U}_c$ (m.p.h.)	Standard deviation of measured speed σ_u^+	$\sigma_u^+/\bar{U}_m$	Mean speed $\bar{U}_m$	$\bar{U}_m - \bar{U}_c$	$\frac{\bar{U}_m - \bar{U}_c}{U_c}$	N	Average speed $\bar{U}$	$\bar{U} - \bar{U}_c$	Air temperature T_a
	m.p.h.		m.p.h.	m.p.h.	Percent		m.p.h.	m.p.h.	°C.
6.6	6.6	0.89	7.4	0.8	12	60	13.0	6.4	20
3.8	7.0	1.70	4.2	.4	11	61	9.1	5.3	20
4.8	4.4	.88	5.0	.2	4	60	7.6	2.8	20
3.9	2.7	.60	4.5	.6	15	54	6.9	3.0	20
5.0	5.6	1.08	5.2	.2	4	66	9.6	4.6	20
3.7	6.4	1.40	4.6	.9	24	48	9.7	6.0	20
4.6	3.9	1.80	2.1	-2.5	-54	63	4.3	- .3	20
5.2	5.7	1.50	3.7	-1.4	-27	47	4.9	- .3	20
2.8	3.2	.89	3.6	.8	29	52	5.2	2.4	20
4.5	3.2	.97	3.3	-1.2	-27	67	4.5	0.0	20
4.4	4.2	1.10	3.8	- .6	-14	58	4.2	- .2	20
4.3	3.8	.58	6.6	2.3	54	60	5.1	.8	20
5.5	3.2	.76	4.2	-1.3	24	61	6.0	.5	20
3.7	2.6	.69	3.8	.1	3	42	4.3	.6	20
3.7	2.4	.67	3.6	- .1	3	50	4.3	.6	20
4.7	4.9	.71	6.9	2.2	47	60	9.8	5.1	20
2.6	1.5	.60	2.5	- .1	4	60	3.0	.4	20
4.4	3.6	1.10	3.2	-1.2	27	52	4.4	0.0	20
5.3	4.9	.69	7.1	1.8	34	54	9.3	4.0	20
4.5	3.0	.75	4.0	- .5	11	52	5.4	.9	17

The tests consisted of one 30-minute observation period on 3 successive days. Periods were chosen during which the mean wind direction was relatively steady.

Because the nonlinearity of the speed scale leads to large errors in reading the trace at speeds above 10 m.p.h., the common practice of estimating the average speed as a half of the sum of the maximum and minimum values would have heavily weighted the least accurate data on the trace. For the comparison to be reported, the average speed was computed from the observed distribution of all impressions.

The strip of record corresponding to the 5-minute cup average was located from the known strip speed of 1 inch per hour. The total impressions per 5-minute interval for each speed class were counted, with the aid of a magnifying glass and a template. The striker bar frequency should give 60 impressions for a 5-minute period; in practice, the sum of the subclass values denoted (N) in the table ranged from 42 to 66. The low values are apparently due to overlap between impressions near the average speed, and the high values due to boundary errors, caused by stylus impressions overlapping intervals or speed classes.

An average speed can be simply computed as the arithmetic sum of the central values of the speed classes and the relative frequency of impressions in that class. This speed ($\bar{U}$) was calculated for each interval (table 1). Such an average still tends to overweight the high-speed excursions. A second calculation intended to remedy this problem consisted of plotting the cumulative frequency distribution on extreme probability paper (fig.2). The mean speed ($\bar{U}_m$), as determined from this graphically fitted distribution, is largely a function of the distribution of impressions in the moderate speed ranges. From this fitted distribution, an estimate could simply be made of the standard deviation of the measured windspeed over the interval (σ_u^+), which was assumed to be approximately the range between the mean and the 85th percentile. The calculated values are shown in table 1.

The table shows wide deviations between the two instruments. While the mean speed ($\bar{U}_m$) approaches the cup speeds more closely than the arithmetic mean ($\bar{U}$) as judged by the relative magnitude of ($\bar{U}$ - $\bar{U}_c$) and ($\bar{U}_m$ - $\bar{U}_c$), simultaneous values of $\bar{U}_m$ and $\bar{U}_c$ may vary by ± 100 percent. Since the thermopile sensor has a low lag time and the averaging procedures described above are carried out over the indicated speeds rather than voltage output, the discrepancies are not due to the nonlinearity of the thermopile output with respect to ambient speed. Indeed when the turbulence intensities (σ+ / $\bar{U}_m$) are calculated, they show no systematic variation with ($\bar{U}$ - $\bar{U}_c$) or ($\bar{U}_m$ - $\bar{U}_c$). Gustiness ratios of over 1.0 are associated with deviations as low as +0.2 and as high as 2.5 m.p.h.

The local air temperature for all but one of the intervals was 20° C. as noted in the table. Therefore, the variation in $\bar{U}$ - $\bar{U}_c$ and $\bar{U}_m$ - $\bar{U}_c$ cannot be ascribed to temperature effects.

Some wind tunnel studies of the same anemometer sensor have been reported.[4] The voltage output of the thermopile probe was compared with the speed indicated by a standard Pitot tube when the probe was rotated about its axis of symmetry. The results showed a pronounced directionality, resulting in a range of output corresponding to 1 m.p.h. in terms of the average velocity calibration for a rotation of 360° with airspeeds in the range of 1 m.p.h. to 5 m.p.h. This directionality occurs in cycles of 70° of rotation. It would be expected that for higher turbulence intensities and thus greater variation in wind direction, directional effects would tend to average out for 5-minute intervals. As noted above, however, the data in the table show no such tendency.

A complicating factor may be found in the response of the recording system, that is, differing effects of overshoot at the low and high speed portions of the scale. It is also possible that the two types of instrument have a radically different response to vertical gustiness, which may not be evident in wind tunnel calibrations.

While the source of error is still unknown, it would seem that some extended measurements are needed before such a thermopile instrument can be considered compatible with a cup anemometer system.

[4] *Allen, L. H. Annual progress report of microclimate investigations. pp. 207-212, 1968. U. S. Dep. Agr., Agr. Res. Serv., Soil and Water Conserv. Res. Div., Ithaca, N. Y.*

1969

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FOREST SERVICE
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CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Starvation in Antelope with Stomachs Full of Feed

Henry A. Pearson[1]

Heavy snows in northern Arizona completely covered vegetation available to antelope herds. After native and supplemental feed became available, antelope died from starvation with stomachs full of feed, apparently due to rumen malfunction. No ciliate protozoa were observed in the rumen contents although several types of bacteria similar to those described in domestic and wild ruminants were observed.

Seven feet of snow fell on northern Arizona between December 13 and 21, 1967. All native vegetation available to antelope (Antilocapra americana) was completely covered. The herds were subjected to low temperatures, and forced to move through deep snow. When conditions permitted, the Arizona Game and Fish Department provided alfalfa hay as supplemental feed to the antelope herds. Following snowmelt, native browse again became available. Soon thereafter, antelope were found dead on the range with their stomachs full to a point of impaction. In some of the dead antelope, rumen ingesta consisted primarily of fourwing saltbrush (Atriplex canescens (Pursh) Nutt.) and Bigelow sagebrush (Artemisia bigelovii A. Gray), while in others the ingesta was mainly alfalfa hay. Since the antelope bone marrow was red and gelatinous and fetuses were bloody, death was attributed to starvation. Atrophy of body fat was apparent in all animals examined. These antelope were without feed 10 to 14 days before either native or artificial feed was available.

Rumen samples were collected from six dead antelope on January 13, 1967, and preserved in 10 percent formalin for analysis of the rumen microflora and fauna (table 1). One rumen sample was carried to the laboratory for analysis prior to addition of formalin. This sample was analyzed within 2 hours after collection. Observations and microorganism counts were made by techniques similar to those reported by Pearson (1965).

Microscopic examination of the rumen contents revealed no ciliate protozoa in any of the six dead antelope. Bacteria observed included various cocci, rod-shaped, and spiral organisms, similar to those described in domestic and wild ruminants (Bryant 1959; Hungate 1960; Pearson 1965, 1967). Direct microscopic examination of the nonformalin rumen sample revealed that many of the bacteria were viable. The average number of bacteria counted in this sample was 4.3 billion/ml. of rumen fluid, which is similar to counts reported from other rumi-

[1]*Range Scientist, located at Flagstaff, in cooperation with Northern Arizona University; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Table 1.--Notes taken January 13, 1968, concerning antelope that died following a severe snowstorm December 1967

Animal number	Sex	Age	Remarks
1	Female	3-5 years	Animal dead approximately 24 hours (1 to 2 days); had two bloody fetuses; rumen full of feed (alfalfa hay, sagebrush, and saltbush); true stomach empty, others full; lungs bloody and ulcerated; femur bone marrow red and gelatinous; content in rumen not completely frozen, reticulum frozen.
2	Male	Yearling	Animal dead 3 to 4 days; rumen contents frozen; all stomachs full of feed (sagebrush and saltbush in rumen); bone marrow red and gelatinous.
3	Female	Fawn	Animal dead 3 to 4 days; rumen contents frozen; all stomachs full (sagebrush and saltbush in rumen); bone marrow red and gelatinous.
4	Female	3-5 years	Animal dead 3 to 4 days; rumen contents frozen; two embryos more normal than number 1 in color, apparently less reabsorption; bone marrow red and gelatinous but somewhat firmer and not as red as number 1; rumen full of saltbush and sagebrush.
5	Female	Mature	Animal died within last 12 to 16 hours; not frozen; stomachs full of alfalfa hay; two bloody fetuses; bone marrow red and gelatinous.
6	Female	5 years	Animal attacked by coyote in last 8 to 12 hours, bone marrow less red and gelatinous than number 5 or 1, indicating more fatty tissue; rumen full of alfalfa hay; rumen contents taken to laboratory in fresh condition.

nants. Of the total bacterial numbers in the rumen contents of the six antelope, two types were predominant: (1) Selenomonads, 10.5 percent, and (2) Quin's ovals, 12.6 percent (fig. 1). These amounts are apparently higher than would be expected on roughage diets, although selenomonads may constitute 20 to 40 percent of a total colony count from steers fed corn and urea (Hungate 1966). Quin's ovals in rumen contents apparently are so scarce that they are seldom mentioned in rumen studies. These organisms have not been successfully cultured (Purdom 1963).

Counts of bacteria from contents of an antelope killed during the regular hunting season (September 23, 1968) were similar in total number and kind to bacteria observed in antelope that starved. The average number of bacteria counted in this apparently normal animal was 5.2 billion/ml. of rumen fluid with 14.3 percent selenomonads and 6.5 percent Quin's ovals. These subsequent findings suggest that the antelope that died from starvation contained a normal rumen microflora. Quin's ovals were fewer in the normal animal. The average number of protozoa counted in the normal animal was 800/ml. of rumen fluid. According to descriptions given by Zielyk (1961), the protozoa were Entodinium dubardi.

Quin's ovals have been described as being closely related to the selenomonads (Hungate 1966). McGaughey and Sellers (1948) found these ovoid forms overwhelmingly predominant in rumen contents of sheep fed meadow hay and mangolds (sugar beets). The organisms were absent or in low numbers when the sheep were fed only meadow hay, but within 3 days of the addition of mangolds to the diet they appeared in great numbers. Apparently these organisms thrive on high carbohydrate diets, which produce excess fatty acids in the rumen.

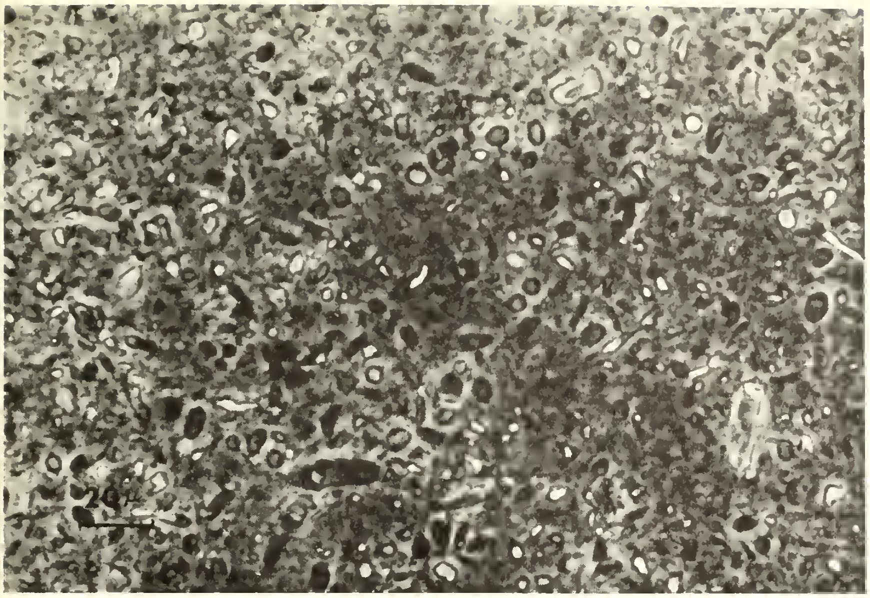

Figure 1.--

Photomicrograph of rumen micro-organisms from antelope that died from starvation.

Excess fatty acids are produced when large amounts of concentrated feeds such as mangolds are added to the diet, or when the rumen wall does not absorb the nutrients quickly enough to remove the concentrated starch and glucose byproducts from the rumen. The latter occurs in cases of rumen atony.

Acid indigestion, rumen atony, and death in domestic animals are associated with overeating of high-carbohydrate concentrates, and with animals that have been semistarved and later gained access to lush feeds (Hungate 1966, Kingsbury 1964). In these cases, acid production was greater than the normal neutralizing mechanisms of the rumen could handle, which resulted in low pH and cessation of rumen action. During prolonged fasting, ruminal fluid composition approaches that of saliva (Turner and Hodgetts 1955); therefore, a starving animal would be expected to have a ruminal fluid pH near 8. The rumen fluid pH in these antelope varied between 6.3 and 7.0, which indicates acid was being produced.

Antelope herds known to visit an available haystack in the area during the storm survived. The available hay prevented complete starvation and rumen malfunction. When native feed became available after the storm, the rumen quickly resumed normal absorption and activity, which averted death. Deer have survived in similar circumstances where some native forage was available when hay was fed, while others without native forage died with stomachs full of feed (Doman and Rasmussen 1944). Animals generally lose weight in winter, but available native or artificial forage provided immediately with onset of stress periods apparently prevents rumen malfunction and eventual death.

If supplemental feeding is considered as a management measure, to be effective it should be started before the starvation process has become irreversible. The physiology of starvation is still too poorly understood in most wild ruminants to make specific feeding recommendations for specific situations. This is an area where research is clearly needed. Physiological and nutritional studies of wild ruminants under controlled stress conditions should include:

1. Rates of fermentation of the rumen digesta.
2. Molar proportions and amounts of rumen volatile fatty acids.
3. Chemical and botanical analyses of the digesta.
4. Total and differential counts of rumen micro-organisms from normal animals and those under varying degrees of stress.
5. Gas production by the rumen digesta.
6. Rumen pH influence on microbial activity.
7. Isolation and culture of the micro-organisms.

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U.S. FOREST SERVICE
RESEARCH NOTE RM -149

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

Establishment and Survival of Several Grasses in the Sagebrush Type, West-Central New Mexico[1]

O. D. Knipe[2]

At the end of four growing seasons, only two of the eight grass species were rated as good stands; Russian wildrye and buffalograss appear best suited for erosion control and soil protection in the testing area.

Extensive acreages of abandoned cropland and rangeland in the sagebrush type of the western States have been improved by seeding to adapted grasses. The value of planting buffalograss [3] and alkali sacaton in the sagebrush type of west-central New Mexico has not been tested.

The purpose of this study was to compare the relative value of buffalograss and alkali sacaton to several species which have been proven adapted to sagebrush sites in other areas—blue grama, Indian ricegrass, Russian wildrye, crested wheatgrass, pubescent wheatgrass, and western wheatgrass.

Description of the Study Area

The study area was located approximately 11 miles west of Cuba, New Mexico, near the southeasternmost extension of the sagebrush type. Vegetation consisted of a heavy stand of big sagebrush (Artemisia tridentata Nutt.) with occasional plants of greasewood (Sarcobatus vermiculatus (Hook.) Torr.), blue grama, and crested wheatgrass.

The mean annual precipitation at Cuba is 13.94 inches, distributed approximately as follows: 35 percent winter (October-March), 14 percent spring (April-June), and 51 percent growing season (July-September). Soils of the area are heavy clay loam.

Procedures

The area was protected from grazing for the duration of the study, June 1965-October 1968. About 90 percent of the sagebrush plants were eradicated by plowing to a 10-inch depth with an ordinary moldboard plow and farm tractor. Grasses were seeded in late June 1965 with a drill equipped with double disc openers and adjustable depth bands. Blue grama and alkali sacaton were planted 0.5 inch deep; the wheatgrasses, buffalograss, and Russian wildrye, 1 inch; and Indian ricegrass, 2 inches. Seeding rate was controlled by drill calibration and dilution with autoclaved seed. Each species was replicated four times in 10- by 200-foot plots, with six rows per plot.

Plants were counted (1) shortly after emergence the first season, (2) each fall at the close of the

[1] *Study conducted in cooperation with the U. S. Bureau of Land Management, Albuquerque, New Mexico.*

[2] *Plant Ecologist, located at Albuquerque, in cooperation with the University of New Mexico; central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[3] *See table 1 for scientific names of grass species.*

growing season, and (3) early each summer at the start of the growing season (table 1).

Results and Discussion

The first growing season (summer 1965), which had above-average (15.80 inches) precipitation, resulted in a good stand of all wheatgrasses, Russian wildrye, and buffalograss (1 to 3 plants per square foot), a fair stand of alkali sacaton and blue grama (0.50 and 0.59 plant per square foot), and a poor stand of Indian ricegrass (0.15 plant per square foot). However, the stand of Indian ricegrass reached 0.90 plant per square foot the following spring; seeds germinated and emerged in the early spring before the winter moisture was depleted.

A period of low precipitation during the spring is characteristic of the areas; only 0.13 inch fell in the area from April through June 1966. Total 1966 precipitation was 9.86 inches, 4.08 inches below average. This dry period resulted in an appreciable loss in plants of all species except blue grama, and buffalograss, and Indian ricegrass which increased as the result of emergence before the winter moisture was depleted. Precipitation during 1967 and 1968 was approximately average for the area.

At the end of the fourth growing season, the only species present in sufficient numbers to be considered a good stand were buffalograss and Russian wildrye. The number of plants of Russian wildrye actually increased from 1.33 per square foot at the start of the second growing season to 2.10 at the end of the fourth growing season. These Russian wildrye plants were very vigorous, and because of their rosette-type growth habit, were judged to be excellent from the standpoint of soil stabilization. Buffalograss completely occupied the sample frame as a result of its stoloniferous growth habit. Had the seeding rate of this species been higher, the plants probably would have completely blanketed the soil surface by the end of the second growing season.

A sufficient number of pubescent wheatgrass, western wheatgrass, and Indian ricegrass plants survived to be considered a fair stand (approximately 0.50 plant per square foot).

The results of the study suggest that Russian wildrye and buffalograss should be considered for erosion control when seeding areas within the southeasternmost extension of the sagebrush type of west-central New Mexico. Russian wildrye provides considerable soil protection by its rosette-growth form; buffalograss, by its stoloniferous growth.

Table 1.--Establishment and survival of several grass species in the sagebrush type of west-central New Mexico, by date of count

Species	1965		1966		1967		1968	
	July 30	October 8	June 28	October 1	July 5	October 1	July 1	October 1
	- - - - - - - Number per square foot[1] - - - - - -							
Blue grama *Bouteloua gracilis* (H.B.K.) Lag.	0.59	0.62	0.50	0.34	0.12	0.12	0.12	0.16
Pubescent wheatgrass *Agropyron trichophorum* (Link) Richt.	2.28	2.15	1.47	1.25	.47	.47	.47	.46
Crested wheatgrass *Agropyron desertorum* (Fisch.) Schult.	3.17	2.13	1.13	1.28	.23	.23	.18	.18
Western wheatgrass *Agropyron smithii* Rydb.	1.38	1.33	1.00	1.06	.53	.53	.53	.53
Alkali sacaton *Sporobolus airoides* Torr.	.50	.27	.12	.14	.14	.14	.10	.03
Indian ricegrass *Oryzopsis hymenoides* (Roem. & Schult.) Ricker	.15	.03	.90	.72	.50	.50	.44	.40
Russian wildrye *Elymus junceus* Fisch.	3.88	2.52	1.33	2.06	2.00	2.10	2.16	2.18
Buffalograss[2] *Buchloë dactyloides* (Nutt.) Engelm.	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13

[1]Each value is the mean of 15 one-square-foot samples per each of four replications.
[2]After July 30, 1965 samples of buffalograss filled the square foot sample frame because of its stoloniferous growth habitat; since it was not possible to distinguish new individuals from the mother plant the numbers have been kept constant.

U.S.D.A. FOREST SERVICE
RESEARCH NOTE RM- 150

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Strength Tests on Newly Fallen Snow[1]

Ronald I. Perla[2]

In situ strength tests previously applied to metamorphosed snow were modified to measure the mechanical properties of newly fallen snow during storms. A large drop cone penetrometer, protected from the wind by an aluminum shell, was used to determine snow "hardness." A lightweight model of the Haefeli ram penetrometer measured "Ram Numbers." Shear strengths were obtained from large, lightweight frames. Some preliminary tests were made with a shear vane driven by a torque wrench. A new technique was devised for measuring tensile strength: a cantilever beam of snow is undercut until it fails under its own weight.

In many regions affected by avalanches, the most dangerous conditions arise during storms. This is partially due to the structural instability of the newly fallen snow (LaChapelle 1967). Mechanical characteristics of fresh snow pertinent to avalanche formation must be measured during and immediately after storms.

Because of their fragility, samples of newly fallen or weakly metamorphosed snow usually are disturbed in transit despite careful handling. The alternative is to test the snow **in situ**. Although the literature contains many references to **in situ** testing of metamorphosed snow, reports confined to such measurements of newly fallen snow are scarce. Roch (1966) performed systematic **in situ** tests on alpine snow profiles. His techniques were designed to test snow in various stages of metamorphism; consequently, his fresh snow measurements did not discriminate among the many possible varieties of newly fallen snow. Keeler and Weeks (1968) explored the consistency of various **in situ** test schemes. Like Roch, however, they were primarily interested in the entire profile of the alpine snowpack. Martinelli[3] measured the properties of freshly deposited snow in the starting zone of several avalanches, and suggested several of the modifications reported in this Note.

Many difficulties are encountered in setting up consistent experiments on fresh snow. An important problem is the structure and property variation in the Z direction (fig. 1) which necessitates sampling the entire profile of newly fallen snow at closely spaced intervals. For most tests, a practical interval is **5 cm**. The problem of variation in the X and Y directions can be minimized by the choice of a suitable study area, free from wind and precipitation anomalies. Because of rapid metamorphism, measurements must be taken at 8-hour intervals during the storm period. Finally, the tests must be performable during blizzard conditions, and must cover a strength range of at least two orders of magnitude.

[1]Research reported here was financed through a cooperative agreement between the Wasatch National Forest, Salt Lake City, Utah, and the Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo. The drop cone and lightweight ram penetrometers were designed by E. R. LaChapelle, Wasatch National Forest.

[2]Avalanche Hazard Forecaster, USDA Forest Serv., Alta Avalanche Study Center, Alta via Sandy, Utah.

[3]Martinelli, M., Jr. The physical and mechanical properties of freshly deposited snow in alpine area. (In preparation for publication, Rocky Mountain Forest and Range Exp. Sta., USDA Forest Serv., Fort Collins, Colo.)

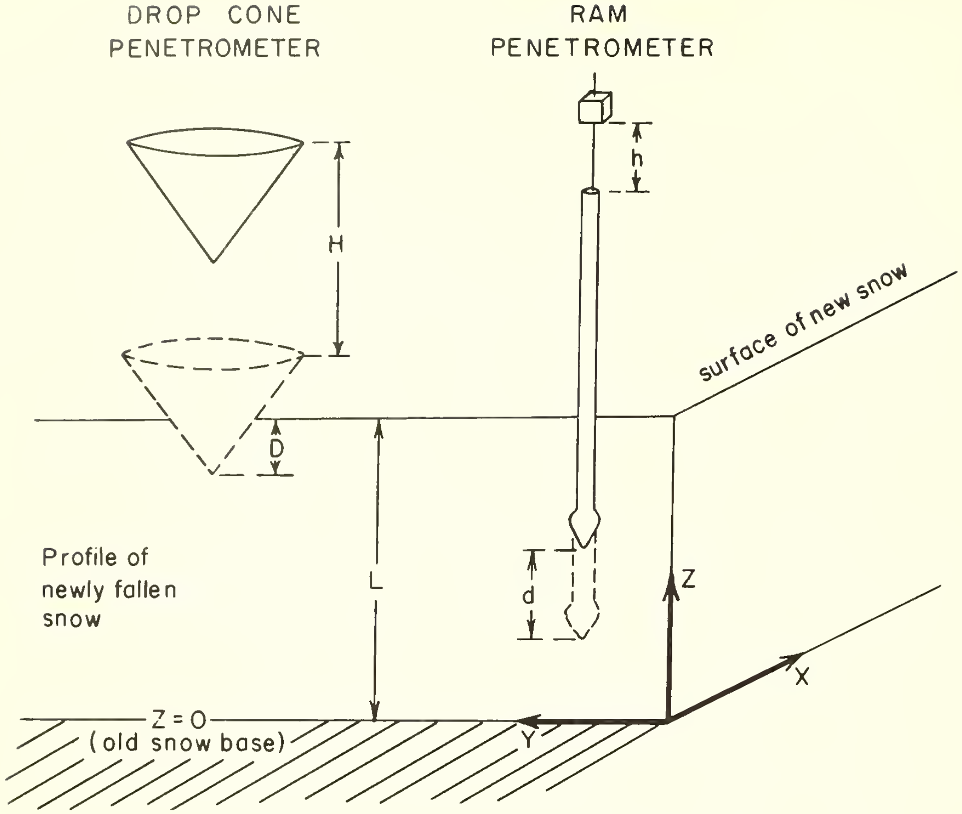


Figure 1.--Coordinate system and symbols used in this study for testing strength of newly fallen snow.

This report summarizes the development of four **in situ** tests which overcome the above difficulties. The drop cone penetrometer, the ram penetrometer, and the shear frame are modified versions of devices previously applied to metamorphosed snow. A cantilever test is introduced for measuring tensile strength.

Drop Cone Penetrometer

Drop cone penetrometers have provided self-consistent values for hardness of snow. Takahashi and Kudo (1941) performed drop cone experiments on snow in the density range of 250 to 420 kgm^{-3}. Their data led to the following relationship:

$$U = mgH = qD^{p} \qquad [1]$$

where U = energy of impact
m = mass of the drop cone
g = acceleration due to gravity
H = distance of fall (fig. 1)
D = depth of penetration (fig. 1)
q and p are constants related to the snow structure.

They defined hardness of the snow, P, as simply:

$$P = \frac{U}{\text{Volume of depression}} \qquad [2]$$

Inaho (1941) applied the drop cone to a variety of snow types. In his experiments, p ranged from 1.6 to 5.2. This showed the limitation of the hardness definition given by equation [2], which assumes p = 3. Other drop cone experiments have been reported (Bader et al. 1951, Yosida et al. 1957, Anisimov 1958). Drop cone hardness of clay has been related to shear strength (Hansbo 1957).

At the Alta Avalanche Study Center, a drop cone penetrometer (table 1) was developed for testing freshly fallen snow. Its operation (fig. 2) is as follows: the instrument rests on the snow, supported by its flange in a level position. The cone assembly is held up by the clamp. The operator looks through the observation window, loosens the clamp, gently lowers the cone assembly until it touches the snow, and notes the meter stick reading Z_r. The cone assembly is then lifted to an initial reading on the meter stick (Z_1), released and allowed to fall, penetrate the snow, and come to rest at position Z_2.

Table 1.--Results of drop cone penetrometer experiment conducted at the Alta Avalanche Study Center, spring, 1967

Date	Time of day	Number of samples	Density (ρ)	Constants related to snow structure		Hardness number ($\overline{P}$)[1]
				q	p	
			kg m^{-3}			
February 26	1300	10	100	[2]0.54	3.75	[2]6
March 14	1500	25	120	.14	4.40	9
March 15	1100	10	180	1.18	3.70	11
March 16	1500	11	310	.38	4.40	24
March 19	0800	17	120	.30	3.89	5
March 19	1500	25	110	1.91	3.36	7
March 29	1500	20	170	2.56	3.40	10
March 30	1100	15	100	.75	3.52	4
March 30	1700	28	210	[3]34.80	2.56	20
April 1	1500	15	70	1.23	3.40	5
April 13	1100	20	210	.33	4.42	22
May 6	1700	20	390	.55	4.30	26
May 11	1500	15	110	1.57	3.26	5
May 13	1700	10	100	.27	3.84	4

[1] $\overline{P}$ based on L = 15 cm.
[2] All values in this column are to be multiplied by 10^{-4}.
[3] Ice crust on the surface.

The distance of fall and depth of penetration are, respectively

$$H = Z_2 - Z_1$$
$$D = Z_2 - Z_r$$

U can be increased by decreasing Z_1 (that is, raising the cone assembly) or by adding weights to the cone assembly.

With previous drop cone models, the diameter of the cone impression had to be measured. This was a time-consuming operation, and restricted the experimenters to two or three drops per determination of U. Using the procedure described above, the operator can make quickly 5 to 10 drops for each determination. The aluminum frame provides ample protection from the wind during blizzard conditions.

Provision was made for using 120°, 90°, 60°, and 45° cones. After comparative studies 60° cones, with base diameters 15, 25, and 40 cm, were selected as most suitable. Though 120° and 90° cones gave consistent results, the base diameter of these cones would have to be large to allow for deep slab penetration. The 45° cone was disqualified because of a peculiar inconsistency; certain snow types would fracture around the impact point of this narrow-angle cone.

On a log-log diagram, U is approximated to be a linear function of D (fig. 3); in most cases this is an excellent approximation. From the log-log diagram it is possible to determine the p and q of equation [1].

Because penetration is a complex process, it is difficult to uncover intrinsic values of strength or

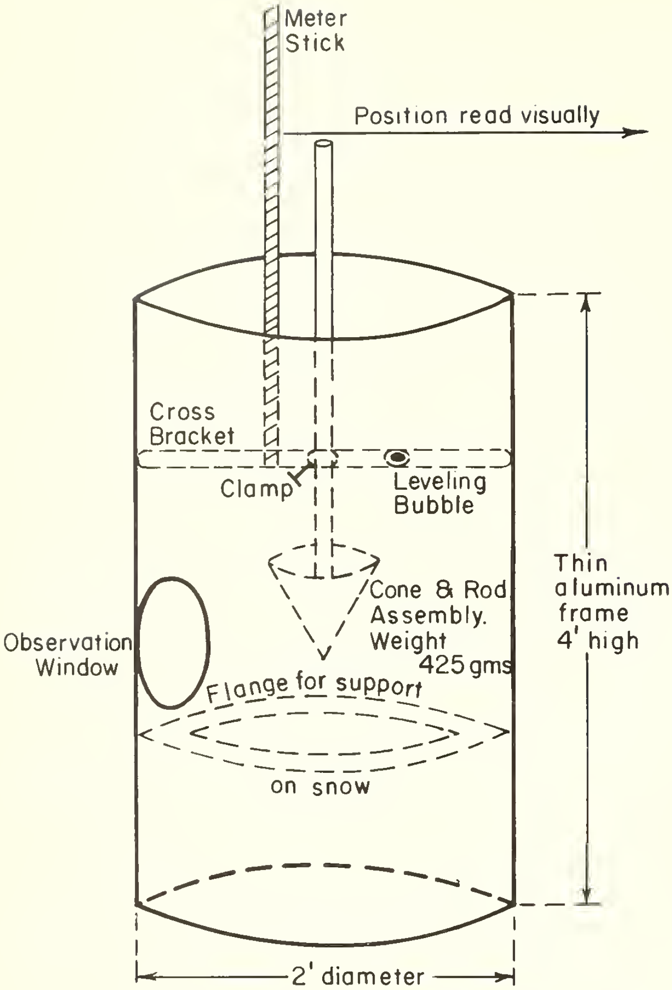


Figure 2.--Drop cone penetrometer developed at Alta Avalanche Study Center, Utah.

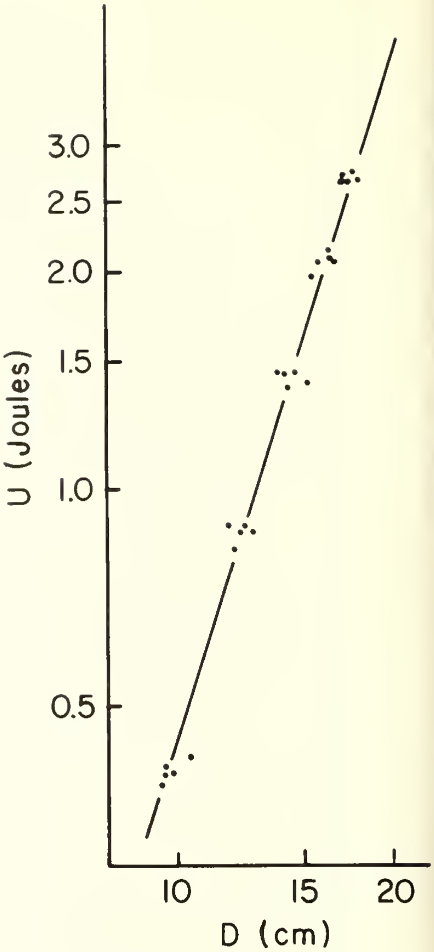


Figure 3.--Impact energy (U) as a linear function of penetration (D) on a log-log diagram. Density of newly fallen snow tested was 110 kgm^{-3}, Alta Avalanche Study Center, March 19, 1967.

resistive pressure from equation [1]. Mellor (1964) summarizes some of the power relationships that have been used, and Kinosita (1967), making a distinction between brittle and plastic failure, reports power relationships for the force which resists the intrusion of a cone. In newly fallen snow, it is useful to derive power relationships for resistive pressure directly from equation [1] by lumping all of the mechanisms that resist penetration into a single conservative force.

$$\vec{F} = - \nabla U \qquad [3]$$

Then, from equation [1]

$$F = p\, qD^{p-1}$$

and

$$dF = q\ (p-1)\ p\ D^{p-2}\ dD$$

For a 60° cone, an incremental band of area is

$$dS = \frac{4}{3} \pi\ D\ dD \qquad [4]$$

The resistive pressure, P, is

$$P = \frac{dF}{dS} = \frac{3}{4\pi} q\ (p-1)\ p\ D^{p-3} \qquad [5]$$

Finally, the "Hardness Number," $\bar{P}$, of a layer is defined as an average of the resistive pressure taken over the thickness of the layer, L

$$\bar{P} = \frac{1}{L}\int_0^L P\,dD = \frac{3q}{4\pi}\frac{p\,(p-1)}{(p-2)}\,L^{\,p-3} \qquad [6]$$

Clearly, the thicker the layer, the more resistance it offers to conical penetration. For comparison of snow types, all values of $\bar{P}$ should be based on the same value of L.

Ram Penetrometer

A ram penetrometer for measuring the relative mechanical strength of snow was designed by Haefeli (1939). Each winter this instrument is used in many alpine regions to determine the strength changes of the snow profile in relation to the avalanche hazard. Correlations have been established between this well-known instrument and intrinsic snow properties (Keeler and Weeks 1968).

The Haefeli penetrometer is too heavy (about 1 kg per section) to be used on newly fallen snow. On a suggestion by M. Martinelli, a lightweight ram was designed at Alta (fig. 4) and applied to newly fallen snow during the season 1967-68.

Haefeli (1939) recommended a "Ram Number" defined by

$$W_1 = \frac{Rh}{d} + R + Q \qquad [7]$$

where R = mass of driving hammer (kg)
h = height of fall of driving hammer (cm) (fig. 1)
d = depth of penetration (cm) (fig. 1)
Q = mass of penetrometer, not including hammer (kg)
W_1 = Ram Number (kg)

Equation [7] is based on a coefficient of restitution, $\eta = 1$. Haefeli demonstrated that a ram number, W_η could be derivedin terms of a general η

$$W_\eta = \left(\frac{\frac{h}{d}\,\frac{(1+\eta^2)}{2} + 2}{\frac{h}{d} + 2}\right) W_1 \qquad [8]$$

He chose equation [7], however, partially because of its simplicity and partially because he felt η would have a high value because of the low ratio of strain energy of the penetrometer to total impact energy. This last argument was not clear, and Waterhouse (1966) discussed a corrected form of equation [7] which in principle is equation [8].

Based on data compiled by Chellis (1961), a reasonable value of η for the Alta Ram is $\eta = 0.5$. The equation [8] becomes

$$W_\eta = \left(\frac{0.63\,\frac{h}{d} + 2}{\frac{h}{d} + 2}\right) W_1 \qquad [9]$$

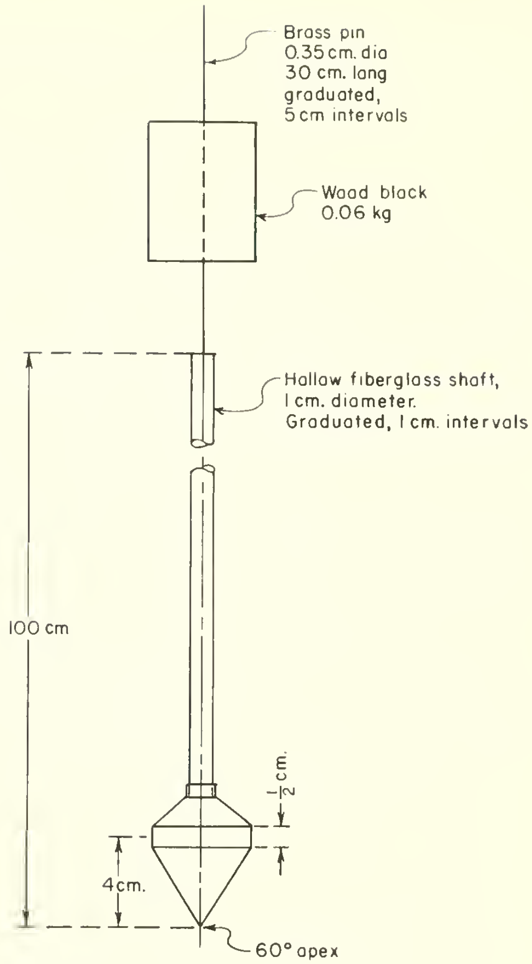


Figure 4.--Light-weight ram penetrometer designed at Alta Avalanche Study Center, Utah. Mass of penetrometer, (not including wood block) is 0.06 kg.

When the Alta Ram is applied to a moderately strong layer of newly fallen snow, h/d may be 10 or larger and, from equation [9],

$$\frac{W_n}{W_1} \approx 0.70$$

Thus, the corrections are important and equation [9] should be used when a consistent comparison is desired between the Ram and other tests.

Olson and Flaate (1967) summarized various formulas that could possibly replace equation [9] and avoid the use of η . On the other hand, equation [9] is in convenient form for correcting W_1, the Ram Number used in most previous studies.

In contrast to metamorphosed snows which typically have Ram Numbers of the order of 10^1 to 10^2 kg, the Ram Numbers of newly fallen snows are of the order of 10^{-1} to 10^0 kg.

The main advantage of the Ram is its ease and speed of use. A 3-meter-thick layer of newly fallen snow can be tested in about 2 minutes. Other tests which depend on digging snowpits and slicing out samples are far more time consuming.

From some preliminary experiments, the Alta Ram appears suitable for strength tests at the fracture zone of avalanche slopes during periods of soft slab formation.

Unfortunately, the Ram Number is related to the complex mechanism of penetration rather than direct shear or tensile strength. Difficulties can be expected when attempts are made to correlate the Ram Number with intrinsic snow properties despite the careful selection of a relationship such as equation [9].

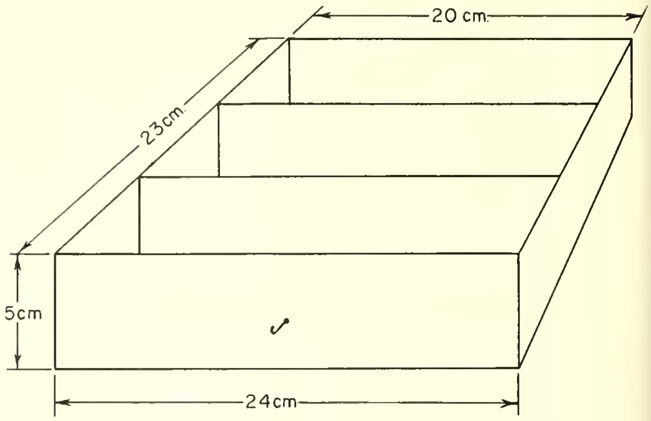
Shear Frame

The Alta Shear Frame (fig. 5a) is a modification of a shearing apparatus introduced by Roch (de Quervain 1950). Since strength of new snow varies widely, two separate frames are necessary. Both frames have the same dimensions; but one frame is fabricated from very thin gage aluminum (about 0.75 mm) so that it is easily supported by weak, low-density snow; the second frame is fabricated from thicker aluminum (about 1.5 mm) and can be used on stronger snows. A low-range spring scale (O - 10 N) is used to pull the light frame; a higher range scale (0 - 100 N) is used on the heavier frame. The scales are equipped with memory attachments. Readings are taken at 5 cm intervals in the wall of a snowpit.

Roch (1966) reported consistent measurements with a rate of loading that induced failure between 1 and 2 seconds after the initial application of the force. This rate is facilitated by a rapid but smooth pull on the spring scale. All of the tests reported in this paper presume brittle-type failure which can be achieved by the rapid application of stress (Kinosita 1967).

Figure 5.--Snow-testing instruments as modified by Alta Avalanche Study Center, Utah:

A, Shear frame.



B, Shear vane.

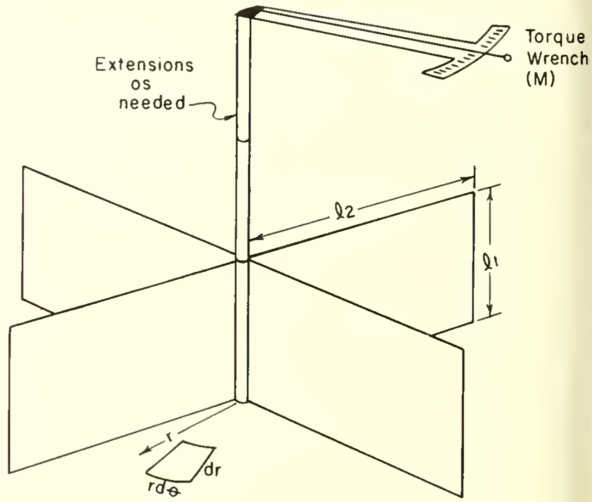


Table 2.--Comparison of shear frame strength (τ) and beam number (B) for newly fallen snow, Alta Avalanche Study Center, 1968

Depth (Z) in cm	Snow density (ρ)	Shear frame		Cantilever beam	
		Maximum force (F)	Shear strength (τ)	Beam length (λ)	Beam number (B)
	$kg\ m^{-3}$	N	$N\ m^{-2}$	cm	$N\ m^{-2}$
37-32	103	6.9	138	8	389
31-26	130	14.7	294	11	925
25-20	133	19.6	392	14	1530
19-14	146	34.3	696	21	3840
13-8	165	40.2	804	24	5520
7-2	225	51.0	1020	--	--

The shear strength of the snow, τ, is maximum force F divided by area of frame, which for the Alta unit is

$$\tau = 20\ F\ (N\ m^{-2}) \qquad [10]$$

Some typical values of shear strength calculated according to equation [10] are shown in table 2.

Roch (1966) determined the Coulomb-Mohr envelopes of his samples by placing various weights on a glass plate. He verified Haefeli's prediction with respect to fresh snow, that a small normal load on the shear frame tends to break the dendritic branches and cause a slight reduction in strength (Haefeli 1939). Roch also observed an increase in strength with an increase in normal loading, but he judged that the increased loading caused the fresh snow to densify by successive failures, which resulted in a major alteration in the structure of the original test specimen. It is anticipated that Roch's technique of normal loading can be applied to freshly fallen snow; further investigations are planned.

Closely related to the shear frame is the shear vane (fig. 5b). The moment, M, applied by the torque wrench at the instant of failure is balanced by the shear strength, τ, according to

$$M = 2 \int_0^{2\pi} \int_0^{\ell_2} \tau r^2\, d\,r\, d\theta + 2\pi\, \ell_1\, \ell_2^2\, \tau \qquad [11]$$

Suggested dimensions for use on newly fallen snow are $\ell_1 = 5$ cm and $\ell_2 = 10$ cm. Because a snowpit is not required for its operation, the shear vane is a faster test than the shear frame.

Cantilever Beam

Tensile strength of alpine snow has heretofore been determined by a centrifugal test (fig. 6) (de Quervain 1950), and calculated from

$$\sigma = \frac{1}{S} \int_0^{\ell} \frac{V^2}{r}\, dm \qquad [12]$$

where σ = tensile strength
S = cross section area of cylinder
2ℓ = length of cylinder
dm = mass of infinitesimal disc
r = distance of disc from axis of rotation
v = linear speed of disc at failure

This test appears to be reliable and may offer a true indication of the actual tensile strengths of small cylindrical samples. Unfortunately, cylindrical samples of newly fallen snow are not easily collected; an alternative for measuring tensile strength is needed.

The following in situ test has been developed: A snowpit is excavated, according to figure 7a. A flat aluminum plate, graduated in centimeters, is inserted into the pit wall (fig. 7b), and then with-

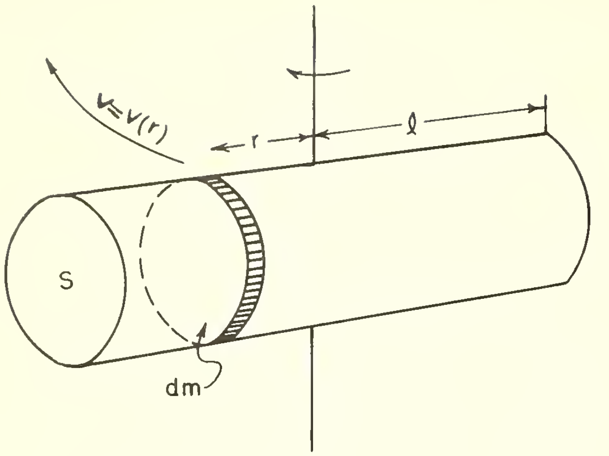
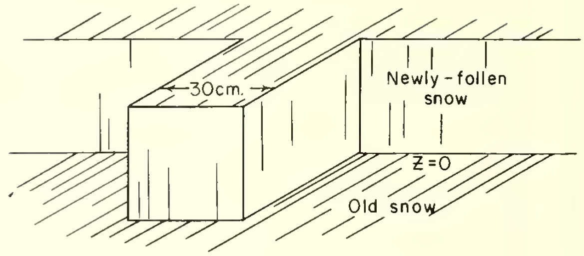


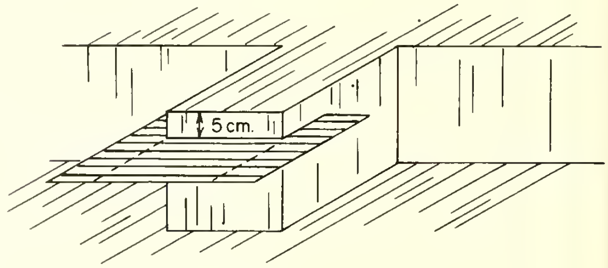
Figure 6.--Centrifugal test.

Figure 7.--Cantilever beam test:

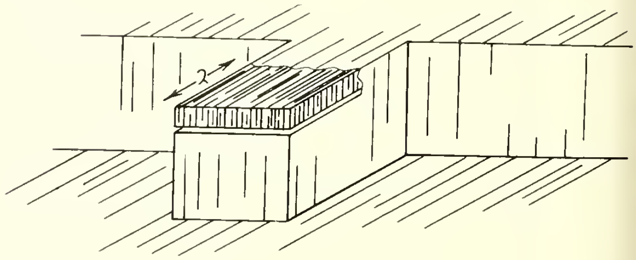
A, Excavation of snow pit.



B, Insertion of plate into pit wall.



C, Failure at a length, λ.



drawn quickly with a downward pressure. These two steps are repeated, with a deeper insertion of the plate each time, until the cantilever beam fails (fig. 7c). After removing the 1 or 2 centimeters of snow which were compressed by the downward pressure of the plate, the sequence can be repeated for the next 5 cm interval and so on down through the snow profile.

This test must be accompanied by a density profile taken at about 5 cm intervals. For newly fallen snow, it is most convenient to collect density samples in cylindrical cans (1,000 cm^3 in volume or about 5 cm high and 8 cm in radius).

In situ beam tests have been applied to investigate the flexural properties of fresh ice and sea ice (Tabata et al. 1967), but a search of the literature has not revealed any previous application of beam testing to low-density snow. The precise interpretation of snow beam data in terms of tensile strength is an open question.

A reasonable approximation[4] to the tensile strength σ, sustained by the top fiber of the beam, may be

$$\sigma = \frac{Mc}{I} \qquad [13]$$

where M = the moment of the beam
c = the distance from the neutral axis to the top fiber
I = the cross-sectional moment of inertia of the beam

For a beam of length λ, thickness L, and density ρ, equation [13] becomes

$$\sigma = \frac{3g\ \rho\lambda^2}{L} \quad (N\ m^{-2}) \qquad [14]$$

[4]*Personal correspondence with Zyungo Yosida, Inst. Low Temp. Sci., Hokkaido Univ., Sapporo, Japan.*

Equation [14] is based on the symmetric stress distribution shown in figure 8a. For other stress distributions, such as the unsymmetric case shown in figure 8b, σ is still of the order of $g\rho\lambda^2/L$. Following the analogy of the "Ram Number," a "Beam Number" (B) can be defined as

$$B = \frac{3g\ \rho\lambda^2}{L} \quad (N\ m^{-2}) \qquad [15]$$

Values of B are shown in table 2. It is expected that B can be related to the tensile strength perhaps as suggested by the above study, simply

$$\sigma = k\ B \qquad [16]$$

where k makes an adjustment appropriate to the stress distribution of the beam.

The foregoing analysis presupposes tensile failure. Observations of the beam fracture patterns (fig. 9) do not verify that this is necessarily the case. In consideration of the possible role that shear failure plays, it is preferable to assert

$$\sigma \geq k\ B \qquad [17]$$

Three sequential profiles of newly fallen snow are shown in figure 10. For each layer, the "Ram Number" is plotted as a solid line and the "Beam Number" as a dashed line. The first profile (a) was taken at the beginning of the storm, 1700 hours, February 12, 1968; (b) was taken at 0900, February 13, 1968; and (c) at 1600 February 13, 1968.

In table 2, a comparison of τ and B indicates that newly fallen snow is considerably stronger in tension than in shear. It is of interest that Keeler and Weeks (1967) show 10:1 for the ratio of tensile to shear strength, while Roch (1966) shows up to 8:1. These high ratios are not easily reconciled with the standard theory of strength of materials which predicts

$$\frac{\sigma}{\tau} \leq 2 \qquad [18]$$

Martinelli[5] has also obtained relatively high ratios for tensile to shear strength, but feels that these ratios reflect the peculiarities of the tests rather than the intrinsic strengths of the snow. In fact, Sommerfeld[6] associates the reported high ratios with the stress concentrations that are introduced by vanes in the shear-testing devices and the lack of the same in the tensile tests.

The distribution of B with density is shown on a semi-log diagram (fig. 11). Further investigations will be needed to determine if the order of magnitude variation in B at all densities is a real variation in tensile strength as opposed to a peculiarity of the cantilever test.

[5] *See footnote 3, p. 1.*

[6] *Personal communication with R. A. Sommerfeld, Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.*

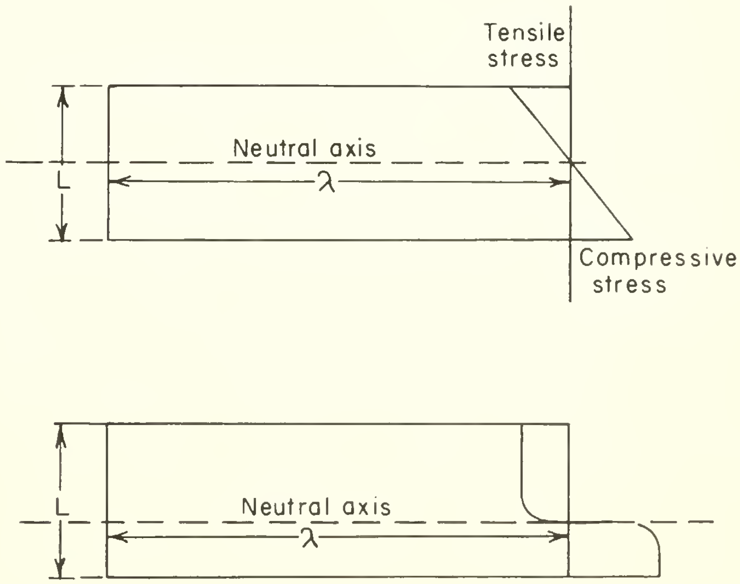


Figure 8.--Stress distribution of a cantilever beam:

A, *Symmetric.*

B, *Unsymmetric.*

Conclusions

Preliminary studies at Alta have demonstrated that mechanical properties of newly fallen snow can be determined by a variety of simple **in situ** tests, most of which are well known and are at least self consistent. These tests can all be performed during the most severe alpine weather. Future experiments are needed to establish the mutual consistency of these tests, as well as their relationship to the intrinsic properties of the snow.

Generally speaking, penetration experiments are easy to perform but difficult to interpret. From drop cone data, the "Hardness Number" can be calculated, as

$$\bar{P} = \frac{3q}{4\pi} \frac{p\ (p-1)}{(p-2)} L^{p-3} \qquad [6]$$

and corrected "Ram Numbers" can be obtained from

$$W_n = \left(\frac{0.63\ \frac{h}{d} + 2}{\frac{h}{d} + 2} \right) W_1 \qquad [9]$$

It may be possible to relate these numbers theoretically or experimentally to shear and tensile strengths.

Shear and tensile experiments, although more difficult to perform, are feasible if the apparatus is made light and large in comparison to the similar apparatus used on metamorphosed snow. Further development of the shear frame test is needed to determine the Coulomb-Mohr behavior of newly fallen snow.

The cantilever test, despite problems of interpretation, gives an indication of the tensile strength in terms of a "Beam Number"

$$B = \frac{3g\ \rho\lambda^2}{L} \qquad [15]$$

The high ratio of tensile to shear strength reported here and in previous studies should receive more attention. It may be possible to either discover the mechanism in the crystal structure which permits this high ratio, or alternatively show that peculiarities in the tests are responsible for this unexpected behavior.

When relationships between these tests are established, the more expedient tests can be conducted at the fracture zone of avalanche paths.

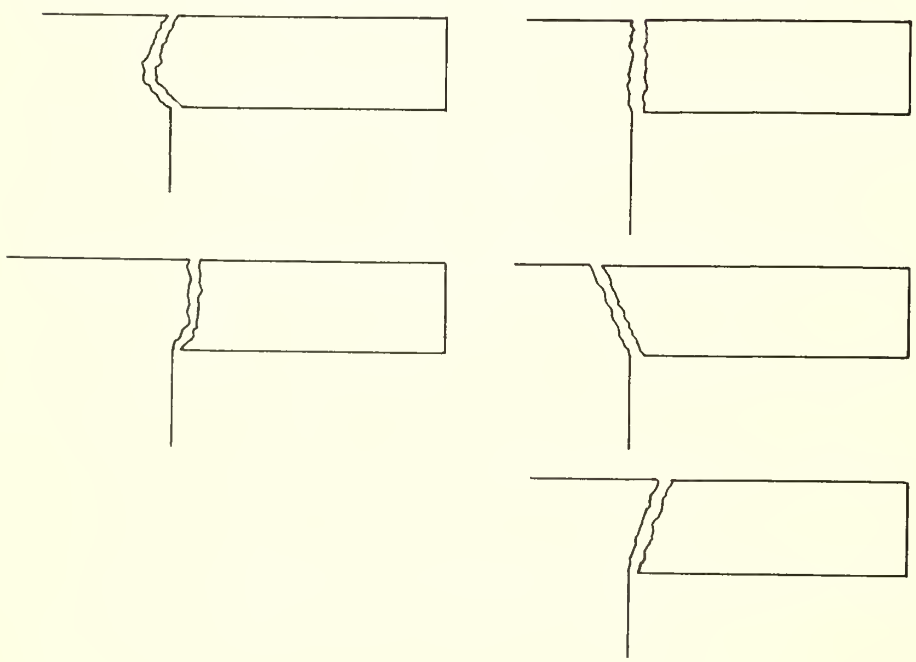


Figure 9.--Typical fracture patterns observed in the cantilever beam test.

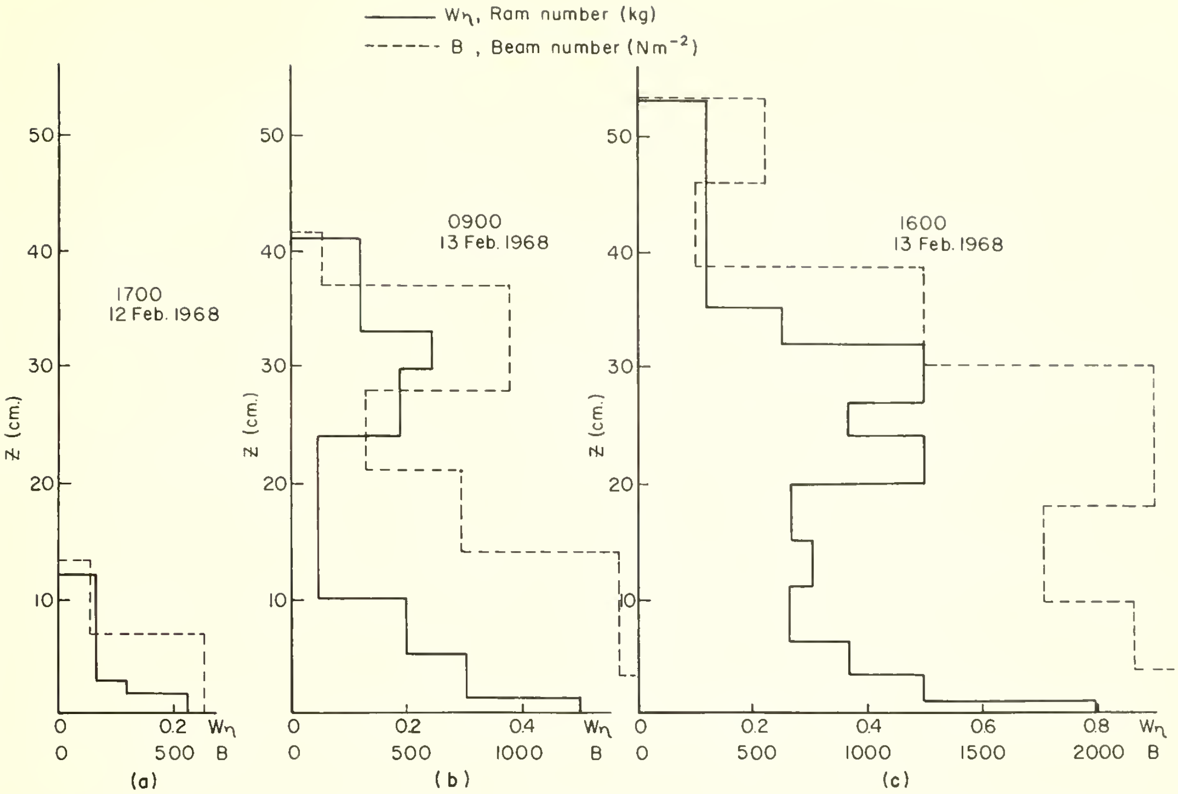


Figure 10.--Comparison of Ram number (solid line) and Beam number (dashed line). Newly fallen snow February 1968, at Alta Avalanche Study Center, Utah.

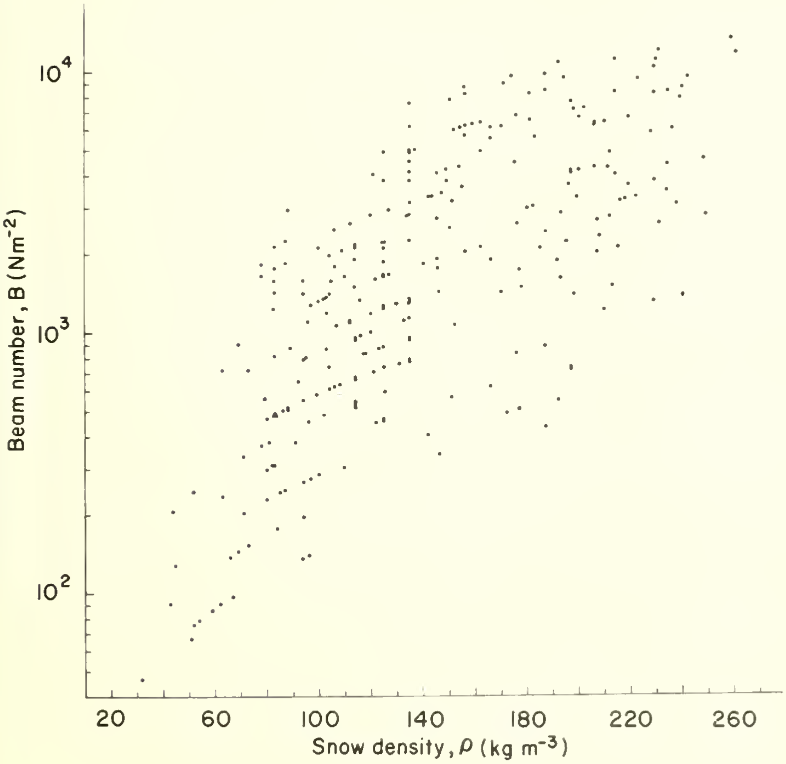


Figure 11.--Beam number (B) plotted against snow density on a semi-log diagram. Data from 1967-68 winter, Alta Avalanche Study Center, Utah.

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