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EFFECT OF ROOTING MEDIUMS AND HORMONE APPLICATION ON ROOTING OF WESTERN WHITE PINE NEEDLE FASCICLES

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ABSTRACT

Two treatments, hormone application and a medium containing forest soil, produced equal but independent rooting responses in needle bundles obtained from 2-year-old western white pine (Pinus monticola Dougl.) seedlings. Apparent sources of variation in rooting response are discussed.

Personnel working in the western white pine blister rust resistance unit at this Station have initiated new investigations into the basic biology of blister rust resistance. These studies require application of genetic control on both the host and the pathogen. Studies concerning the rooting and vegetative propagation of western white pine (Pinus monticola Dougl.) seedling needle fascicles as a means of such host genetic control have been conducted by Hoff and McDonald (1968) and McDonald and Hoff.[2] These studies indicated that a culture medium of forest soil:sand:peat moss (1:1:1) might be of considerable value for stimulating the rooting of western white pine needle bundles. Further research on the rooting of these needle bundles is presented herein.

Doran (1940) rooted various species of hardwoods and conifers in both sand and a sandy loam with and without hormone (indolebutyric acid) treatment. The best rooting results were obtained with a sandy loam rooting medium plus hormone treatment applied to the needles. However, in most instances, the hormone treatment had no greater effect on rooting than did the sandy loam. Doran also found considerable variability in the response of different species to both rooting medium and hormone.

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[1]Research Plant Pathologist and Research Plant Geneticist, respectively, stationed in Moscow, Idaho, at Forestry Sciences Laboratory, maintained in cooperation with the University of Idaho.

[2]McDonald, G. I., and R. J. Hoff. Effects of Cronartium ribicola infection on rooting potential of detached Pinus monticola needle bundles. (In preparation)

Isikawa and Kusaka (1959) studied the rooting of needle bundles of Pinus thunbergii Parl. in two soil mediums with and without indolebutyric acid application to the bundles. One treatment, a "red soil" medium plus IBA application, gave 54 percent rooting compared to 0 and 8 percent for the remaining three treatments. According to Doran (1957) cuttings of Pinus strobus L. have generally rooted best in unused sand; but occasionally, used sand or sand:peat moss mixtures gave better results.

Deuber (1940) tested various types of sand and sand:peat mixtures and concluded that clean sand was the preferred medium because it caused a lower incidence of rot in the cuttings.

Delisle (1942) rooted cuttings and needle bundles of Pinus strobus L. in sand:peat moss mixture (2:1) with indoleacetic acid treatment. Thimann and Delisle (1942) reported the rooting of Pinus strobus L. needle bundles in a sand:peat moss mixture. Needle bundles taken from 3-year-old trees, and treated with auxin resulted in 74 percent rooting (71 out of 97) after 9 months. Jeckalejs (1956) rooted 17 out of 25 Pinus resinosa Ait. needle bundles by treatment with methoxane in a sand:peat moss mixture. Kummerow (1966) used clean sand to root Pinus radiata D. Don needle bundles, with his best results producing 61 rooted out of 100. Rudolph and Nienstaedt (1964) rooted Pinus banksiana Lamb. needle bundles in a sand medium. Their best treatment provided eight rooted bundles out of 10, after 8 months. Reines and Bamping (1964) reported 51 percent rooting from 30 needle bundles removed from 3-year-old Pinus elliottii Engelm., and 19 percent rooting from 30 needle bundles obtained from 3-year-old Pinus taeda L. when placed in a sand medium. Several different hormone treatments produced no significant effects.

MATERIALS AND METHODS

Needle bundles were removed from 2-year-old nursery grown Pinus monticola seedlings on March 5, 1968. They were removed by cutting through the short shoot. Some of the short shoots were dipped in Rootone[3] powder (Amchem Products, Inc., containing 0.067 percent naphthylacetamide, 0.033 percent 2-methyl-1-naphthylacetic acid, 0.013 percent 2-methyl-1-naphthylacetamide, and 0.057 percent indole-3-butyric acid). Both hormone-treated and untreated shoots were then placed in washed river sand or a mixture of this sand:peat moss:forest soil (1:1:1). The rooting mediums were contained in metal trays that were 14 inches wide by 20 inches long by 3.5 inches deep with drain holes in the bottom. Ten trays were prepared in the above manner according to the following treatment schedule: three received sand and untreated needle bundles; two received sand and Rootone-treated needle bundles; three received forest soil:sand:peat moss and untreated needle bundles; and two received forest soil:sand:peat moss and Rootone-treated needle bundles.

The completed trays were placed at random in a greenhouse under humidistat controlled mist nozzles with a relative humidity of approximately 50 percent, an air temperature of approximately 70°F., and a photoperiod of 16 hours. This system served to keep the trays moist but not waterlogged. Rooting was tallied on June 10, 1968. The needle bundles were taken from the blister rust test nursery and therefore were inoculated with Cronartium ribicola J.C. Fisch. ex Rabenh. The analysis of variance was carried out on percentages transformed by arc sin $\sqrt{\%}$ according to Snedecor (1956).

RESULTS AND CONCLUSIONS

The results of this study are presented in table 1. Data on C. ribicola needle lesions show that the level of such infection was nearly the same for all treatments. McDonald and Hoff[2] have discussed the relationships between this infection and the rooting of needle bundles.

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[3]The use of trade names herein is for identification only and does not necessarily imply endorsement by the USDA Forest Service.

Table 1.--Percentage of *C. ribicola* infection present and percentage of fascicle rooting under four different rooting medium-chemical treatment combinations

Medium	Number of fascicles treated	Rootone applied	*C. ribicola*[1] infection	Rooting
			- - - - Percent - - - -	
Sand	183	no	48	31
	212	no	40	23
	202	no	36	7
Sand	196	yes	47	50
	193	yes	44	45
Forest soil:sand: peat moss	188	no	47	45
	198	no	50	49
	187	no	38	55
Forest soil:sand: peat moss	202	yes	49	78
	203	yes	49	84

[1]*C. ribicola* infected needle bundles were included because infection could not be accurately assessed when the experiment was established.

Since most propagators use sand, this medium without chemical treatment was used s the base level. Either treatment of needle bundles with Rootone or addition of orest soil and peat moss to the sand produced a 30 percent increase in rooting combined total: 60 percent); however, the significant result is that by adding both of hese treatments an additional 30 percent (combined total: 90 percent) of rooting is btained. This result indicates that the medium and the Rootone treatment have equal, dditive, and independent effects on initiation of rooting in the species and under onditions of this experiment. This conclusion is statistically valid as shown by the nalysis of variance in table 2.

Table 2.--Analysis of variance for the data of table 1

Source of variation	Degrees of freedom	Sum of squares	Mean square	*F*
Forest soil	1	888.87		[1]19.14
Rootone	1	769.18		[1]16.56
Soil X Rootone	1	6.23		.13
Residual	6	278.70	46.45	
Total	9	1,942.98		

[1]Treatment effect significant at 1-percent level.

DISCUSSION

Mergen and Simpson (1964) listed five main categories of factors which influence rooting of needle bundles in the pines. These categories were: (1) age of the ortet; (2) position of the fascicle on the ortet; (3) time of planting (basically physiological stage of development of the ortet); (4) chemical treatment; and (5) planting medium. Three additional categories are: (6) genetic background of the ortet which has often been observed in relation to rooting of cuttings (Kummerow, 1966) and was pointed out by Hoff and McDonald (1968) and McDonald and Hoff[2] in the case of P. monticola fascicles; (7) infection with an obligate parasite has an effect in special circumstances, reported by McDonald and Hoff[2] and (8) an eighth category which may be added for certain species (Ginzburg and Reinhold, 1967) is the presence of developed buds; however, this aspect needs further documentation.

The results thus far reported from this laboratory by Hoff and McDonald (1968) and McDonald and Hoff[2] have been based on 2-year-old ortets. A great majority of the needle bundles were removed from the apical leader. Consequently, variation of the factors described in categories 1 and 2 has been controlled. Variation of factors in categories 3 (physiological stage of development) or 8 (fascicular buds) may explain further observations. Categories 4 and 5 were examined in this study. The category 6 factor was controlled in this study by random selection of needle bundles from the nursery beds for all treatments. Although material from a different year's nursery test was used, approximately the same group of parents produced the progenies in all cases. The seventh category was controlled in the same manner. All needle bundles were infected to about the same frequency, as shown in table 1.

Hoff and McDonald (1968) reported 14 percent rooting of budded fascicles obtained from 2-year-old greenhouse seedlings, treated with Rootone and placed in a sand culture on February 4. This treatment and rooting success can be compared to the present treatment which also used sand and Rootone but gave 48 percent rooting. There were three differences between these two treatments: (1) the former was applied to greenhouse grown ortets and the latter to nursery grown ortets; (2) the former treatment contained only fascicles with developed buds and the latter contained no developed buds; and (3) the former contained only healthy fascicles and the latter contained 46 percent infected bundles. This third difference can be disregarded on the basis that infection lowers root initiation in the absence of Rootone (McDonald and Hoff[2]). This leaves the two differences of developed buds and greenhouse growth. The tendency is to attribute the difference in rooting to greenhouse conditions rather than to the presence of developed buds since Kummerow (1966), Isikawa and Kusaka (1959), and Rudolph and Nienstaedt (1964) have obtained relatively high rooting of budded needle fascicles obtained from other pine species. It is felt that greenhouse growing conditions may have shifted the physiologic growth cycle to a time of low rooting such as was observed for P. strobus cuttings by Deuber (1940). The essential fact is that growth of the greenhouse plants was about 2 months ahead of the nursery plants.

The reproducible nature of the rooting response is indicated by the close agreement between the present study and the rooting results obtained by Hoff and McDonald (1968) with a treatment of forest soil:sand:peat moss with no Rootone, and 50 percent infection. The two rooting values, 50 percent and 54 percent, were obtained in different years from different sets of progeny, although many parents were the same, and contained totals of 742 and 573 fascicles, respectively. The agreement between studies also shows that the method of watering does not have a great deal of influence, since in the earlier study the watering was intermittent (approximately every 2 days) and in the present study was more or less a continuous mist.

Each treatment produced striking results and contained sufficient numbers of needle bundles so as to leave little doubt about its effect on rooting. Unfortunately, there are two relationships that remain unknown. These are the interaction of infection

and Rootone and the interaction of infection and medium. Information regarding these interactions was to have been obtained; however, by neglecting to class individual fascicles as either infected or healthy when the rooting was tallied, this opportunity was missed.

We have obtained rooting results nearly identical to those reported for *Cornus florida* L. by Doran (1940) where the effects of hormone application plus a medium containing soil were independent, equal, and additive. Doran speculates that auxin produced by soil bacteria and fungi could account for the soil effect. Other substances or actions produced by soil microflora could be important. More possibilities include substances exuded from living plants and materials derived from the decomposition of organic matter. One further observation is that since Doran's experiments did not include peat moss the implication is that the effects noted are due to the soil portion of the medium.

It is clear that both Rootone treatment of the needle bundles and the addition of forest soil and peat moss to the rooting medium have a large positive effect on rooting; consequently, it appears that a high percentage of needle bundles obtained from 2-year-old western white pine can be successfully rooted.

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FOLIAGE DRY MATTER OF PINUS MONTICOLA; ITS VARIABILITY WITH ENVIRONMENT AND BLISTER RUST RESISTANCE

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ABSTRACT

Foliage dry-matter content was measured to determine its association with western white pines (Pinus monticola *Dougl.) that are resistant and susceptible to blister rust (causal organism* Cronartium ribicola *J.C. Fisch. ex. Rabenh.). No significant difference between blister rust resistant and susceptible trees was found, even though environmental influences, including rust infection, were largely eliminated.*

Dry-matter content of foliage is occasionally used as a limited indicator for photosynthetic activity in individual crop plants as well as in stands (Schwarze 1958). In forest trees, Langlet (1936) found that percentage dry matter of foliage varied according to the seed source of the tree in Scotch pine (Pinus sylvestris L.). This relationship, moreover, was closely associated with frost hardiness.

Resistance to infection by micro-organisms has also been shown to be closely tied to the water balance of plant tissues. Gaskill (1950) has shown that sugar beets with a high moisture content were relatively more resistant to storage decay. Further, the susceptibility of poplar bark to Dothichiza populea Sacc. and Br. increases with reduction of water content (Butin 1957). Resistance in poplar to D. populea appears to be associated with the rate of formation of wound epiphloem. Apparently, resistance was decreased because of a weakening of the synthetic processes that lead to formation of wound peridermal tissues.

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Three times, in the course of other work at the Moscow, Idaho, laboratory,[2] [3] western white pine (Pinus monticola Dougl.) from natural stands has been studied to determine the relationship between percentage dry-matter content of foliage and resistance or susceptibility to blister rust (Cronartium ribicola J.C. Fisch. ex Rabenh.). In these comparisons, the susceptible trees were infected in various degrees; however, the foliage analyzed was healthy and was collected from branches without cankers. In all three investigations, resistant selections were found to have on the average a lower percentage of dry matter--approaching significance at the 5-percent level. Therefore, in order to secure more conclusive evidence, we decided to test variation of foliage dry-matter content in relation to rust resistance on a broader base of materials while holding sampling techniques and environmental factors constant. Thus, included in this study are within- and between-tree environmental variations.

METHODS

Two types of plant materials were used. These were grafted clones and 10- to 15-year-old trees growing in an arboretum. Because the amount of foliage on the clones was limited, eight 1-year-old needle bundles (40 needles) were selected as an optimal sample size.

To minimize percentage dry-weight errors arising from differential evaporation, all the samples were put on dry ice immediately after collection and kept there for 24 hours. Preliminary tests showed that dry-ice storage caused a moisture loss that resulted in a 2- to 3-percent increase of dry weight, which occurred mainly during the first 30 minutes after sampling. Since all tested individuals reacted uniformly in this respect, the possibility of comparison remained unchanged.

Dry weight was determined by drying the needles in an oven at 105°C. Samples were weighed after 24 hours and daily thereafter, to an accuracy of 0.1 mg. Constancy of weight could not be obtained within 7 days. However, because in every sample tested dry weight decreased slowly and uniformly from the second day on, dry weight after 72 hours in the oven was used in this study.

DETERMINATION OF WITHIN-TREE VARIATION

As a preliminary to the main investigation, it was necessary to study the range of within-tree variation so as to determine a sampling method that might isolate variations related to rust resistance. Needle samples from different parts of 10- to 15-year-old open-grown trees were analyzed, using the methods described above. The following sources of variation were considered. For variation due to side of crown, needles were taken from the north, south, east, and west, and because of the higher shading effects on the north, samples were also collected from the northeast and northwest sides. For crown depth, needles from the outer (the distal portion of the branches) were compared with the inner crown (the proximal portion of the branches). For crown height, comparisons were made among the upper, middle, and lower portions of the crown. For needle age, comparisons were made between first and second year needles. For needle depth, comparisons were made of needles from the distal portion to the proximal portion of a stem of 1 year's wood.

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[2]Hanover, J. W. Comparative biochemistry and physiology of western white pine (Pinus monticola Dougl.) resistant and susceptible to infection by the blister rust fungus (Cronartium ribicola Fischer). Ph.D. Thesis, Wash. State Univ., Pullman, Wash. 176 pp. 1963.

[3]Hoff, R. J. Comparative physiology of Pinus monticola Dougl. resistant and susceptible to Cronartium ribicola J.C. Fisch. ex Rabenh. Ph.D. Thesis, Wash. State Univ., Pullman, Wash. 76 pp. 1968.

Table 1.--Within-tree variation in dry-matter content of needles of *Pinus monticola*

Source of variation	Range of dry-matter content	Tendency	Number of trees
	Percent		
Crown side (N:E:S:W:)	2.5**	S>W or E>N	9
Crown side (NW:N:NE)	1.0	NE>N or NW	3
Crown depth (inner: outer crown)	2.2**	Outer>inner	4
Crown height	3.1**	Upper>lower	4
Needle age	1.5*	2-year>1-year	9
Needle depth	1.8*	distal>proximal	4

* Significant at the 0.05 level of probability, paired t test.
** Significant at the 0.01 level of probability.

The variation was significant for most of the comparisons made, particularly in respect to the difference in the amount of light to which the sampled needles had been exposed (table 1). Without exception, needles from a sunny part of the crown had less dry matter than shaded needles.

Twig order (leaders vs. laterals) was found to be another source of variation. Whereas some of these trees had higher values for foliage dry matter in the twigs of second order, others showed the opposite tendency, and a third group did not show any differences. The average percent foliage dry matter based on 10 trees was 46.8 for both twig orders. The range was 44.6-49.2 for the first twig order and 45.6-48.7 for the second twig order.

Since dry-matter production, among other factors, is influenced by photosynthesis and transpiration, and since there are many examples of diurnal variation for both photosynthetic activity (Ståfeldt 1960) and transpiration (Walter 1960), there was little doubt that percent dry weight of western white pine would follow a particular diurnal rhythm.

This supposition was shown to be justified on 10 trees studied under various weather conditions. Generally, a small increase could be observed from 10:00 a.m. to 12:00 noon, and a more pronounced decrease was evident for the later afternoon. This tendency, however, varied with weather conditions and from tree to tree. On the other hand, there was a close relationship in the curves of diurnal fluctuation of foliage dry matter between 1- and 2-year-old needles of the same tree. These conclusions suggested that trees should be sampled during the hours of smallest variation. Most frequently this was the period between 8:00 and 10:00 a.m.

Because of the high within-tree variation, the sampling procedure applied in the main study was strictly standardized: from 8:00 to 10:00 a.m. eight 2-year-old needle fascicles were taken from the north side, at the middle of the crown (3-5 ft. high), and the inner portion of the internode.

DETERMINATION OF VARIATION BETWEEN TREES OF VARYING RESISTANCE

Grafts and seedlings of a known degree of resistance against the blister rust fungus were compared in respect to their foliage dry-matter content at four locations in northern Idaho.

GRAFTS

Needle samples were taken from 4-year-old grafts of four resistant and four nonresistant clones, outplanted at Moscow, Idaho; Emerald Creek (4 miles west of Clarkia, Idaho); and Sandpoint, Idaho, and analyzed during July 1966. Except for shelter, the ecological conditions within a plot were fairly uniform.

SEEDLINGS

Further comparisons were carried out with 10- to 15-year-old F_1 progenies from parent trees with either high or low combining ability for rust resistance (Bingham, Squillace, and Wright 1960). The material was located in the "Moscow Arboretum," a hilly, wind-exposed area located 1 mile west of Moscow, Idaho.

INFECTED VS. UNINFECTED PLANTS

In order to determine whether differences in dry-matter content between resistant and susceptible trees found in previous studies could be attributed to the presence or absence of the pathogen in the host tissue, a final series of 10 pairs of trees was selected from the arboretum. Both trees of a pair grew close together (from 40 to 400 ft., average 155 ft.) and both belonged to the same F_1 combination; one, however, had stem cankers and the other one was healthy.

RESULTS

In the studies of grafts from resistant and nonresistant clones, even small differences in the amounts of shelter or shade led to remarkable variation in foliage dry matter.

Although individual variation was apparent, there was no indication of a difference in dry-matter content between resistant and susceptible clones (table 2). The high variation between ramets of the same clone was the most pronounced feature of the data. A later analysis of the same material (November 1966) gave similar results. Although the dry weight had generally decreased from 3 to 4 percent, there was still a large intraclonal variation, and again no indication of a relationship between resistance and dry-matter level could be found.

After several comparative samples of the 10- to 15-year-old seedlings were analyzed, a lower dry-matter content for resistant seedlings could be observed. However, because of a high intrafamily variation, these differences were not significant. Even when the conditions of wind- and light-exposure of the sampled trees were relatively uniform, the dry-matter difference between resistant and susceptible combinations was not found to be significant at the $P = 0.05$ level.

In the study of infected and uninfected plants, in spite of a wide variation in the dry-matter content of infected and uninfected plants, no consistent difference was found between pairs. On the average, the infected trees did not differ from the rust-free ones with respect to dry matter (41.16%:41.24%).

Table 2.--Range and mean of percent foliage dry matter from 4-year-old grafts of four resistant (R) and four nonresistant (NR) clones[1] planted in three locations in Idaho and sampled July 19, 1966

Clone	Moscow Range	Moscow Mean	Emerald Creek Range	Emerald Creek Mean	Sandpoint Range	Sandpoint Mean	Grand mean
NR 1	40.5-42.7	41.3	43.8-46.9	45.4	[2]41.6-41.8	41.7	
NR 2	--	--	[3]42.3-45.1	44.1	--	--	
NR 3	42.0-43.3	42.7	43.0-44.6	44.2	40.5-41.6	41.2	
NR 4	38.9-42.0	40.4	41.0-44.0	42.7	[3]41.2-44.3	42.1	
Mean		41.4		44.1		41.8	42.4
R 19	39.0-43.3	40.5	40.9-46.7	43.3	38.4-40.9	40.0	
R 22	39.7-44.3	42.3	41.4-48.7	44.9	42.6-44.6	43.5	
R 24	40.8-43.5	42.3	41.6-43.9	42.9	[3]41.8-43.8	42.6	
R 58	40.7-42.6	41.6	44.2-45.5	44.9	39.4-42.1	41.1	
Mean		41.7		43.9		41.7	42.4

[1]Data cover four ramets in each clone except as noted otherwise.
[2]Two ramets only.
[3]Three ramets only.

CONCLUSIONS

Comparisons between foliage dry-matter data of different *P. monticola* trees are complicated by a large within-tree variability, for which light intensity seems to be a controlling factor. By strict standardization of sampling procedure, this source of error can be considerably reduced.

Differences of up to 1.5 percent in foliage dry matter were found between blister rust resistant and susceptible plants in F_1 progenies of known combining ability; however, they were not significant because of a broad variation within the families. On the other hand, similar comparisons between grafts did not show this difference at all, nor did comparisons between rust-cankered and healthy trees.

These findings lead to the conclusion that foliage dry-matter content of *P. monticola* is not a reliable indicator of the degree of rust resistance, at least not under the field conditions tested. Strong influences of environmental factors such as water supply, light, and wind, as well as genetic diversity of the seedling material, remain as big obstacles to progress that will be difficult to overcome. Also, resistance against blister rust is possibly a rather complex genetic character. Beyond the percentage of surviving seedlings from resistant parents, relatively little is known about the nature of the resistance mechanisms. Perhaps only one of several factors is correlated with dry-matter content or maybe none at all. Possibly, similar investigations during the period of dormancy or under greenhouse conditions may give better results.

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INFILTRATION AND SOIL EROSION ON COOLWATER RIDGE, IDAHO

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ABSTRACT

The infiltration and erosion caused by simulated rainfall were measured on a granitic subalpine ridge in north-central Idaho. Erosion was closely correlated with the amount of exposed soil. Infiltration was not highly correlated with any single factor. However, three soil properties (organic-matter content, clay content, and moisture-holding capacity at 20-centimeter tension) in combination were found to be good predictors of infiltration.

Coolwater Ridge is a deteriorated subalpine range at the northern boundary of the Nezperce National Forest in central Idaho. Present vegetation is mostly low-value forbs--for example, knotweed (Polygonum spp.). Soils consist of decomposed granite, typical of actively eroding sites on the Idaho batholith.

This area was selected as one of the study sites of a major study designed to determine how soil and plant cover characteristics influence infiltration and erosion on summer range in the Intermountain Region. During the summer of 1963, simulated rain tests were made at 15 sites to determine infiltration and erosion potentials. Selected cover characteristics and soil properties were measured and related to infiltration and erosion.

The study plots had an average slope gradient of 33 percent. The surface inch of soil on the plots contained an average of 57 percent sand, 11 percent clay, and 10 percent organic matter.

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METHODS

Simulated rain was applied to infiltrometer plots (0.1 milacre in size) at a constant intensity of 5 inches per hour for 30 minutes, using the rainfall simulator described by Dortignac.[2] Resultant runoff was measured and all soil washed from the plots was collected, oven-dried, and weighed.

Both areal cover density and air-dry weight of vegetation were measured on each plot. The areal cover provided by vegetation, litter, and stone, was measured with a point analyzer,[3] using first strikes at 100 equally spaced points. Vegetation and litter were removed separately after the rain test; then, this material was air-dried and weighed.

A number of soil properties were measured, including bulk density, moisture content at 20- and 60-centimeter tension, texture, aggregation, and organic matter content. The data were analyzed by multiple regression techniques to develop prediction equations relating infiltration and erosion to soil and cover characteristics.

EROSION

The amount of soil eroded under the impact of 2.5 inches of simulated rain ranged from 0.1 to 27.7 pounds per milacre, with an average of 9.6 pounds and a standard deviation of 9.3 pounds per milacre. These weights were more highly correlated with percentage of soil surface exposed to direct raindrop impact (percentage of first strikes of the point analyzer on bare soil) than with any other measured variable.

The following equation explains 63 percent of the variance in eroded soil and has a standard error-of-estimate of 5.9 pounds per milacre:

$$\hat{Y} = 27.75X^2,$$

where:

$\hat{Y}$ = estimated erosion (pounds per milacre),

X = proportion of the soil surface not protected by plants, litter, or stone.

The curve defined by this equation is plotted in figure 1, along with the data. No significant increase in explained variance was obtained by adding any other variable in multiple regression. None of the other measured variables, including slope gradient, exerted significant influence on the weight of soil eroded beyond that due to the proportion of bare soil.

INFILTRATION

The plots retained an average of 0.97 inch of water during the 30-minute rainfall test. Variation in amount of water retained was not large, ranging from 0.60 to 1.38 inches with a standard deviation of 0.24 inch. The difference between applied rain and the measured runoff is the water retained by the plot. These values were used as the dependent variable characterizing infiltration.

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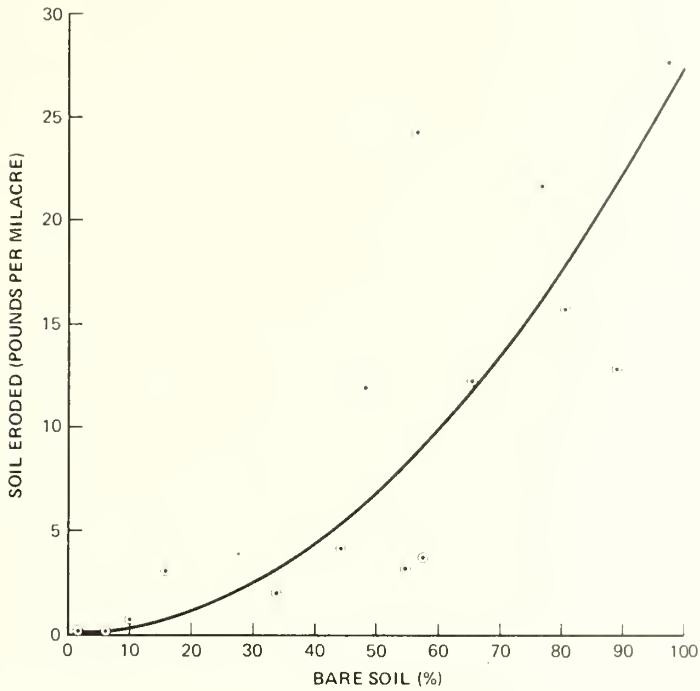
[2]Dortignac, E. J. Design and operation of Rocky Mountain infiltrometer. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Sta. Pap. 5, 68 pp. 1951.

[3]Levy, E. B., and E. A. Madden. The point method of pasture analysis. New Zealand J. Agr. 46: 267-279. 1933.

Figure 1.--Pounds per milacre of soil eroded by 2.5 inches of simulated rainfall in relation to percentage of the soil surface exposed to direct raindrop impact.



Only three measured site factors were significantly correlated (at the 5 percent level) with water retained:

Air-dry weight of litter (r = -0.52);
Bulk density of the surface inch of soil (r = +0.51);
Clay content of the surface inch of soil (r = +0.51).

The inverse relation between litter weight and water retained and the positive relation between soil-bulk density and water retained were contrary to results of similar studies on other areas. Apparently some process is operating to reverse the expected relations between litter weight and water retained, and between soil-bulk density and water retained. Consequently, a series of multiple regression analyses were made to delve further into these apparent anomalies. An equation that explained 73 percent of the variance and has a standard error-of-estimate of 0.14 inch was developed:

$$\hat{Y} = -1.394 + 0.058X_1 + 0.933X_2 - 0.026X_1X_2,$$

where:

$\hat{Y}$ = estimated inches of water retained during the 30-minute simulated rain test,

X_1 = moisture content by volume of the surface 2-inches of soil at 20-centimeter tension,

X_2 = the ratio of organic matter to clay content in the surface inch of soil.

The following inferences may be drawn from this equation, graphically presented in figure 2:

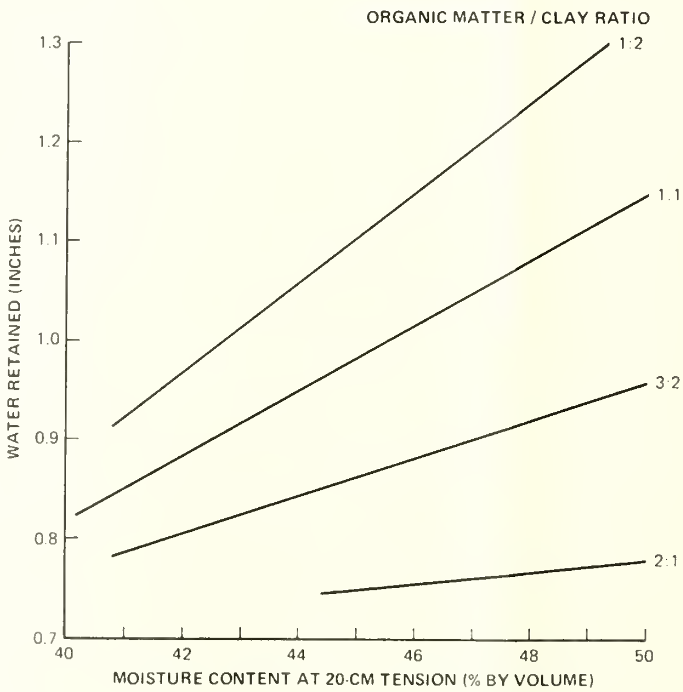
1. The amount of water retained increases as the moisture-holding capacity at 20-centimeter tension increases unless the surface inch of soil contains about twice as much organic matter as clay.

2. A high ratio of organic matter relative to clay limits infiltration. This effect is particularly noticeable at higher moisture-holding capacities.

This adverse effect of organic matter is inconsistent with the current concept that organic matter favors development of porous and permeable soil. However, in this sandy soil, there is little opportunity for organic matter to aggregate the soil and render it more permeable. We hypothesize that organic matter contains constituents that coat the mineral soil particles and render them water repellent. The greater the organic matter content, the more extensive and effective are these water-repellent coatings. Clay, which has a much greater surface area per unit weight than sand, tends to dilute and reduce effectiveness of the water-repellent constituents of organic matter. Thus, infiltration is inversely related to the ratio of organic matter to clay.

The correlation between litter weight and water retained is negative on this study site because of the significant positive correlation between litter weight and soil organic matter content ($r = +0.71$). Similarly, the correlation between soil bulk density and water retained is positive because of the strong negative correlation between soil bulk density and organic matter content ($r = -0.85$).

Figure 2.--Inches of water retained during a 30-minute simulated rainstorm as a function of soil moisture content at 20-centimeter tension, and the ratio of organic matter to clay.



CONCLUSIONS

As generally reported for other areas where erosion has been studied, the amount of protective cover present is the dominant factor controlling erosion on Coolwater Ridge. On the basis of the few measurements made here, it appears that at least 90 percent of the soil surface should be protected from direct raindrop impact by plants, litter, or stone to prevent accelerated erosion on this highly-erodible granitic soil. Erosion under study conditions exceeded 1 pound per milacre on all plots with more than 10 percent bare soil (figure 1).

The surface soils on Coolwater Ridge tend to be water repellent. The degree of water repellency appears to be closely related to organic matter content or, more specifically, to the amount of organic matter that is not bound to clay particles. Organic matter apparently forms water-repellent coatings on the coarser soil particles. A similar phenomenon has been reported by DeBano and Krammes[4] in the southern California chaparral type where non-wettable layers are formed in coarse-textured soils as a result of fire.

This water repellency, whether fire-induced or not, severely limits infiltration in soils that otherwise would be highly permeable. It may pose a serious problem for watershed management and should be investigated further.

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[4]DeBano, L. F., and J. S. Krammes. Water repellent soils and their relations to wildfire temperatures. Bull. Int. Assoc. Sci. Hydrol. XI(2): 14-19. 1966.

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
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1969

CONVERTING GAMBEL OAK SITES TO GRASS REDUCES SOIL-MOISTURE DEPLETION

Ronald K. Tew[1]

ABSTRACT

Replacement of Gambel oak (Quercus gambelii *Nutt.) with grass on an experimental plot in northern Utah resulted in a reduction of soil-moisture depletion by 3.09 inches the first year and 2.35 inches the second year. Moisture savings occurred primarily in the lower 4 feet of the 8-foot measured soil profile. In contrast to the moisture-savings on this grass-covered plot, a plot containing 2-year-old oak sprouts used only about 0.4 inch less soil moisture during the growing season than would a mature oak stand on the same site.*

Information regarding soil-moisture depletion by various types of vegetation is important to the development of forest management practices designed for water-yield improvement. Prior to a conversion of vegetation for increased water yields, even on a limited basis, the potential benefits and limitations of such a conversion must be known to ensure success. This study was undertaken to evaluate changes in soil-moisture depletion before and after conversion of Gambel oak sites to grass in northern Utah. Soil-moisture depletion by mature oak stands on this site[2] and by mature and sprout stands of oak in central Utah[3] were measured and reported upon previously.

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[1]Former Associate Plant Physiologist, stationed in Logan, Utah, at Forestry Sciences Laboratory, maintained in cooperation with Utah State University. Now serving as Soil Scientist with the USDA Soil Conservation Service, Manti, Utah.

[2]Tew, Ronald K. Soil moisture depletion by Gambel oak in northern Utah. USDA Forest Serv. Res. Note INT-54, 7 pp. 1966.

[3]Tew, Ronald K. Soil moisture depletion by Gambel oak in central Utah. USDA Forest Serv. Res. Note INT-74, 8 pp. 1967.

METHODS

The study area, previously described by Tew,[2] consisted of three 0.1 acre plots located at an elevation of 7,100 feet in northern Utah. Runoff tanks were installed at the foot of each plot. Nine soil moisture access tubes were inserted to a depth of 8 feet on each plot to permit use of the neutron probe to make moisture measurements. The measurements taken between 1962 and 1965 were used for calibrating soil-moisture relations between the three Gambel oak covered plots in their untreated condition. Regression equations were developed which related average moisture content in the depth intervals of 0 to 4 feet and 4 to 8 feet on plot 1 to that on either plot 2 or 3, thus providing an accurate means of evaluating later treatment effects. Correlation coefficients exceeded 0.99 for all equations.

The three plots were treated in the fall of 1965. The mature oak was left on plot 1 as a control, but was clearcut and removed from plots 2 and 3. Oak was allowed to resprout on plot 2. On plot 3, these 5 grass species were planted immediately following oak removal: tall oatgrass (*Arrhenatherum elatius* (L.) Presl); orchardgrass (*Dactylis glomerata* L.); smooth brome (*Bromus inermis* Leyss.); intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.); and timothy (*Phleum pratense* L.). In the spring of 1966 a mixture of 2,4-D and 2,4,5-T was used to spray broadleafed vegetation, young oak sprouts, and tree stumps on the seeded plot. This plot was sprayed again in mid-summer to eliminate new oak sprouts.

RESULTS

Sediment and Runoff

There was neither measurable sediment production nor measurable overland flow from the plots during the 6 years of this experiment; this was true before and after the site conversion from oak to grass. However, no high-intensity summer storms were recorded during the spring of 1966 when grass was becoming established and ground cover was sparse on plots 2 and 3.

Soil-Moisture Use by Oak Sprouts

The regression equations developed from data gathered previous to treatment were used to predict soil-moisture contents and accurately measure the effect of oak removal on soil-moisture depletion. It was possible to detect differences of approximately 0.1 inch in soil-moisture use at the 5-percent level of significance.

The changes in soil-moisture depletion which occurred during the first 2 years following clearcutting and subsequent sprout establishment on plot 2 are shown in table 1. During 1966, the first year after clearcutting, evapotranspirational loss from the sprout stand was 1.04 inches less than would have occurred if mature oak occupied that plot. This represented a moisture savings of 0.33 inch in the 0- to 4-foot soil depth and 0.71 inch in the 4- to 8-foot depth as a result of changing oak age classes. In 1967 there was no significant difference between mature oak and sprouts in the amount of soil moisture lost from the upper 4 feet of soil, although the sprout stand did use 0.06 inch more than expected for a mature stand. However, in the lower depth interval under the sprouts a significant savings of 0.44 inch was noted.

Table 1.--Moisture content in the soil profile at the end of the first and second growing seasons following treatment

	Plot 2: Oak sprouts				Plot 3: Grass			
	1966		1967		1966		1967	
	0-4 ft.	4-8 ft.	0-4 ft.	4-8 ft.	0-4 ft.	4-8 ft.	0-4 ft.	4-8 ft.
	Inches							
Predicted[1] (for mature oak)	5.41	7.03	5.32	7.37	5.19	5.92	5.11	6.10
Measured	5.74	7.74	5.26	7.81	6.46	7.74	5.33	8.23
Difference	0.33	0.71	-0.06	0.44	1.27	1.82	0.22	2.13
Total moisture savings	1.04		0.38		3.09		2.35	

[1]Based on regression equations developed prior to treatment using plot 1 as a control.

Soil-Moisture Use by Grass

The inherent moisture-holding capacity of the soil on plot 3 was considerably less than on the other two plots (mature oak and oak sprouts , with the greatest difference occurring in the 4- to 8-foot depth. Prior to treatment, the oak on plot 3 was less vigorous and less densely populated than on the two adjacent plots, probably as a result of having less soil moisture available to it.

Plot 3 was relatively bare during the early part of the first growing season following oak removal; but, by September the sown grass was well established and appeared to fully occupy the site. All five of the introduced species were well represented. However, intermediate wheatgrass was the dominant species and produced the greatest amount of vegetation.

During 1966, total soil-moisture depletion on plot 3 (grass) was 3.09 inches less than would be expected for mature oak on that site; the greatest conservation of moisture was in the lower 4 feet of soil although a reduction in soil-moisture depletion also occurred in the upper 4 feet (table 1).

In 1967, 2.35 inches more soil moisture were present in the 8-foot profile on plot 3 at the end of the growing season than would be expected if mature oak had been present. Essentially the same amount of moisture was conserved in the lower 4 feet during this second year (1967) as in the first year. However, moisture savings in the upper 4 feet of soil was reduced during this second growing season.

DISCUSSION

Moisture depletion was essentially the same in the upper 4 feet of soil when either oak or grass occupied the site. Nearly 60 percent less moisture was lost from the lower 4 feet of soil following oak eradication. However, even after oak eradication, approximately 1.6 inches of soil moisture were lost from these lower depths. Deep seepage probably accounted for much of this, as grass roots were concentrated in the upper 4 feet.

To achieve a substantial decrease in soil-moisture depletion, oak must be completely eradicated because oak sprouts use nearly as much moisture as mature stands. However, even when oak is eradicated and the site sown to grass, the quantity of moisture saved is dependent upon the soil depth and its inherent moisture-holding properties. For example, the soil under plot 3 had low moisture-holding capacity in the lower 4 feet when compared to either plot 1 or 2. If either plot 1 or 2 (with their higher moisture content) had been converted to grass, a larger treatment effect might have been realized than was obtained by converting plot 3.

After conversion to a shallow-rooted vegetation, such as some grasses, seepage would still occur deep in the soil profile even though evapotranspirational losses would be reduced. It would, therefore, be erroneous to assume that all soil-moisture losses in the lower 4 feet of soil can be eliminated by converting oak sites to grass, even though grass roots do not reach depths equal to the oak roots. Soil-moisture depletion due to evapotranspiration is true loss with respect to water yield from the watershed. However, soil-moisture depletion due to deep seepage, as probably occurred from the lower depths of plot 3 after its conversion to grass, is not a loss; instead, this deep seepage is a gain if it ultimately appears as streamflow, or if it becomes ground-water that can be utilized.

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
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TRIAL RESULTS OF NET COUNT PROCEDURES FOR ESTIMATING VISITOR USE AT DEVELOPED RECREATION SITES

J. Alan Wagar and Joel F. Thalheimer[1]

ABSTRACT

Net counts of vehicles were used to estimate visitor use at developed recreation sites. These counts were obtained using electric counters that printed the approximate number of vehicles present each hour, rather than the total flow of traffic for a period of time. In conjunction with sample counts of visitors, net counts of vehicles permitted visitor-use estimates of good precision.

The estimation of visitor use at developed recreation sites, like other sampling problems, often involves higher costs than we would like to pay for a desired level of precision.[2] However, if sampling efficiency can be increased, results of acceptable precision can be obtained at reduced costs. The net count method of estimating visitor use was therefore developed and tested as one effort to increase the efficiency of estimating visitor numbers from sample counts. However, the net count system of sampling visitor use must be judged as unsuitable for administrative use because no dependable counter has been designed as of this time for the necessary net counts of vehicle axles. This report is intended (1) to record the methodology, so it need not be redeveloped if suitable counters become available; (2) to show what accuracy of results can be provided by net count procedures; and (3) to indicate desirable attributes for counting equipment.

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[1]Senior author formerly was stationed in Logan as leader of the recreation research unit maintained in cooperation with Utah State University. He is now assigned to the Pacific Northwest Forest and Range Experiment Station, and stationed on the University of Washington campus in Seattle. At the time this work was conducted, the junior author was a graduate student at Utah State University.

[2]As used here, the term "site" refers to a campground, picnic area, or other complete recreation facility. The facility clusters normally used by a family or other small group are called "units."

STUDY AREAS

The net count method was tested for three seasons at the 27-unit Sunrise Campground on the Cache National Forest in Utah, and for one season on the Mirror Lake Recreation Complex on the Wasatch National Forest, also in Utah. The Mirror Lake Complex included 117 camping units, plus picnicking, fishing, boating, a lodge and cabins, and a trail head to the adjacent High Uintas primitive area. Therefore, it provided an especially rigorous test of this method.

GENERAL PRINCIPLES

As a modification of the widely used system of double sampling developed by James and Ripley (James 1966), the net count system followed the same basic principles of (1) relating randomly scheduled counts of visitor use to mechanical traffic counts for the same times, and (2) applying the resulting relationships to the season-long traffic count record to obtain an estimate of season-long visitor use. However, the net count system differed from the original double-sampling system in that 20 on-the-hour counts were taken instead of 12 day-long sequences of counts. Also, a traffic counter was used that records the vehicles actually present at specific times (i.e., net counts) rather than one that records the total flow of traffic during a period of time (fig. 1).

The counter was wired to two electric switching tapes--one placed across the incoming traffic lane and the second placed across the outgoing traffic lane. Once each hour, it printed a cumulative total for "axles in" in one column and a cumulative total for "axles out" in another. The difference between the "in" and "out" totals represented the "net count" of axles actually present at the on-the-hour moment of printing.

Over time, an error developed due to differences in the sensitivities of the tape switches. However, the counter was calibrated every 5 or 6 days and the error was easily prorated during summarization of the counter tapes. This gave corrected "net axle counts."

During this summarization, the net axle count that corresponded with each on-the-hour visitor count was identified. All data were then punched onto cards, and a computer run was made to determine (1) regression relationships between visitor use and net counts; (2) season-long regression estimates of visitor use (total and for selected activities); and (3) confidence limits for all estimates.

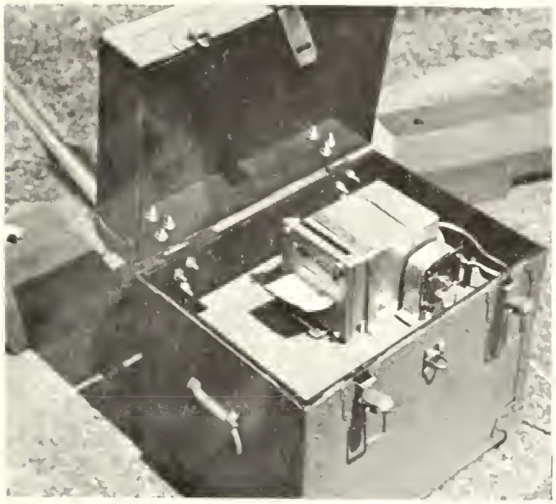
SAMPLING SCHEME

For each site sampled, 20 dates were selected at random from the summer use season. Weekdays and nonweekdays (including holidays) were selected in proportion to the total number of weekdays and nonweekdays in the season. Then, for each selected day, an on-the-hour sampling time between 0800 and 2000 (inclusive) was selected, using random procedures.[3]

Sample counts of visitors were made to bracket the randomly selected on-the-hour times. For example, if it would have taken approximately 20 minutes to count the people present at 1300 on August 3, the count would have been started at 1250 and continued until approximately 1310. Counts could extend as much as 45 minutes on each side of the scheduled hour, allowing up to $1\frac{1}{2}$ hours per count.

[3] All times were expressed on a 24-hour basis. Thus 11:00 a.m. is 1100, 12:00 noon is 1200, 1:00 p.m. is 1300. . . and 12:00 midnight is 2400.

Figure 1.--Island counter installation used to obtain "net counts" of vehicle axles present within a recreation site at on-the-hour times. At left is the printing counter.



During each sample count, the number of visitors present was recorded on a tally form. In addition to a total season-long use estimate and estimates by activities, an estimate of total "visitors" was desired. This required that total visitor-hours be divided by average hours-per-visit. Average hours-per-visit was determined by asking every nth visitor for his length of visit and then computing the weighted average (Lucas 1963). The interval n was preselected as the interval needed to sample approximately 60 visitors per site for their lengths of stay. Based on previous visitor-use estimates, the value 10 was selected for n at Sunrise Campground and the value 35 at Mirror Lake.

It may not be desirable to sample for length-of-stay in the future because (1) the *visitor-day* is now standard for reporting use at federal recreation areas, and (2) computation of visitors greatly complicates both data collection and processing.

SUMMARIZING THE COUNTER TAPES

The printed paper tapes from the counter were summarized to provide (1) net axle counts for each on-the-hour time and (2) season-long totals of axle counts for both daytime and nighttime periods.

As mentioned earlier, an error developed between the number of axles present and the number shown by the counter. This was corrected by periodically calibrating the counter and then prorating the error during summarization of the tapes.

Each time the counter was calibrated the tapes were marked to aid future handling. At the time of each calibration, the tape used up to that moment was torn off and marked at the top with the cumulative total for axles "out," cumulative total for axles "in," number of axles actually counted in the recreation site, and the date and time of calibration. The end of the tape still in the counter was then marked with the date and time of the next printout (fig. 2).

During calibration, the "in" and "out" counter registers were both reset to zero, and the number of axles present was entered in the "in" counter register, using an electric push-button provided for the purpose.

As shown in figure 2, dates and hours were marked along the left margin of each tape to identify which counts occurred at which times. Then, lines were drawn across the tapes to separate daytime counts (0800 through 2000) from nighttime counts (2100 through 0700).

If net counts of vehicle axles are to be determined, the number of axles "in" minus the number "out" should equal the number present. So this would be true, a multiplier was computed for adjusting the number "out." This was obtained by subtracting the number of axles present from the number of axles "in" to get the correct "out" figure and then dividing the results by the number shown as "out." For example, at the top of the tape in figure 2,

$$\frac{2,116 - 81}{2,746} = 0.7411.$$

This is the multiplier used to adjust the "out" number so that axles "in" minus adjusted axles "out" equal axles present. The multiplier is just the ratio of the correct "out" count to the actual "out" counter reading, which was too large because of the inaccurate readings obtained from the counter. In figure 2,

$$2,116 - 0.7411\ (2,746) = 2,116 - 2,035 = 81, \text{ etc.}$$

Visitor use was related to both adjusted net axle counts (X_i) and the squares of these axle counts (X_i^2). Therefore, each on-the-hour net count had to be computed so that both ΣX_i and ΣX_i^2 could be determined. However, the advantages of including the X_i^2 do not seem worth the complications it adds to computations. Therefore, in the future, ΣX_i should be computed by using the multiplier to adjust the total of all "out" numbers and then subtracting this adjusted total from the total of all "in" numbers.

$$\Sigma X_i = \Sigma \text{ "in" numbers} - \text{multiplier } (\Sigma \text{ "out" numbers}).$$

Note that separate totals for "in" and "out" numbers must be determined for daytime periods and for nighttime periods.

STATISTICAL PROCEDURES

Computations for the net count method provided regression equations for each visitor activity, site occupancy, equipment usage, total daytime use, and overnight use. Each equation was of the form

$$Y = a + bX + cX^2$$

where

- Y is the estimate of visitor-hours for an on-the-hour time
- X is the number of axles shown at a site for an on-the-hour time
- a is a constant (the "Y intercept") established by regression from sample data
- b and c are coefficients established by regression from the sample data.

However, to provide estimates on a season-long basis, these equations were used in the form

$$\Sigma Y = a(N) + b(\Sigma X) + c(\Sigma X^2),$$

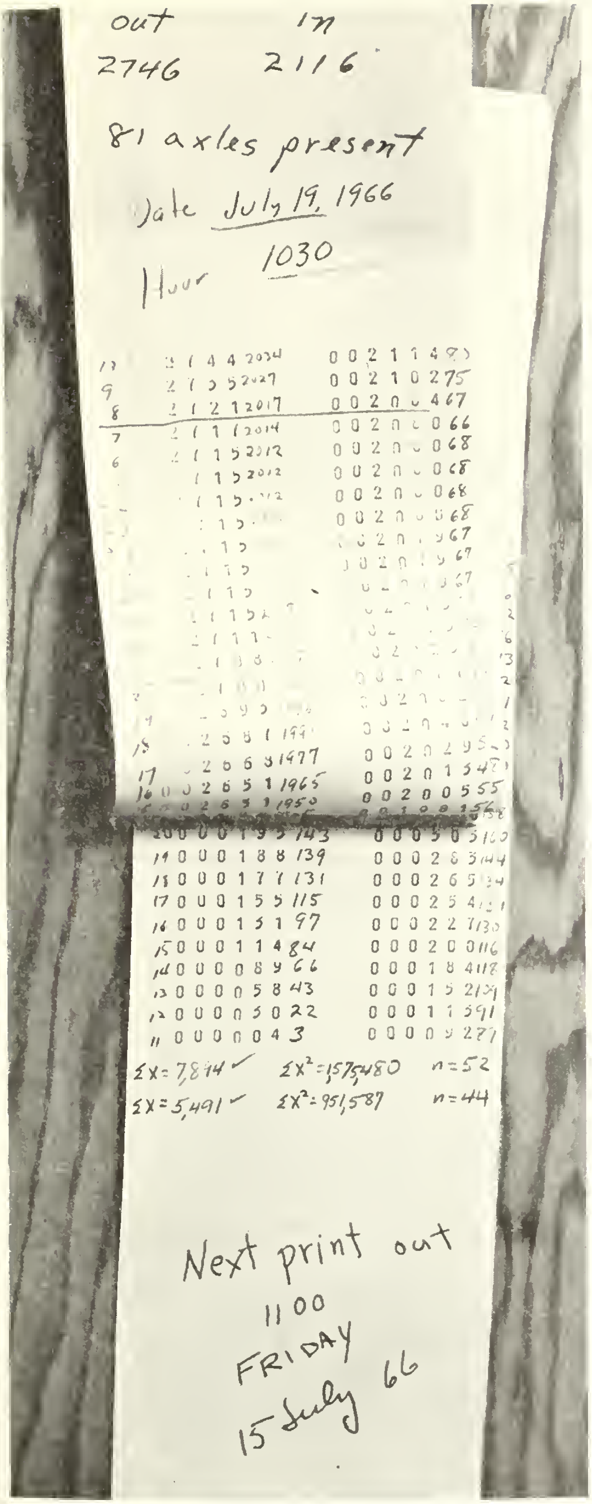


Figure 2.--A counter tape with error prorated to give corrected "net axle counts" along the right-hand margin. Dates and hours are written along the left-hand margin.

where

N is the season-long number of hours to which the estimate applies

ΣY is the estimate of visitor-hours for the N hours

ΣX is the summation of "net axle counts" for the N hours

ΣX^2 is the summation of the squares of "net axle counts" for the N hours.

The final term, $c(\Sigma X^2)$ added little accuracy but made data handling procedures more complex. Therefore, it should probably be left out of any future use of net count procedures for visitor sampling.

With the equation simplified in this manner, the variance for ΣY would be determined by the formula

$$s^2_{\Sigma Y} = N(N - n)\, s^2_{y \cdot x} \left\{ \frac{1}{n} + \frac{(\overline{X}_N - \overline{X}_n)^2}{\Sigma x^2} \right\}$$

where

$s^2_{\Sigma Y}$ is the variance of ΣY

N is the number of hours to which estimate applies

n is the number of hours sampled (usually 20)

Σx^2 is the sum of squared deviations from the mean for the set of X values used for regression

$s^2_{y \cdot x}$ is the mean squared deviation from regression.

Confidence intervals would then be computed as

$$\pm t \sqrt{\text{variance}}$$

at n – 2 degrees of freedom.

If an estimate of "visitors" is desired, in addition to an estimate of "visitor-hours" or "visitor-days," then an estimate of *hours-per-visit* is necessary. This complicates both data collection and handling.

The average length of visit can be computed without bias from sample data if a simple weighting procedure is used (Lucas 1963). Deming (1944) provided procedures not only for determining an unbiased average but also for determining the variance of a dividend (such as visitor-hours divided by hours-per-visit) where there is correlation between the values that determine the numerator and denominator.

From Deming, the average length of stay is

$$\bar{Z} = \frac{\Sigma W_i Z_i}{\Sigma W_i},$$

where

$\bar{Z}$ is the average length of stay

Z_i are the sample observations of hours-per-visit

W_i are the weighting factors associated with respective Z_i.

From Lucas, the weighting factors are the reciprocals of the length of time each visitor was exposed to sampling. For example, if the *i*th visitor was present for 27 hours but was exposed to sampling during only 18 of those hours, the term $W_i Z_i$ would equal 1/18 times 27.

Also as based on Deming:

$$s^2_{\bar{Z}} = \frac{\Sigma(W_i Z_i^2) - \bar{Z}^2 \Sigma W_i}{(\Sigma W_i)\ (n-1)},$$

where

$s^2_{\bar{Z}}$ is the estimated variance of $\bar{Z}$

n is the number of Z_i, and

other values are as previously defined.

The total number of "visitors" equals the total number of *visitor-hours* divided by the average *hours-per-visit*:

$$\Sigma V = \frac{\Sigma Y}{\bar{Z}}$$

where

ΣV is the season-long estimate of "visitors" and other values are as previously defined.

Variance for the number of "visitors" can be computed by the formula (derived from Deming, p. 40):

$$s^2_{\Sigma V} = \frac{1}{\bar{Z}^2} \left\{ s^2_{\Sigma Y} + \frac{(\Sigma Y)^2}{\bar{Z}^2} s^2_{\bar{Z}} - \frac{2 \Sigma Y}{\bar{Z}} s_{\Sigma Y}\ s_{\bar{Z}}\ r_{YZ} \right\}$$

where r_{YZ} is the correlation coefficient between Y and Z, and the other symbols are as previously defined.

Confidence intervals could include *t* values with two difference degrees of freedom because this variance was derived from two different samples (one for ΣY, one for $\bar{Z}$). However, the *t* value used was the one applicable to the sample with the smaller value of n to be conservative and to simplify computations. Thus degrees of freedom would normally be 20 - 2 = 18, based on 20 on-the-hour sample counts of visitor use.

RESULTS AND DISCUSSION

As shown in the tabulation below, the precision of the net count system was excellent for total visitor use--giving estimates of total use that had a 95-percent probability of being no more than 11.6 percent from the true value at the 117-unit Mirror Lake Complex and no more than 21.4 percent from the true value at the 27-unit Sunrise Campground.

	Mirror Lake (Percent error)	Sunrise Campground (Percent error)
Total visitor-hours	±11.6	±21.4
Total visitors	±27.8	±29.4
Average number of units occupied, daytime	(not sampled)	±21.9
Average number of units occupied, nighttime	(not sampled)	±15.8
Range for individual activities	[1] ±22.9 to ±178.8	[2] ±27.5 to ±105.7

[1] Seven out of 14 sampled activities had errors of less than 50 percent.
[2] Two out of 7 sampled activities had errors of less than 50 percent.

Good estimates were also provided for the more usual activities. However, activities that are strongly affected by time of day, season, weather, or other factors may be too erratic for accurate estimates. For example, at Mirror Lake, the confidence intervals ranged from ±22.9 percent for the rather consistent trailer camping to ±178.8 percent for swimming or bathing. The fact that the lake is located 10,000 feet above sea level makes swimming rarely possible during much of the season and thus too variable for accurate estimation.

Estimates were also provided for occupancy of camp units and for camping equipment by types. All estimates of daytime activities should be without bias because relationships between visitor use and net counts of axles were based on daytime sampling. However, these relationships were also applied to axle counts taken during nighttime periods. Estimates for nighttime periods will therefore be biased if the number of visitors per axle count changes from day to night.

An additional source of bias may enter into estimates of total camping by types of equipment used. Such an estimate determined from daytime sampling could differ considerably from the equipment patterns actually present at night because people using different types of equipment are likely to arrive and depart from recreation sites at different times. This bias could be particularly large for areas used primarily by one-night visitors. By contrast, the bias should be very small for campgrounds used by vacationers who stay a week or more.

Nearly unbiased estimates of nighttime use and equipment usage could be made from counts scheduled for late evening on a random selection of sampling days. Dates for evening counts should be selected independently from daytime sampling data.

DESIRABLE CHARACTERISTICS FOR COUNTING EQUIPMENT

The future usefulness of net count visitor sampling procedures depends greatly on the availability of suitable counter equipment. This must be dependable, reasonably inexpensive (perhaps $200 - $500), and operable throughout a variety of weather and temperature conditions and at remote locations. Counters might either print out one set of numbers for "in" axle counts and a second set for "out" axle counts, or they might simply record net numbers of axles. In either case, the information should be recorded for each on-the-hour time. Ideally, this information should be either on punched paper tape or magnetic tape so it could be summarized by computer rather than by clerical personnel. The counter should also mark daytime numbers with a unique character so they can be separated from nighttime values. Regardless of the type of output used, the counter should have dials that permit the "in" and "out" axle numbers, or else a net axle number, to be read directly. Provisions should be made for periodic calibration of the counter, either by entering calibration information directly onto the tape or by keeping records that could be used at the time of summarization of the tapes. The counter must also have a button for entering "axles present" in the "in" or "net" counter register during each calibration.

It would be desirable to have cars actuate the counters by crossing magnetic loops buried in the road rather than by crossing exposed electric switching tapes. The latter have some problems involving damage by traffic, vandalism, and malfunction. Also, if strategically located, magnetic loops could record incoming and outgoing vehicles without requiring any divider to separate traffic lanes.

CONCLUSIONS AND RECOMMENDATIONS

The net count visitor sampling method could be highly effective for selected situations if suitable counting equipment were available. A single counter would permit accurate statistics for large recreation complexes, such as those surrounding one or more lakes in a valley served by a single dead-end road.

At the moment, it seems desirable to postpone further consideration of net count sampling until such time as visitor sampling seems to require automation. By that time it may be easier to assemble effective counter equipment from off-the-shelf items.

Before net count sampling procedures are applied on an administrative basis, they should be refined in accordance with what has been learned from this study. To simplify the summarization of counter tapes, the net axle counts should be used only in their prime and not in their squared form. Also, if possible, such summarization should be done by computer. It would also simplify data collection and processing if all estimates are made in terms of *visitor-days* and not in terms of visitors. As a final refinement, independent sample counts should be taken and independent estimates made for daytime and nighttime use.

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Research Note

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INSECTS AFFECTING WESTERN WHITE PINE FOLLOWING DIRECT SEEDING IN NORTHERN IDAHO[1]

Patrick C. Kennedy and David G. Fellin[2]

ABSTRACT

*Insect damage to direct-seeded western white pine (*Pinus monticola *Dougl.) on three clearcut areas that were prescribed burned in successive years was investigated in north central Idaho. Ground beetles ate seeds, and grasshoppers and cutworms ate seedlings in the field and in the laboratory. The amount of damage to seedlings was inversely related to the age of the burn. Insects only slightly restricted successful first-year development of western white pine following direct seeding.*

Insects, mammals, birds, and fungi are the major biotic factors that destroy direct-seeded western white pine (Pinus monticola Dougl.) seeds and seedlings. Any one or a combination of these factors may limit the successful establishment of new stands following direct seeding.

Most evidence that insects are involved has been only circumstantial. Wahlenberg (1925) summarized the results of past direct-seeding projects in the northern Rocky Mountain region and attributed the death of an undetermined number of western white pine seedlings to cutworm larvae. Haig (1936) and Haig et al. (1941) noted that soil insects, chiefly cutworm (Noctuidae = Phalaenidae) larvae, were one of the most important direct agents of conifer seedling mortality in the western white pine type in northern Idaho. Schopmeyer (1939) and later Schopmeyer and Helmers (1947) determined that either cutting or clipping was one of the major kinds of injury during the first growing season to direct-seeded western white pine. They observed several forms of cutting in both screened spots and unscreened spots. They speculated that "cutworms, grasshoppers, and other insects may have had a part" in causing the damage. In a recent study of seedspotting in Oregon (Franklin and Hoffman 1968), insects, along with other animals (rodents, birds, slugs, shrews), were believed to account for one-third of the mortality of western white pine germinants.

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[1]Based on a part of a thesis entitled "Biotic factors influencing direct seeding of western white pine (Pinus monticola)" prepared by the senior author in partial fulfillment of the requirements for the master of forestry degree at the University of Michigan in May 1964.

[2]Authors are respectively: Forestry Staff Specialist, Agricultural Chemicals Division, Geigy Chemical Corporation, Ardsley, New York; and Entomologist, Intermountain Forest and Range Experiment Station, USDA Forest Service, stationed in Missoula at the Forestry Sciences Laboratory, maintained in cooperation with the University of Montana.

Since in most of these past studies insects were only suspected as being responsible for clipping injuries, our objectives in this study were to (1) identify the most important insects damaging seeds and seedlings of direct-seeded western white pine and (2) assess the extent of the damage. Since this study was completed, the management program of western white pine in the northern Rocky Mountains has been realigned (Ketcham, Wellner, and Evans 1968). As a result, planting and direct seeding of western white pine has been discontinued on an operational basis. However, we feel that the information presented here is still of value because of its application to direct seeding of other conifers in the northern Rocky Mountains.

STUDY AREA AND PROCEDURE

We conducted our studies in 1962 and 1963 in the Musselshell area of the Clearwater National Forest in northern Idaho. Three areas were selected, each of which had been clearcut, and then prescribed burned in successive years--1960, 1961, and 1962.[3]

In the fall of 1962, two 10-acre blocks were selected on each of the burned areas. On one block in each burn, two types of exclosures were set up, both designed to exclude vertebrates but not most kinds of invertebrates. One type of exclosure was a 2- by 2-foot wooden frame to which was fastened a covering of 1/4-inch hardware cloth. Four of these were sunk 8 inches into the soil on each of the three blocks. The other type was a cone-shaped exclosure with a covering of the same material. Five of these were set up on each of the same three blocks.

That same fall, 100 western white pine seeds were broadcast sown under each frame exclosure and six seeds were spot sown under each conical exclosure. All seeds were coated with Endrin, Arasan[4] and aluminum powder as outlined by Spencer.[5]

In early spring of 1963, eight 1-foot-high (aboveground) 2- by 2-foot-square wooden frame exclosures were placed on each of the other three blocks. Each was covered with fine mesh Saran screening. These exclosures did not prevent insects from crawling under the frame, but did, no doubt, deter some insects from getting to the seeds and seedlings as well as keep out mammals and birds. Later that spring we removed the vegetation from within each exclosure and broadcast sowed 150 seeds. Prior to sowing, the seeds were chemically scarified with sulfuric acid and hydrogen peroxide to promote germination. These seeds had been taken out of a seedlot from which we had dissected 1,000 seeds, which were found to be free of seed insects.

By 1963, the vegetation on the three burns was quite variable. On the 1960 burns, the main types of vegetation were grasses, sedges, and mosses, and occasionally some thistles (Cirsium spp.) and fireweeds (Epilobium spp.). On the 1961 burns, there were several species of annuals but mostly thistles and fireweeds (fig. 1). The 1962 burns had few plants until late in the spring and early summer of 1963 when thistles started to invade.

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[3]This study is only a portion of a more comprehensive study concerning the biotic factors that influence the direct seeding of western white pine. The overall study was established by and is under the supervision of Raymond J. Boyd, Associate Silviculturist, Intermountain Forest and Range Experiment Station, stationed in Moscow, at the Forestry Sciences Laboratory, maintained in cooperation with the University of Idaho.

[4]These chemicals are usually used before normal seeding operations to protect seed from vertebrates, insects, and fungi. Mention of trade names does not imply endorsement by the USDA Forest Service.

[5]Spencer, D. A. A formulation for the protection of seed from animal damage. Wildlife Res. Lab., Bur. Sport Fish. & Wildlife, Denver, Colo. Unpub. Rep., 4 pp. 1959.

Figure 1.--Clearcut burned in 1961 on the Clearwater National Forest. Thistles and fireweed predominated when this photo was taken in 1963.

All plots were examined periodically for germination and insect damage to seeds and seedlings. Insects suspected of causing damage were collected and caged in the laboratory with a supply of seeds or seedlings for food.[6]

RESULTS AND DISCUSSION

INSECT DAMAGE TO SEED

One percent of the coated seeds sowed on the plots covered by hardware cloth was apparently destroyed by insects. The damage to seeds resembled the feeding injury to Douglas-fir seeds caused by ground beetles (Coleoptera: Carabidae) as described by Dick and Johnson (1958) and Lawrence and Rediske (1962). We often collected the ground beetle, Amara erratica (Sturm) from the plots, especially on the 1960 burn. It was probably responsible for damage to the seeds; if so, it was the principal seed-destroying insect. In addition, we found chemically scarified seeds, which undoubtedly were damaged by carabids. However, we were unable to determine the incidence of damage.

In the laboratory, A. erratica readily ate chemically scarified seeds; the chemical treatment removed the outer seed coat, which made the soft inner tissue easily accessible. The beetles died, however, after feeding on seeds coated with Endrin, Arasan, and aluminum powder.

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[6]We would like to acknowledge the assistance of P. J. Spangler and E. L. Todd, Insect Identification and Parasite Introduction Research Branch, Entomology Research Division, Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C., and I. J. Cantrall, Professor of Zoology and Curator of Insects, Museum of Zoology, University of Michigan, Ann Arbor, Michigan, who identified the insects.

Figure 2.--Cutworm damage to western white pine seedling. Seedling to left of toothpick has been severed by a cutworm larva, leaving a portion of the hypocotyl. An undamaged seedling is to the right.

INSECT DAMAGE TO SEEDLINGS

Insects damaged or destroyed about 25 percent of the seedlings growing on the Saran-covered plots. The following tabulation shows damage to seedlings was greatest on plots in the 1960 burn, less on plots in the 1961 burn, and absent on plots in the 1962 burn.

Year of burn	Seedlings developed	Seedlings damaged	Seedlings damaged (Percent)
1960	215	95	44
1961	87	5	6
1962	94	0	0

The reason for the more extensive damage on the 1960 burn and the absence of damage in the 1962 burn was probably the greater abundance of insects on the older burn. In another phase of our studies, we collected soil and duff samples on each burn biweekly throughout the summer and found more insects and other invertebrates on the 1960 burn than on either the 1961 or the 1962 burn.

There were no seedlings damaged on the plots covered by hardware cloth on the 1961 and 1962 burns. Only 12 seedlings were clipped on the 1960 burn as shown below:

Type of plot	Seedlings developed	Seedlings damaged	Seedlings damaged (Percent)
Square (broadcast sown)	378	7	1.9
Round (spot sown)	83	5	6.0

The insects responsible for the damage to seedlings were larvae of one or more species of cutworm (Lepidoptera: Phalaenidae) and grasshopper nymphs and adults (Orthoptera: Acrididae and Tettigoniidae). It is of interest that cutworms and grasshoppers are the same kinds of insects that Wahlenberg (1925) and Schopmeyer and Helmers

(1947) suspected of damaging seedlings. We collected five species of grasshoppers within and around the plots: Melanoplus bivittatus (Say), M. packardii Scudder, M. indigens Scudder, Trimerotropis suffusa Scudder, and Anabrus longipes Caudell. All of these grasshoppers readily ate seedlings in the laboratory. The one cutworm that we were able to rear and identify was Euxoa sp.--probably holobera (Smith). This species also readily consumed seedlings in the laboratory. Several other unidentified cutworm larvae clipped western white pine seedlings in the laboratory.

Grasshopper and cutworm damage to western white pine seedlings can usually be distinguished from one another. Grasshoppers usually consume the entire hypocotyl clear down to the ground line while cutworm larvae sever the hypocotyl leaving a portion of it protruding from the soil (fig. 2). However, we are not sure what percentage of the seedling damage can be attributed to cutworms and what percentage to grasshoppers, because both were seen feeding on seedlings on plots in the 1960 burn before we observed the difference in feeding damage. Cutworm larvae were abundant on the area during May and June while grasshoppers did not become noticeably abundant until the end of June. Similar damage to slash pine, Pinus elliottii Engelm. seedlings is caused by an arctiid, Apantesis radians Wlk. (Lepidoptera: Arctiidae) in Florida (Ebel 1967).

Of the 12 seedlings clipped in the plots covered by hardware cloth, one was clipped in the spring and the other 11 were clipped during July or later. The five clipped in the plots covered by cones were distributed in four different plots. Cutworm larvae probably clipped the single seedling while grasshoppers no doubt cut the remaining 11, although cutworms generally clip seedlings in groups, according to Fowells (1940).

Of the 100 seedlings damaged within the Saran-covered plots, we suspect that at least 40 percent was damaged by cutworms. In the spring and early summer of 1963, the senior author on several occasions observed cutworm larvae on these plots during late evening examinations. During one examination in the spring, a cutworm larva was observed actually consuming a seedling. On that particular plot, 40 seedlings had already been clipped prior to this examination.

Some of the seedling damage on the plots within the 1960 burn may have been done by carabids. Although we did not observe carabids feeding on seedlings, they were frequently found on the plots after the seeds had germinated and the seedlings were growing. Nusslin and Rhumbler (1922) observed a carabid, Harpalus pubescens Muller, chewing off spruce seedlings just above the ground surface.

CONCLUSIONS

The season of 1963 was considered to be favorable for the establishment of western white pine by direct seeding; it appears that insects were not an exceptionally important factor in restricting such establishment. However, conditions in other years could result in higher populations of insects and result in greater damage to seeds and/or seedlings. Hence, insects are always a potentially limiting factor in the regeneration of western white pine by direct seeding.

The only invertebrates damaging western white pine seeds or seedlings were insects. Of these only three groups were involved: ground beetles, which damaged seed; and cutworms and grasshoppers, which damaged seedlings.

Seeding areas during the year of burning will result in the least amount of insect damage. The ground fire reduces insect populations, hence providing some protection for the seeds and newly developing seedlings.

Spring sowing of seeds treated with Endrin, Arasan, and aluminum powder prevents carabid damage to seeds.

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

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Research Note

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TEST OF AN EQUATION FOR PREDICTING BARK THICKNESS OF WESTERN MONTANA SPECIES

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ABSTRACT

Describes results of testing a generalized equation for predicting bark thickness using data from western Montana species. The most satisfactory least squares solution for use with a combination of species is given.

Upper-stem diameters measured using an optical dendrometer include the bark. Therefore, to estimate volume of wood alone, the measurement must be adjusted to diameter inside bark. However, average bark thickness and the pattern of its distribution on the stem may vary among species. It might be possible to develop a satisfactory equation for predicting bark thickness for each species in an area if a large enough sample of bark thickness measurements were available for each species. When such information is not available, it would seem reasonable to use a generalized model for predicting bark thickness in which one of the variables is a measurement of bark thickness at breast height on the standing tree. This variable should explain much of the difference in upper-stem bark thickness between species and between trees, because the factors that affect bark thickness (such as age and species) up the stem also affect thickness at breast height.

Grosenbaugh (1967) incorporated three options for estimating bark thickness in his STX program for converting dendrometer measurements on standing trees to volume, surface area, and length. One of these was the equation

$$B_i = B_{4.5} \frac{D_i}{D_{4.5}} \left(\frac{1}{2 - \frac{D_i}{D_{4.5}}} \right) , \qquad (1)$$

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where

B_i = bark thickness at the i^{th} level on the tree stem
D_i = diameter outside bark at the i^{th} level on the tree stem
$B_{4.5}$= bark thickness at breast height
$D_{4.5}$= diameter at breast height outside bark

This equation can also be used to estimate bark thickness in the NETVSL computer program, which was designed to calculate volumes of felled or standing trees (Stage, Dodge, and Brickell 1968). Whether single or double bark thickness is used is immaterial. If $B_{4.5}$ is a single bark thickness measurement, the predictions, B_i, will be for single bark thickness. If $B_{4.5}$ is a double bark thickness measurement, then predictions will be of double bark thickness. All fractions in the equation are equal to unity and predicted bark thickness is equal to actual bark thickness when D_i is $D_{4.5}$.

Mesavage (1969) found that equation (1) gave reasonably accurate bark thickness predictions for four southern pine species of sawtimber age. For other species and ages, where predictions from equation (1) may not be as accurate, we can use the equation

$$B_i = B_{4.5} \frac{D_i}{D_{4.5}} \left(\frac{Q - 1}{Q - \frac{D_i}{D_{4.5}}} \right) \qquad (2)$$

where Q is a coefficient to be estimated from a sample of bark thickness measurements taken from the population for which the equation will be used. The coefficient Q can be estimated by least squares regression.

Even more flexibility--perhaps too much--will result from including more coefficients so that

$$B_i = B_{4.5} \left(\frac{D_i}{D_{4.5}} \right)^{b_1} \left[\frac{b_2 - 1}{b_2 - \left(\frac{D_i}{D_{4.5}} \right)^{b_3}} \right]^{b_4} \qquad (3)$$

where the b_i's are coefficients to be estimated and b_2 replaces Q in equation (2). Equation (3) retains the property of predicting a bark thickness equal to actual bark thickness when D_i is $D_{4.5}$. Equation (2) is equivalent to equation (3) when coefficients b_1, b_3, and b_4 are restricted to unity. In this paper, we will describe the results of testing equations (2) and (3).

DATA USED FOR TESTING THE MODEL

Using trees felled on the Kootenai National Forest in western Montana, we took 443 measurements of double bark thickness. The following species were represented in the sample:

Western white pine	(Pinus monticola Dougl.)
Ponderosa pine	(Pinus ponderosa Laws.)
Lodgepole pine	(Pinus contorta var. latifolia S. Wats.)
Grand fir	(Abies grandis Lindl.)
Subalpine fir	(Abies lasiocarpa Nutt.)
Inland Douglas-fir	(Pseudotsuga menziesii var. glauca (Mirb.) Franco)
Western larch	(Larix occidentalis Nutt.)
Engelmann spruce	(Picea engelmannii Parry)
Western hemlock	(Tsuga heterophylla (Raf.) Sarg.)
Western redcedar	(Thuja plicata D. Don)

Measurements were taken on sawn cross-sections of the trunk at points 8 feet apart, beginning 4.6 feet above breast height and continuing up the stem until a point was reached where diameter outside bark was less than 4 inches. All bark measurements used were taken from points where diameter exceeded 4 inches. The maximum and minimum axes of the cross-section were measured outside bark and called DOB_1 and DOB_2, respectively. Inside bark measurements on the same axes were called DIB_1 and DIB_2. Then double bark thickness was calculated as

$$DBT = \sqrt{DOB_1 DOB_2} - \sqrt{DIB_1 DIB_2} \ .$$

All measurements were taken to the nearest 1/100 foot (0.12 inch), corresponding to single bark thickness measurement to the nearest 0.06 inch. The average double bark thickness over the entire sample was 0.96 inch.

USE OF COMPUTER PROGRAM "NLLS" TO FIT NONLINEAR REGRESSIONS

Equations (2) and (3) cannot be made linear with respect to their parameters by transformation. Therefore, they cannot be fitted to data using linear regression methods. Instead, the unknown coefficients were estimated using a computer program for nonlinear regression (Marquardt 1963, 1966; Draper and Smith 1966) that minimizes the sum of squared residuals. To use the NLLS (nonlinear least squares) program, the desired function is written into a FORTRAN subroutine. Initial estimates must be provided for each coefficient to start the iterative fitting process.

FITTING THE BARK THICKNESS MODEL

Equation (2) was fitted first. This is a one-parameter model and the initial estimate of the coefficient was 2.0. This made the equation equivalent to equation (1) and made it possible to see what improvement in fit, if any, could be obtained by a different estimate of the coefficient. The result was as follows:

	Starting	Final solution
Coefficient estimate	2.0	1.67342
Sum of squared residuals	86.8995	80.2518
Standard error of residuals	.4434	.4261

The reduction in sum of squares, while statistically significant according to the test described by Williams (1959, p. 81), is small. The standard error of residuals was reduced by less than 0.02 inch.

Because it is more flexible, equation (´) could be expected to account for more variation than was possible with equation (2). The results of fitting equation (3) were:

	Starting	Final solution
Coefficient estimate b_1	1.0	0.548235
Coefficient estimate b_2	2.0	5.80698
Coefficient estimate b_3	1.0	4.84516
Coefficient estimate b_4	1.0	4.40345
Sum of squared residuals	86.8995	68.7208
Standard error of residuals	.4449	.3957

These results show a more substantial reduction in residual sum of squares than was obtained with equation (2). However, the high correlation between the estimates of the parameters indicated that a two-parameter model might provide an equally close fit. Therefore, coefficients b_3 and b_4 were deleted from equation (3); that is, they were held to a constant value of unity, giving

$$B_i = B_{4.5}\left(\frac{D_i}{D_{4.5}}\right)^{b_1}\left[\frac{b_2 - 1}{b_2 - \left(\frac{D_i}{D_{4.5}}\right)}\right] \quad (4)$$

Fitting this equation gave:

	Final solution
Coefficient estimate b_1	0.0352
Coefficient estimate b_2	1.25638
Sum of squared residuals	69.4400
Standard error of residuals	.396813

Using this model, the coefficient of correlation between estimates of the coefficients was 0.8958.

Variance around the surface described by equations (3) and (4) was very nearly proportional to observed bark thickness. Equation (4) was fitted a second time assigning each observation a weight inversely proportional to bark thickness so as to attain the condition of homogeneous variance about regression. The resulting estimates were:

	Final solution
Coefficient estimate b_1	-0.009363
Coefficient estimate b_2	1.22228
Sum of squared residuals[2]	70.9300
Standard error of residuals[2]	.401047

Two observations can be made from these figures. First, weighting of the observations did not result in much change, either in the estimated coefficients or in the residual sum of squares. In other words, weighting did not change the position or shape of the regression surface appreciably. This may indicate that the equation being fitted is quite appropriate to the relationship between variables represented by these data. Second, it is noteworthy that the coefficient b_1 is nearly zero. This indicates the value for b_1 that reduces the variation in the quantity

$$\left(\frac{D_i}{D_{4.5}}\right)^{b_1}$$

to a minimum best satisfies the requirements of least squares. The above expression would always be equal to one, if b_1 were exactly zero, no matter what the values of D_i and $D_{4.5}$. Variation in the ratio of diameter outside bark to diameter at breast height (as the ratio appears with an exponent in equation (4)), apparently does not explain any variation in observed bark thickness. Rather, variation in the $D_i/D_{4.5}$ ratio seems to reduce precision of the predicting

[2] Unweighted sum of squares and standard error of deviations from the regression surface fitted to weighted observations. The figures are presented in this way so as to be comparable to those from unweighted regressions.

equation except for its use in the denominator of the fraction. If b_1 is assumed equal to zero, then the ratio raised to that power will always be equal to one, and equation (4) becomes

$$B_i = B_{4.5}\left[\frac{b_2 - 1}{b_2 - \left(\frac{D_i}{D_{4.5}}\right)}\right] \qquad (5)$$

Equation (5) is still a special case of equation (3). Fitted with observation weights inversely proportional to bark thickness it gave:

	Final solution
Coefficient estimate b_2	1.23177
Sum of squared residuals	70.1327

Predictions of double bark thickness given by this equation are shown in figure 1. Double bark thickness would logically be expected to approach zero as the ratio of upper-stem diameter to diameter at breast height approaches zero. Equation (5) does not meet this requirement. None of the bark thickness measurements used to derive the equation were taken from points on the tree stem where diameter outside bark was less than 4 inches. If bark measurements associated with smaller diameters had been used it seems quite possible that a properly fitting equation would have been required to follow the marked decrease in bark thickness that usually occurs in the top of the tree. For practical use this seems to be rather unimportant, because material in treetops smaller than 4 inches in diameter is usually unmerchantable.

DIAMETER INSIDE BARK/DIAMETER OUTSIDE BARK RATIO

Mesavage (1969) cited other authors' findings: that this ratio was nearly constant at all levels on the stem for some species; that it increased with increasing height for other species; and that it decreased with increasing height for still other species. MacDonald (1933) examined the trend of the DIB/DOB ratio up the stem for several coniferous species in Great Britain. He found that, in general, the ratio decreases with increasing distance above breast height through the lower third of the tree bole, remains nearly constant, then increases in the upper half of the stem. According to the bark distribution pattern described by equation (5), the DIB/DOB ratio increases, remains nearly constant, then decreases as measurement progresses to points further up the tree stem. The DIB/DOB ratios at various points on the stem of a tree having a diameter of 10 inches and a double bark thickness of 1 inch at breast height follow:

Diameter	Double bark thickness	DIB/DOB
10[3]	[3]1.00	0.900
9	.70	.922
8	.54	.933
7	.44	.938
6	.37	.939
5	.32	.937
4	.28	.930
3	.25	.917
2	.22	.888
1	.20	.795

[3]At breast height.

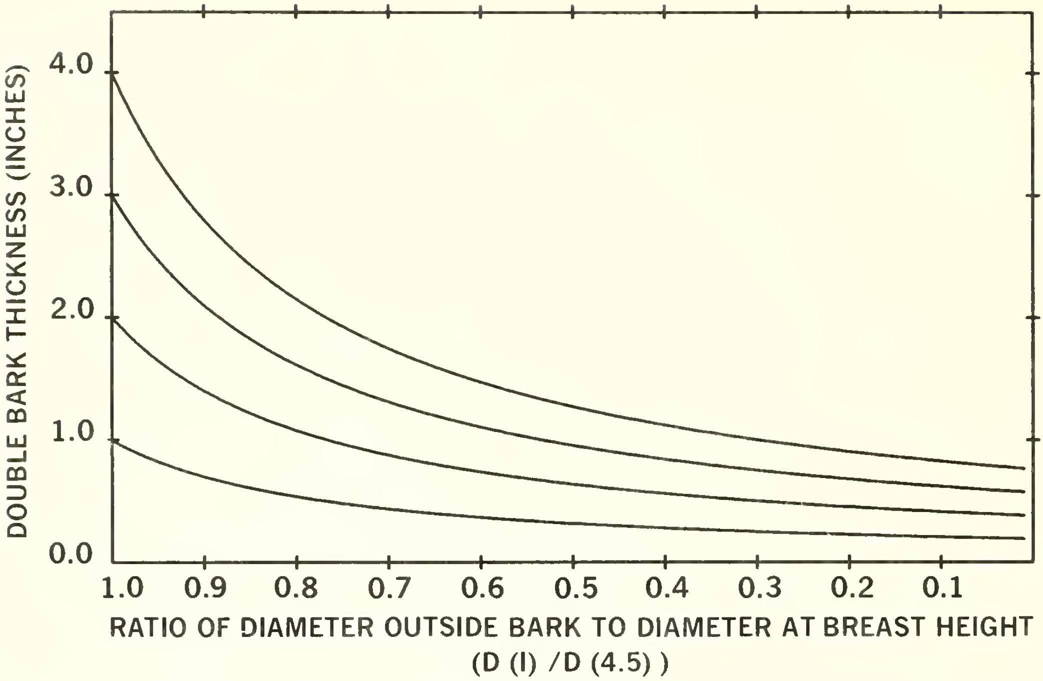

Figure 1.--Double bark thickness predicted from given measurements of double bark thickness at breast height and ratios of diameter outside bark to diameter at breast height.

However, if the bark thickness model given by equations (2) and (3) is appropriate and will accommodate either the increasing, decreasing, or constant trend in DIB/DOB ratio, then fitting either equation to bark thickness measurements by least squares will give estimates of the coefficients. A great deal of concern over the DIB/DOB ratio itself does not seem justified if an equation is available that provides satisfactory predictions of bark thickness for individual species or groups of species. It is bark thickness, not the ratio, that is the item of ultimate interest.

CONCLUSIONS

Adequate information might allow derivation of an equation to predict bark thickness for each species. This could lead to greater accuracy and precision in prediction if the distribution of bark on the tree stem varies from one species to another. Possibly, the ratio of diameters left out of equation (5) should be included for some species as it was in equations (2) and (4). For some species, the coefficient values given in equation (1) might give the best fit by the least squares criterion. Even if equation (1) were most appropriate for some particular species, it appears that equation (5) would be superior for general application to all species in the vicinity of the Kootenai National Forest. One would hope that in a population to which the equation might be applied, each species would be represented in the same proportion as in the sample on which the equation was based. The argument that this might not be the case mitigates against any other all-species equations fully as much as against equation (5).

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Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
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INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
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USDA Forest Service
Research Note INT-108 1970

DO CONTOUR TRENCHES REDUCE WET-MANTLE FLOOD PEAKS?

Norbert V. DeByle[1]

ABSTRACT

A description is given of the January-February flood and associated events that took place on the east side of the Sierra Nevada in 1963, especially those occurrences recorded and observed in a small watershed in the flood-source area. Some 110 lineal miles of contour trenches in this 16-square-mile watershed may have reduced flow during that flood by about 60 acre-feet.

Winter floods along the Sierra Nevada and other far western mountain ranges result from prolonged, low-intensity rainfall. If rain falls on a shallow snowpack--as it often does--the resultant melt contributes to the runoff. If it falls on frozen soil, which may be impervious, the overland flow can be substantial. Winter floods from mountain watersheds are not a new nor an unusual phenomenon; however, the amount of damage caused by them has increased markedly with the urbanization of many floodplains A colorful account of the nature and magnitude of an early flood in the Sierra Nevada was written by John Muir in 1875.[2] Recently, Young and Harris[3] described the flood that originated from these mountains in 1963 and compared it to two that took place in 1950 and 1955.

To measure conditions associated with flooding on the east side of the Sierra Nevada range, a network of climatologic and streamflow instrumentation has been maintained in the Dog Creek drainage of the Truckee River watershed since 1957. This Note is based on measurements from this network, on a sampling of the characteristics of the contour trenches in the Dog Creek drainage, and on observations made by the author before and during the 1963 flood.

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[1]Plant Ecologist, stationed in Logan, Utah, at the Forestry Sciences Laboratory, which is maintained in cooperation with Utah State University.

[2]John Muir. Flood-storm in the Sierra. The *Overland Monthly* Devoted to the Development of the Country 14(6): 489-496. 1875.

[3]L. E. Young and E. E. Harris. Floods of January-February 1963 in California and Nevada. U.S. Geological Survey Water-Supply Paper 1830-A, 472 pp., illus. 1966.

Table 1.--Precipitation pattern recorded at the climatic station in watershed 1 January 28 through February 1, 1963

Hours and date	Time period	Precipitation increment	Precipitation intensity
	Hours	Inches	Inches/hour
2130-2400 Jan. 28	2.5	0.04	0.016
0001-0400 Jan. 29	4.0	.02	.005
0400-1400	10.0	.0	.0
1400-2400	10.0	.54	.054
0001-1200 Jan. 30	12.0	.60	.050
1200-1500	3.0	.75	.250
1500-2200	7.0	1.64	.236
2200-2400	2.0	.06	.030
0001-1200 Jan. 31	12.0	1.29	.109
1200-2400	12.0	.98	.082
0001-0500 Feb. 1	5.0	.46	.092
0500-1900	14.0	.24	.017
2130 Jan. 28 - 1900 Feb. 1	93.5	6.62	.071

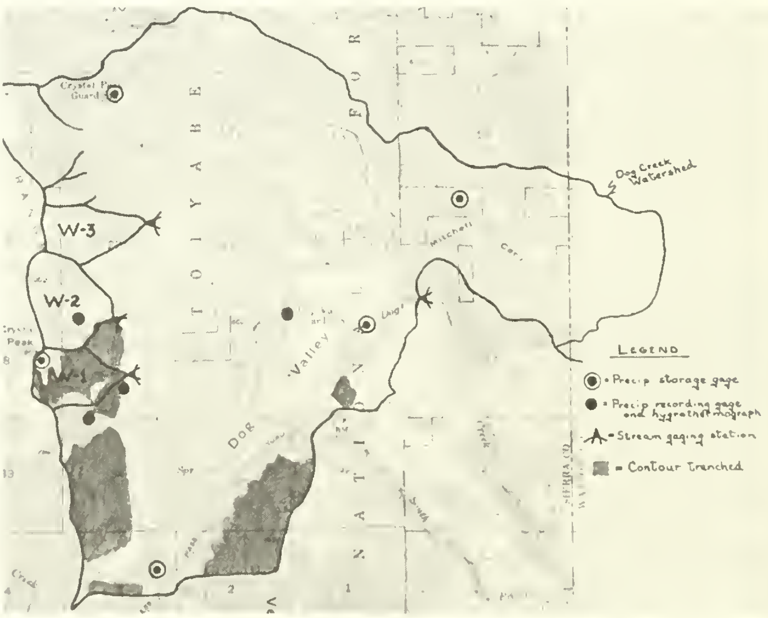

Figure 1.--Map showing Dog Creek watershed, three subwatersheds, instrumentation network, and contour-trenched areas.

THE 1963 WINTER FLOOD

The flood-producing precipitation that fell in and near the Sierra Nevada from January 29 to February 1, 1963, was associated with two warm frontal systems that moved inland from the Pacific. The storm lasted 4 days and set new precipitation maxima for periods greater than 24 hours. More than 20 inches of precipitation fell at many locations on the west side of the range, and 13.58 inches fell at one station, Mt. Rose, Nevada, on the east side.

The floods that resulted produced the greatest peak discharges from some watersheds in the history of recorded streamflow. This was the case at several gaging stations on the Truckee River and its tributaries. Storage in Lake Tahoe, Donner Lake, and Boca and Prosser Creek Reservoirs retarded much of the runoff; even so, about 20 square blocks of downtown Reno were inundated (see footnote 3).

The Dog Creek watershed, to which the remainder of this report is confined, is a part of the flood-source area of the Truckee River and is typical of much of the Truckee watershed. The Dog Creek watershed consists of 16.1 square miles upstream from the gaging station. It ranges in elevation from 5,700 feet at the stream gage to 8,500 feet at the highest peaks and has a modal elevation of 6,300 feet. Most of the acreage is forested with scattered, pole-size, second growth Jeffrey pine *(Pinus jeffreyi)*, large areas of which were killed in a 1960 fire. Good stands of Jeffrey pine, white fir *(Abies concolor)*, and associated species, that grow at higher elevations are interspersed with open areas, especially on south slopes and ridgetops. More than a square mile of the valley bottom is meadowland.

In 1962, heavy October rains soaked the soils in the Dog Creek watershed; so when cold air temperatures prevailed and snow cover was absent over most of the fall and winter, extensive soil freezing resulted, at least in the meadow areas of Dog Valley. Except in protected areas and on north-facing slopes above 7,000 feet, only a trace of snow remained on the ground prior to the late January storm. Over most of the watershed, moist soil and frost persisted beneath the surface few inches of dry soil. Streamflow was below normal for the midwinter period immediately preceding the flood; only 0.4 cubic foot per second (c.f.s.) was recorded at the Dog Creek gage, compared to a 5-year (1957-1961) January normal of 0.83 c.f.s.

The storm began in Dog Valley about 8 p.m. January 28. Before ending the evening of February 1 (table 1), it had deposited 8.28 inches of precipitation at the Dog Valley guard station and 6.62 inches in watersheds 1 and 2 (fig. 1). It is surmised from temperature records that precipitation began as snow, changed to rain January 29, then, near the end of the storm, turned to snow again at higher elevations.

Storm runoff was fed by water bleeding from a saturated mantle and from overland flow, probably an effect of the frozen soil. At the Dog Creek gaging station, this runoff peaked January 31 and again February 1 with mean hourly flows in excess of 700 c.f.s. (fig. 2). Streambanks along Dog Creek were extensively eroded and several erosion control dams in that stream damaged or destroyed (fig. 3).

There was substantive evidence that overland flow and channel cutting had produced some erosion at higher elevations, too. About 145 cubic yards of sediment was trapped behind the weir at the stream gaging station in watershed 1, and about 100 cubic yards in watershed 2. Unfortunately, the streamflow from these drainages was not satisfactorily recorded. The gaging stations did not operate because of ice on their stilling ponds and sedimentation about their inlet pipes.

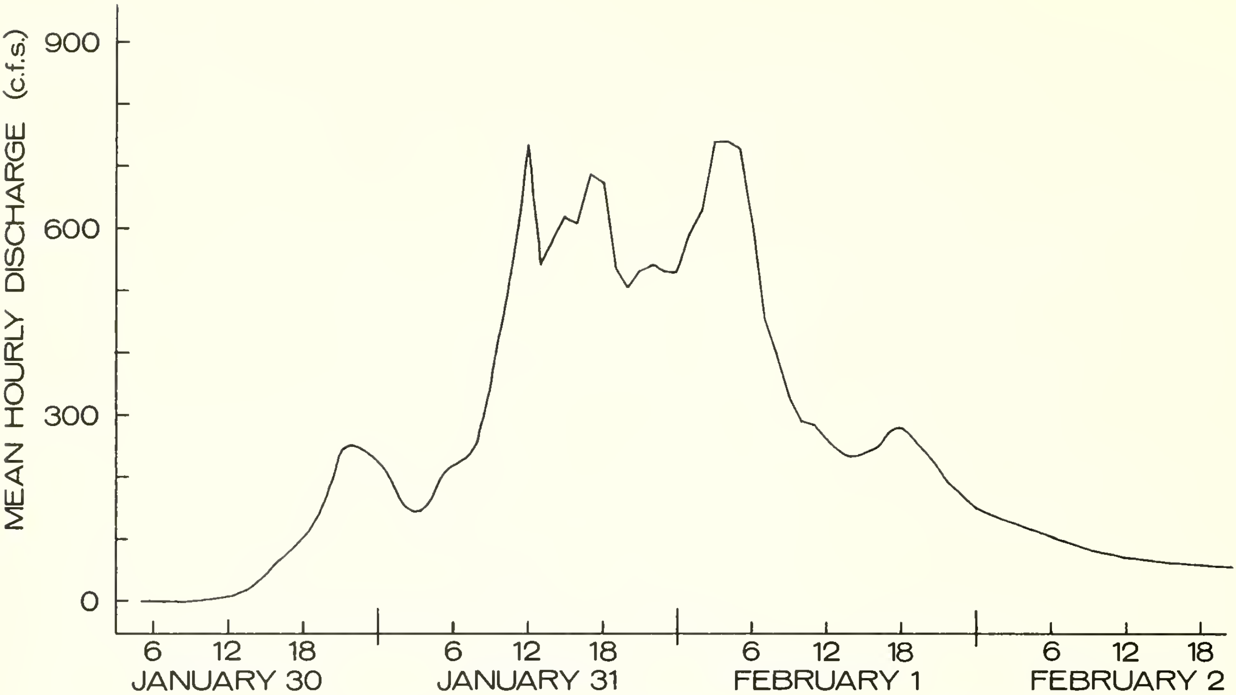

Figure 2.--Hydrograph for Dog Creek during 1963 flood.

Figure 3.--A Dog Valley erosion control dam destroyed during 1963 winter flood. The flow shown here on February 1 was less than half that during the flood peak.

Table 2.--Length, size, and capacity of contour trenches in the Dog Creek watershed in 1963

Area description	Trench length	Average cross-sectional size	Total capacity	
	Miles	Sq. ft.	Cu. ft.	Acre-ft.
In and near watershed 1	13.50	9.29	662,191.2	15.20
South of watershed 1	34.24	8.70	1,572,848.6	36.11
Iron Mountain on the Verdi Range (NW slopes)	50.18	8.44	2,236,181.4	51.34
Miscellaneous small areas	12.61	5.0 (est.)	332,904.0	7.64
Total	110.53	--	4,804,125.2	110.29

THE CONTOUR TRENCHES

In August 1960 the Donner Ridge fire burned extensive areas in the southern half of the Dog Creek watershed. That autumn most of the burn was seeded with cereal rye, and the following year, steep portions were contour trenched, a practice commonly applied in the mountain watersheds of the West.[4] [5] Approximately, 110 lineal miles of contour trenches were constructed on denuded slopes having gradients of approximately 30 to 60 percent (fig. 1). The total capacity of the trenches in 1963 was 110.29 acre-feet (table 2).

During the 1963 flood-producing storm and for a short time thereafter, almost all trenches held some water. On pervious soils they held little; on most sites they were partially full (fig. 4); and in a few cases, they were full, some to overflowing. Although many trenches were full or almost so February 1, later surveys located few instances of eroded trench fill due to overtopping. Fortunately, the system was adequate to withstand the overland flow and seepage from a winter wet-mantle storm, although it was not designed for this purpose.

If all contour trenches in the Dog Creek watershed had been full at the same time, 110.29 acre-feet of water would have been detained on the slopes. This was not the case during the 1963 flood;so detention storage must be estimated at a lesser value. My observations February 1 indicated that actual detention storage was somewhere between 40 and 80 acre-feet. Upon visiting the valley several days later, I observed empty or almost empty trenches in most areas.

[4]Reed W. Bailey and Otis L. Copeland. Vegetation and engineering structures in flood and erosion control. Paper presented at 13th Congr. Int. Union Forestry Res. Organs., Vienna, Austria, Sept. 10-17. 23 pp., illus. 1961.

[5]Edward L. Noble. Sediment reduction through watershed rehabilitation. Paper presented at the Federal Interagency Sedimentation Conf., Jackson, Miss. 29 pp., illus. Jan. 1963.

Figure 4.--Water from the 1963 flood-producing storm trapped in a portion of one contour trench in the Dog Creek watershed. Detention storage of this type should reduce flooding downstream.

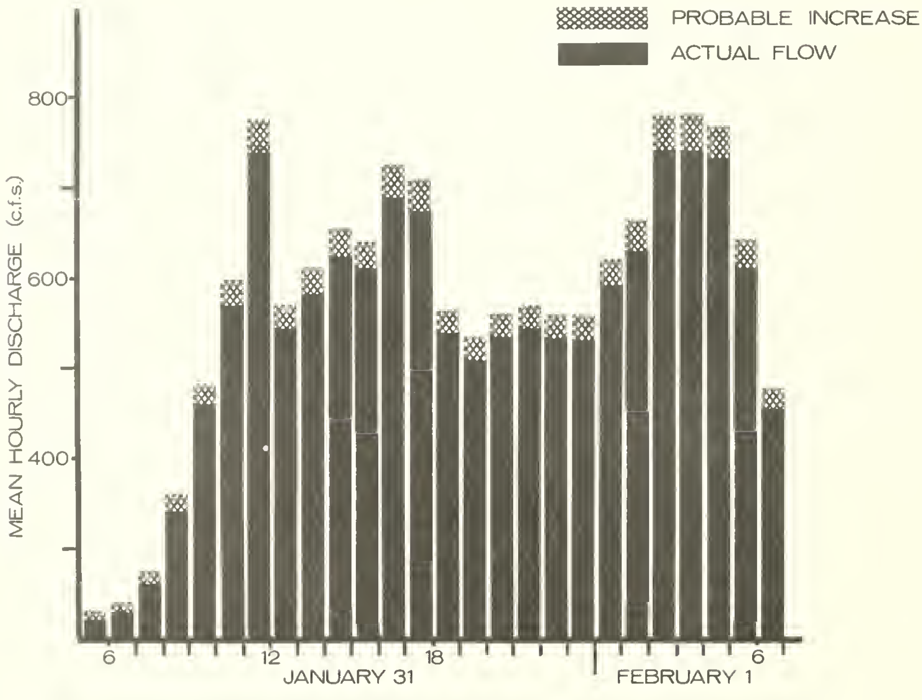

Figure 5.--Probable increased peak discharge from Dog Creek if the contour trench system had not existed in the watershed.

For the purpose of illustrating the hypothesis that the contour trenches affected the flood peak on Dog Creek, let's assume that 60 acre-feet of water was detained in the contour trenches during the peak flow past the Dog Creek gaging station. If those 60 acre-feet had been contributed to the main stem of Dog Creek at the same time as runoff from the remainder of the watershed reached its peak, the hydrograph would have had a different shape and a higher maximum flow. That hypothetical hydrograph is superimposed on the actual hydrograph (fig. 5) to show the amount of storm runoff that might be expected without contour trenching. The peak flow is shown to be higher. The recession flow would probably be more rapid without trenches, too, because overland flow would at least partially replace the temporary storage of water in the trenches and in the soil under them.

If the maximum flow from most Truckee tributaries had been reduced proportionately through contour trenching, the Truckee flood would have been less destructive. After the 1950 and 1955 wet-mantle floods, observers speculated about the effects of depression storage and snowpack characteristics on the timing and volume of runoff generated by rain and melting snow. Some were of the opinion that a slight reduction in the peak flow, at least on the Truckee River, would have resulted in far less damage. Although large reservoirs serve best for wet-mantle flood control, watershed treatments that provide additional depression storage and more tortuous routes for runoff also might reduce maximum flows the necessary few percent. Contour trenches may be the best means of accomplishing this, at least on burned or denuded slopes. This possibility deserves further study. It is a conceivable benefit that might be considered when watershed treatment is contemplated.

CONCLUSIONS

The nature of these observations and data does not permit a rigorous analysis of the effects of contour trenches on wet-mantle winter floods; nevertheless, some reduction in flooding is indicated. Contour trenches were intended originally to control the overland flow caused by intense summer rains falling on a dry mantle and--when adequately designed and properly installed--they serve this purpose admirably. They will not prevent floods caused by long-lasting, low-intensity rains falling on a frozen or a saturated mantle. However, regardless of conditions, streamflow will be affected if runoff water is held in the trenches for several hours. Trenches cannot prevent floods like the Sierra Nevada flood of 1963, but they may reduce the peak flows of such floods to such an extent that damage will be minimized.

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Research Note INT-109

1970

A DEVICE FOR RECORDING SPECIMEN WEIGHTS

E. S. Kotok and D. P. Lowery[1]

ABSTRACT

A device that gives a continuous record of specimen weight change is often desirable in research investigations. Described herein is such a weight-recording device that uses a Toledo balance and a hydrothermograph recorder, equipment common to practically all research laboratories.

In some studies, a continuous record of specimen weight changes is required. A good example of such a study is when wood specimens are being dried and a continuous record of moisture content changes is required. To obtain such weight records, the specimen may be suspended from a balance that is periodically read and weights recorded. However, a more efficient method is to suspend the wood specimen from some type of weight-recording chart recorder. Then, a continuous record is readily obtained as weight of the specimen changes. This method may also be desirable for other sample materials such as soil or herbage.

In conjunction with wood drying experiments a weight-recording device was put together utilizing the balance works of a 2,500-gram Toledo balance[2] and a Bendix hydrothermograph recorder (figure 1).

The specimen is suspended by wire from the balance pan by using a suitable frame. The thermometer entry port on the top of the drying oven is used for access and connection between balance pan and specimen (figure 2).

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[1]The authors are Project Leader-Principal Wood Technologist and Wood Technologist, respectively, stationed in Missoula, Montana, at the Forestry Sciences Laboratory, which is maintained in cooperation with the University of Montana.

[2]The use of trade names herein is for identification only and does not necessarily imply endorsement by the USDA Forest Service.

On the hydrothermograph recorder the arm connecting the temperature actuator and the pen set is disconnected. The pen connector is slightly lengthened, rotated 90 degrees, and connected by a rod to the balance pan. The chart and pen can be calibrated by adjusting the lengths of either the pan connecting arm or the pen connecting arm.

A chart paper that is reasonably well coordinated with anticipated weight readings should be selected; the hydrothermograph recorder clock is set for one revolution per 24 hours, and the device is ready to continuously record specimen weights.

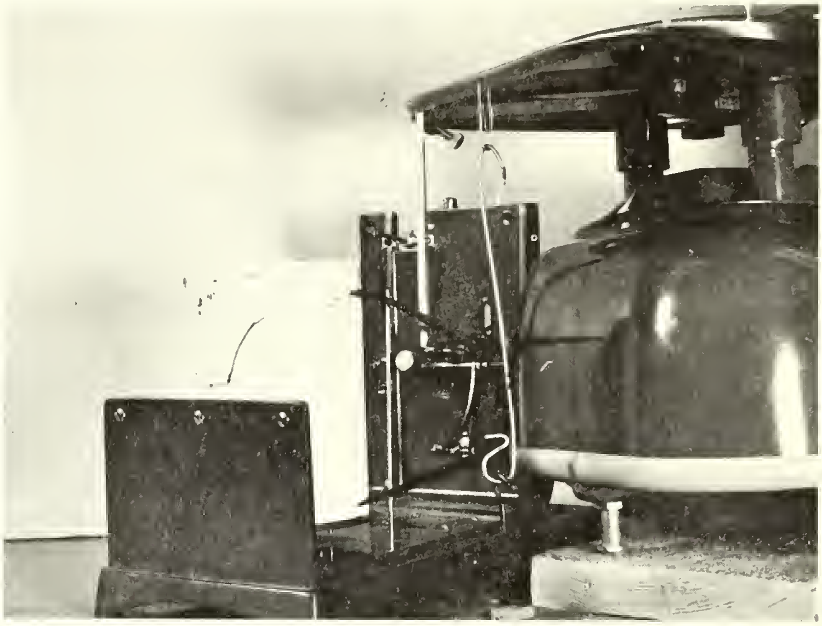

Figure 1.--Essential components of weighing and recording device.

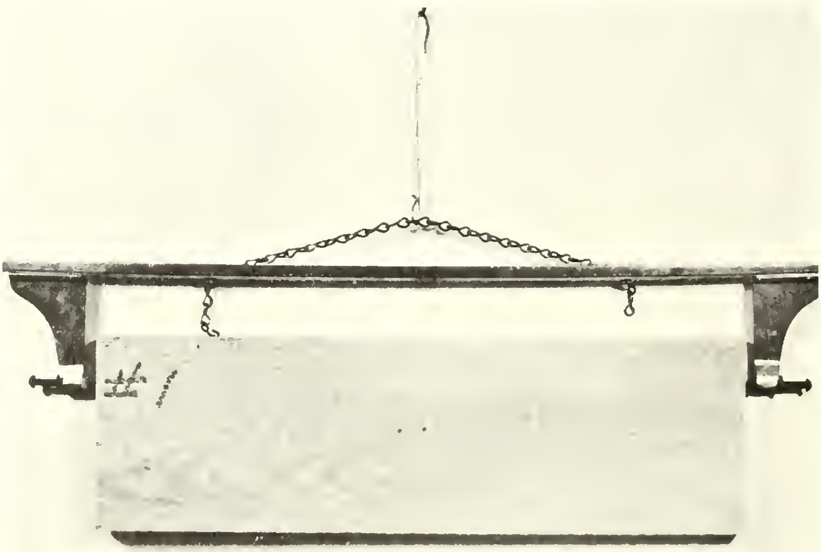

Figure 2.--Device for suspending wood specimen in oven.

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1970

A SYSTEM TO AUTOMATICALLY REGULATE DRYING OVEN TEMPERATURES

E. S. Kotok and D. P. Lowery[1]

ABSTRACT

On occasion, it may be desirable to adjust automatically the temperature in a drying oven to different levels. A relatively inexpensive device designed to accomplish this task is described and illustrated.

To successfully conduct certain wood drying experiments it was necessary to maintain the surface of the wood at some predetermined constant temperature. Surface temperatures of the wood were measured by an infrared radiometer. The drying oven used in these experiments was a Blue M,[2] mechanical convection type with a saturable reactor control system. Temperature changes are obtained in this oven by varying the input voltages to the oven heating element.

In the automatically controlled system developed for the wood drying experiments, infrared radiation was measured by a Barnes IR Microscope through a viewing port in the oven door (figures 1 and 2).

The IR radiometer (figure 3) converts radiation values to microvolts and indicates actual wood surface temperatures on the read-out apparatus. In the described automatic system, microvolts are relayed by electrical circuitry to a Bristol Dynamaster recorder (figure 4). The read-out scale of the recorder was modified to correspond with the output scale of the microscope.

Two limit switches were installed on the upper rod of the recorder slide. These switches were designed so that they could be set at any given position right or left of the recorder slide.

[1]The authors are Project Leader-Principal Wood Technologist and Wood Technologist, respectively, stationed in Missoula, Montana, at the Forestry Sciences Laboratory, which is maintained in cooperation with the University of Montana.

[2]The use of trade names herein is for identification only and does not necessarily imply endorsement by the USDA Forest Service.

Figure 1.--Barnes IR Microscope

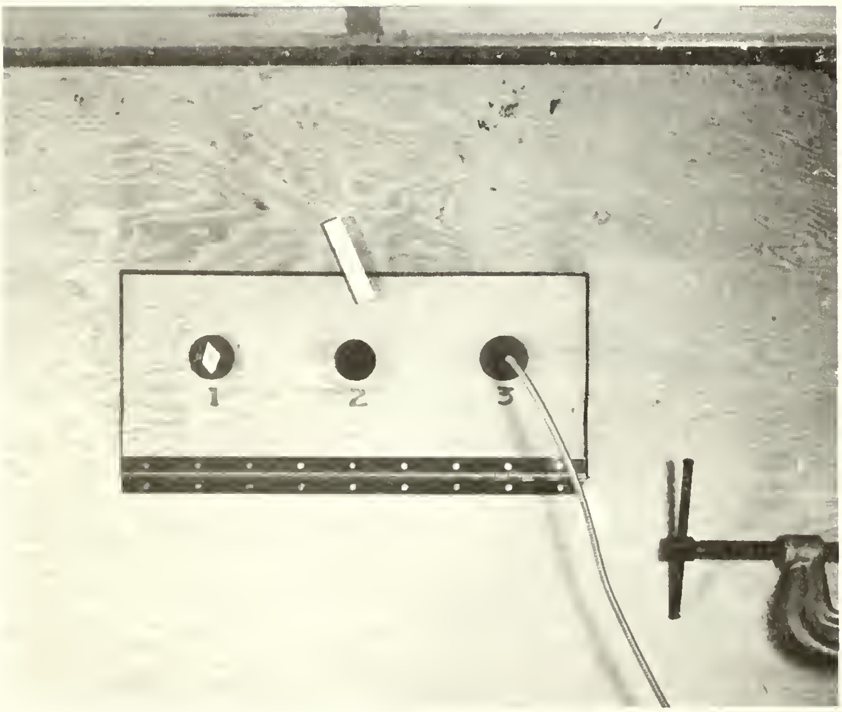

Figure 2.--Viewing port in oven door.

Figure 3.--IR radiometer.

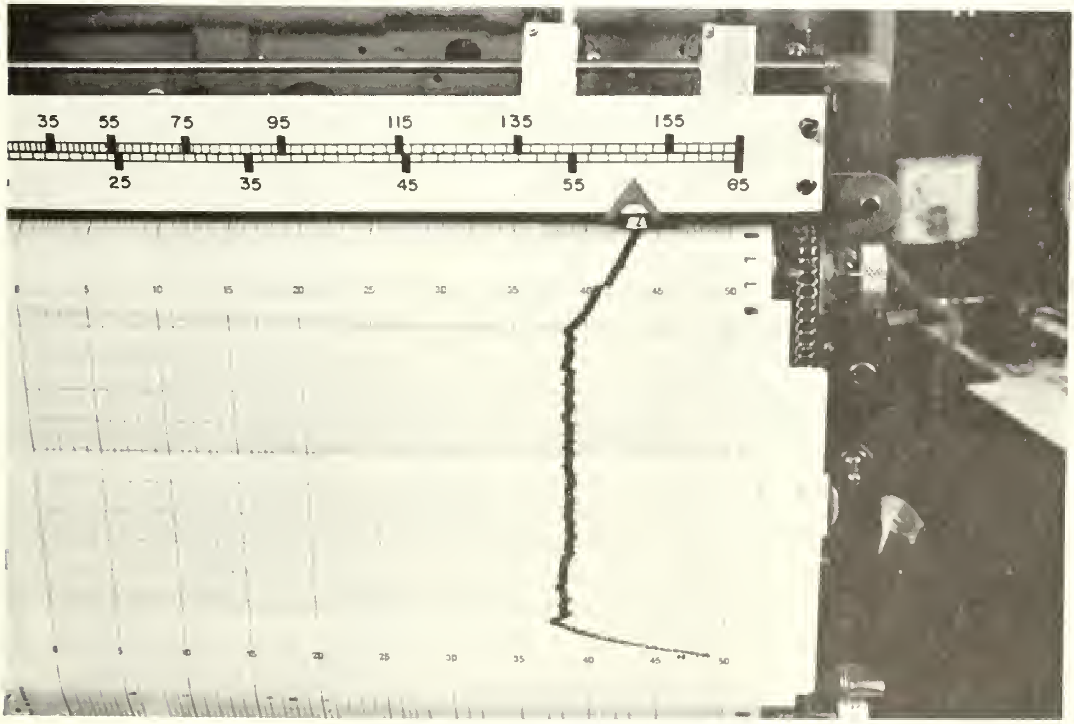

Figure 4.--Bristol Dynamaster recorder.

The oven control servo unit (figure 5) consists of a 115-volt, synchronous reversible electric motor that operates through two gear reduction boxes to a segment gear that is fastened to the oven control shaft. The effective change rate of the oven temperature is approximately 2 degrees per minute when the motor is engaged.

During operation of the automatic system, the surface of the wood being dried is allowed to attain some predetermined temperature as read by the IR microscope. When this temperature is reached, the limit switches on the recorder are set so as to allow about a 2-degree creep on either side of the set temperature. As the wood surface temperature rises, the limit switch on the gain side is closed actuating the servo unit and decreasing the oven input voltage and oven temperature. If too much correction is made, the wood surface temperature decreases below the desired level and the other limit switch is activated causing the oven to increase in temperature.

With this automatically controlled system we were able to maintain the desired wood surface temperature throughout all of the constant-rate drying period with only minor deviations of about 1 degree, plus or minus.

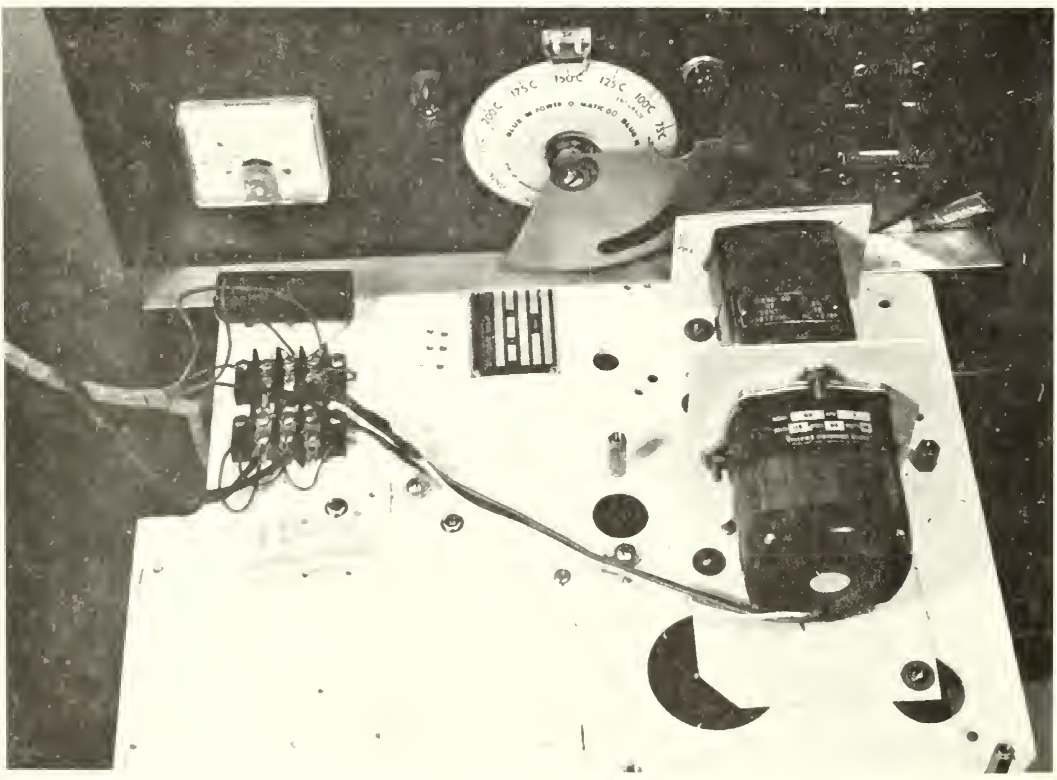

Figure 5.--Oven control servo unit.

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GERMINATION AND EMERGENCE OF THREE MOUNTAIN RANGE GRASSES AS INFLUENCED BY CONTROLLED TEMPERATURES AND DEPTHS OF PLANTING

W. T. McDonough and V. B. Matthews[1]

ABSTRACT

Comparisons were made of germination rates and percentages for crested wheatgrass (Agropyron desertorum *(Fisch.) Schult.), intermediate wheatgrass* (Agropyron intermedium *(Host) Beauv.), and smooth brome* (Bromus inermis *Leyss.) under controlled alternating temperature regimes, and of emergence rates and percentages at the same temperatures from three depths of planting. Generally, germination was little affected by temperature, but emergence declined 10 to 60 percent with decreasing temperatures and 20 to 90 percent with successively deeper plantings. The square root of the emergence rate was linearly related to the germination rate, when rate was expressed as days required to reach one-half of the final germination or emergence percentage.*

There are often large differences between germination percentages determined in seed germinators and emergence percentages from planted seeds of the same lot. Differences are due to the fact that emergence, in contrast to germination, requires growth through the overlying soil. The total seedling growth and the growth rate required for plants to reach the surface before viability is lost depends, in part, on planting depths and soil temperatures during preemergent growth.

A number of studies have been conducted on factors influencing emergence of grasses in the field and under controlled conditions as well. In southeastern Idaho, Hull (1966) found that emergence and survival of intermediate wheatgrass and of smooth brome were influenced by planting season, but not by planting depths of one-half and 1 inch. Under all conditions, low emergence indicated a need for quantitative information on influential factors. Dubetz et al. (1962) studied emergence of 11 crop and forage grasses from shallow plantings under four constant temperatures. They determined that temperature had no effect on rates, but significantly altered emergence percentages for five species. Wiese and Davis (1967) used four alternating temperature regimes and planting depths ranging from one-fourth inch up to 4 inches. They found best emergence of two weed grasses resulted from shallow plantings and intermediate soil temperatures.

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[1]Plant Physiologist and Range Technician, stationed in Logan, Utah, at the Forestry Sciences Laboratory, which is maintained in cooperation with Utah State University.

The objective of the study reported here was to compare the effects of four controlled temperature alternations on germination and on emergence of three grass species from three planting depths. Species studied included: Nordan crested wheatgrass *(Agropyron desertorum* (Fisch.) Schult.); Amur intermediate wheatgrass *(A. intermedium* (Host) Beauv.); and Manchar smooth brome *(Bromus inermis* Leyss.). It was thought that these comparisons would establish relationships between germination and emergence behavior, and would indicate the range of temperatures conducive to high emergence from a particular planting depth.

MATERIALS AND METHODS

New seed was obtained from a commercial source. For germination studies, 50 seeds per 9-centimeter petri dish were placed on double layers of filter paper moistened with distilled water. For emergence studies, 2.4-liter plastic containers with drainage holes were filled to within 7.6 cm. of the top with a sandy loam. Fifty seeds per container were placed on the soil surface and sufficient soil added to give planting depths of 1.3, 2.5, and 3.8 cm. (1/2, 1, 1-1/2 inches). For germination studies, three replications were used for each species and each temperature treatment; for emergence studies, three replications for each planting depth were used along with replications for species and temperature treatment. Results were evaluated by variance and regression analysis and studentized range tests at the 5 percent significance level.

Except for periodic inspections, petri dishes and containers were held in darkness in growth chambers at controlled (12 hrs./12 hrs.) temperature alternations of 20°/15° (12 hours at 20°C., 12 hours at 15°C.), 15°/10°, 10°/5°, and 5°/2°C. Soil temperature at the center of a container reached air temperature within 2 hours of a change. The substrates were kept adequately moistened with distilled water (dishes) or tap water (containers). Germination and emergence counts were made daily when rates were high and on alternate days at other times. Germination was identified by the start of root growth, emergence by shoot growth above the soil surface.

A treatment was ended 7 days after the last germination or emergence if the percentage was 20 or higher, and 14 days if the percentage was less than 20. Treatments giving zero emergence were ended after 108 days. Then, containers with the two deeper plantings at 5°/2°C. were transferred to 20°/15°C. to establish the effect of a more favorable soil temperature on additional emergence. Three weeks after transfer, the overlying soil in these containers was removed and the extent of germination and the growth of unemergent seedlings noted.

RESULTS AND DISCUSSION

Mean germination percentages are shown in table 1. Germination percentages of crested wheatgrass and smooth brome were significantly reduced at 5°/2°C., the lowest test temperature. Otherwise, temperature effects on germination percentages were not significant.

Emergence generally declined 10-60 percent as temperatures decreased and 20-90 percent as planting depths increased (table 2). Regardless of planting depth, the lower temperatures (10°/5° and 5°/2°C.) generally resulted in significantly lower emergence than the higher temperatures. This was true, except for crested wheatgrass at 3.8 cm. and intermediate wheatgrass at 1.3 cm., where differences were not significant. At any temperature, reduction in emergence with increasing planting depth was significant, except for crested wheatgrass and smooth brome at 5°/2°C. (2.5 and 3.8 cm. depth) and intermediate wheatgrass at 20°/15°C. (1.3 and 2.5 cm. depth).

Table 1.--Mean germination percentages of grasses at each of four temperature alternations

Temperature regimes (°C.)	Crested wheatgrass	Intermediate wheatgrass	Smooth brome
	%	%	%
20/15	78	91	94
15/10	81	96	91
10/5	85	95	90
5/2	61	86	69

Table 2. Mean emergence percentages of grasses from three planting depths at each of four temperature alternations

Temperature regimes (°C.)	Planting depths	Crested wheatgrass	Intermediate wheatgrass	Smooth brome
	Cm.	%	%	%
20/15	1.3	67	77	86
	2.5	26	71	73
	3.8	4	34	25
15/10	1.3	65	80	84
	2.5	21	63	63
	3.8	3	25	31
10/5	1.3	57	86	72
	2.5	13	45	30
	3.8	1	3	1
5/2	1.3	36	77	36
	2.5	5	21	1
	3.8	0	2	0

Lower temperatures and deeper plantings were more inhibitory to emergence of crested wheatgrass than to emergence of other species. This reduced emergence, at least with reference to depth, may relate to smaller seed size and available reserves, as has been observed elsewhere in seed lots of crested wheatgrass and other grass species and varieties (Kittock and Patterson 1962; Rogler 1954). In the present study, the mean air-dry weight of sets of 10 seeds (based on five determinations ±S.D. (Standard Deviation)) was 29 ±2, 70 ±3, and 38 ±3 milligrams for crested wheatgrass, intermediate wheatgrass, and smooth brome, respectively.

Rates of germination and emergence, expressed as days required to reach one-half of the total germination or emergence percentage, generally declined with decreasing temperatures (tables 3 and 4). Emergence generally dropped as planting depths increased, although the effect of depth on rate was less pronounced than on emergence percentage (table 4). The time required for half the number of seedlings to emerge generally was within the 3- to 5-day period of maximum daily emergence, and thus was indicative of the time required for peak emergence. For a planting depth of 1.3 cm., a linear relationship was established between the square root of the emergence rate (Y) and the germination rate (X) at the four temperature regimes of table 4. The regression equations were:

Crested wheatgrass	$\hat{Y} = 0.42\ X + 1.96,\ r = 0.97$
Intermediate wheatgrass	$\hat{Y} = 0.47\ X + 1.66,\ r = 0.99$
Smooth brome	$\hat{Y} = 0.52\ X + 1.59,\ r = 0.96$

When containers with plantings at depths of 2.5 and 3.8 cm. were transferred from the 5°/2°C. to the 20°/15°C. temperature regime, additional emergence over a 3-week period varied from 10 percent for intermediate wheatgrass and smooth brome at 2.5 cm. to less than 1 percent for the remaining species and other planting depths. Removal of the overlying soil revealed seedlings in various stages of arrested growth. Not all planted seeds were accounted for, but the number of emergent seedlings, plus germinated but as yet unemergent seedlings approximated the number of seeds germinated in dishes; so delayed germination or failure of germination was not important to reduced emergence under these temperature regimes. Apparently, when growth is suppressed for several months by deep plantings and lower temperatures, most unemergent seedlings lose the ability to resume growth following a return to favorable temperatures. This failure is not evident in grass seed that overwinters under natural conditions at temperatures close to 0° C. In field studies, Frischknecht (1951) and others found that a number of range grasses planted in late fall grew throughout the winter under a cover of snow. Consequently, temperatures in the 0°-10° C. range may determine how long an unemergent seedling will retain its potential for further growth under more favorable conditions.

Providing that soil moisture is adequate, planting depths and the seasonal range of temperatures will largely control the extent of emergence of grasses from field plantings. Then, those concerned with reseeding of mountain rangelands should consider the favorable effects of shallow plantings at higher temperatures on emergence. They should give attention also to the detrimental effect that temperatures fluctuating near 5° C. have on later emergence at higher temperatures.

Table 3.--Rates of germination of grasses at each of four temperature alternations

Temperature regimes (°C.)	Crested wheatgrass	Intermediate wheatgrass	Smooth brome
	Days	Days	Days
20/15	2*	2	2
15/10	5	5	4
10/5	9	8	8
5/2	15	15	15

*Rates are expressed as days required to reach one-half of the final germination percentage.

Table 4.--Rates of emergence of grasses from three planting depths at each of four temperature alternations

Temperature regimes (°C.)	Planting depths	Crested wheatgrass	Intermediate wheatgrass	Smooth brome
	Cm.	Days	Days	Days
20/15	1.3	11*	8	9
	2.5	12	9	10
	3.8	20	11	11
15/10	1.3	13	12	11
	2.5	18	19	15
	3.8	23	19	18
10/5	1.3	29	26	32
	2.5	32	27	34
	3.8	--**	38	--
5/2	1.3	74	79	91
	2.5	83	84	--
	3.8	--	74	--

*Rates are expressed as days required to reach one-half of the final germination percentage.

**Rate not determined because of very low or zero emergence.

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Research Note

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PORTABLE DEBARKING AND CHIPPING MACHINES CAN IMPROVE FORESTRY PRACTICES[1]

John R. Host and David P. Lowery[2]

ABSTRACT

Use of portable debarking and chipping machines may be a suitable means of disposing of thinnings, defective overmature trees, and logging residues. Trial chipping under five different field conditions produced chips suitable for pulping. Chip output per day varied considerably, depending upon the size of the average piece, stand volume per acre, and upon skidding conditions.

Among the problems facing foresters of the Inland Empire is the utilization of excess trees removed by thinning, defective overmature trees, and logging residue.

In the northern Rocky Mountain region,it has been estimated that approximately three and a half million acres of National Forest land and an additional one million acres of private land are in need of thinning if the area's growth potential is to be attained. These stands are primarily western larch, lodgepole pine, grand fir, hemlock, ponderosa pine, and Douglas-fir. Generally, stands are between 20 and 70 years old; trees average about 7 inches in diameter.

Overmature stands often contain a large amount of heart rot and other defective material. Stands of this type--primarily grand fir and hemlock--occupy between 500,000 and one million acres in Montana and Idaho.

After the timber has been harvested, short log sections, tops, and defective logs are left scattered over the ground. In addition, there are usually a few small standing trees. This material either is bulldozed into piles and burned or the area is cleared of standing trees and broadcast burned to prepare the site for planting or natural regeneration. It was estimated in 1962 that there was approximately 75 million board feet[3] of logging residue in the northern Rocky Mountain region.

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[1] The authors are indebted to the Anaconda Forest Products and the Hoerner-Waldorf Companies for providing much of the information contained in this report.

[2] Marketing analyst and wood technologist, respectively, stationed at the Forestry Sciences Laboratory in Missoula, Montana, which is maintained in cooperation with the University of Montana.

[3] U.S. Forest Service. Timber trends in the United States. 235 p. Forest Resource Rep. 17. Wash., D.C., U.S. Govt. Printing Office. 1965.

If equipment and procedures could be developed to utilize the material described above, foresters would be able to recover some of these wood values. Less waste on the ground would reduce the fire hazard. Better utilization also would eliminate or minimize the use of fire for slash disposal and so help to maintain satisfactory air quality.

Portable debarking and chipping machines, which might be a partial solution to the problems discussed above, may be developed into more suitable tools in the future. This paper reports on a trial study of commercially available machines used on five areas in western Montana.

PROCEDURE

Portable debarking and chipping machines were operated in tandem throughout this trial. Both pieces of equipment were mounted on separate trailers towed by a chip truck.

The debarker has a Rosser-type debarking head and a variable feed (maximum rate, 125 feet per minute). A 125-horsepower diesel engine drives the debarker head and the hydraulic pump that powers conveyors, outriggers, and loading arms. The infeed conveyor has four groundline loading arms on each side that lift logs onto the infeed conveyor. Barked material is fed directly onto the chipper infeed. The debarker can handle logs 22 inches in diameter and 50 feet in length.

The chipping unit uses a 280-horsepower diesel engine for power. Infeed rate (to 120 feet per minute) is automatically controlled by the chipper disk rotation speed. Chips are blown directly from the discharge side of the chipper into a chip trailer. One man controls the entire debarking-chipping operation.

In order to determine chip recovery under different topographic and stand conditions, the debarker and the chipper were used on five areas. Each of the areas selected was considered a typical example of different utilization opportunities in the region.

Trees were felled and limbed before the debarking and chipping machines were brought to the area. Tree or log lengths then were skidded directly to the groundline lift arms of the debarker's infeed conveyor.

AREA DESCRIPTIONS

Area I.--This 22.4-acre stand of young second-growth ponderosa pine on relatively flat ground was thinned to 110 trees per acre and yielded 2.7 cords[4] per acre.

Area II.--This 25-acre area was logged in 1966 and prepared for broadcast burning. However, plans for the burning were not carried out. About 5 cords per acre were recovered from the logging residue.

Area III.--This area consists of approximately 6 acres in a creek bottom. The stand was primarily overmature grand fir and Engelmann spruce. All dead and cull (defective) material was used. About 36 cords per acre were recovered from this area.

Area IV.--This area consisted of approximately 10 acres located near a ridgetop. The mixed stand (Douglas-fir, western larch, and lodgepole pine) had been selectively cut earlier. The residual stand was thinned while the debarker and the chipper were in the area. Approximately 11 cords per acre were recovered by thinning.

Area V.--Here, a relatively dense 6.0-acre stand of pole-sized lodgepole pine on fairly level ground was clearcut. About 24.5 cords per acre were recovered from the area. Data for the five areas are shown in table 1.

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[4]One cord of roundwood equals 85 feet or one 2,400-pound bone-dry chip unit.

Table 1.--Log and stand data for the five areas used in the trial study of portable debarking and chipping machines

Area no.	Species	Type of cut	Cords per acre removed	Total cords removed[1]	Average mid-diameter	Average cubic feet per piece
					Inches	
I	Ponderosa pine	Thinning	2.67	59.75	5.5	4.0
II	Western larch and Douglas-fir	Salvage	4.97	124.25	6.6	5.8
III	Grand fir and Engelmann spruce	Salvage	35.93	215.60	9.8	15.3
IV	Western larch, Douglas-fir, lodgepole pine	Thinning	10.82	108.20	7.4	9.8
V	Lodgepole pine	Clearcut	24.33	146.00	5.9	5.9

[1]One cord of roundwood equals 85 feet or one 2,400-pound bone-dry chip unit.

RESULTS AND DISCUSSION

Chips produced by the portable chipper were satisfactory for pulping. No screening was necessary.

Results of this trial are shown in table 2. Area 1 had the smallest amount of wood (59.75 cords) recovered and the lowest daily production (23.9 cords). Low chip production was a reflection of skidding distances and small-piece size (average 4.0 cubic feet). Perhaps the most efficient way to process material from similar areas would be to deck logs before moving the debarking and chipping machines to the location.

Area II produced a total of about 124 cords in 3.5 days, an average of 35.5 cords per day. Material in this area also was relatively small, averaging 5.8 cubic feet. However, daily chip production was greater than that of Area 1, although a larger acreage was covered--25 acres compared with Area 1's 22.4 acres. The area was roaded during logging operations; so higher production can be attributed to better skidding conditions. This area's production rate would have been even greater if the material had been decked before the debarker and chipper were brought in.

Area III produced a total of 215.6 cords in 3.5 days. Improved chip production resulted primarily from a decrease in skidding distances over an area less than 6 acres in size and from the larger cubic volume per piece.

Area IV produced a total of about 108 cords in 2 days, an average daily production of approximately 54 cords. This production rate was less than that of Area III, because the area was larger and the material smaller.

Area V produced a total volume of about 146 cords in 4 days. Daily production of the debarking and chipping machines was affected mainly by material size, since the area included only 6 acres.

High daily production depends to a large extent on the volume of chipping material per acre. If the volume is relatively high, the material should be skidded into place and fed directly to the machines (hot logging). If, on the other hand, the volume is relatively low, the material should be skidded and decked before the machines are moved into the area (cold decking).

Table 2.--Results of debarker-chipper trial on five different areas

Area no.	Cords per acre removed	Total cords removed[1]	Days operated	Cords per day[1]	No. pieces per cord	Dry weight percent[2]
I	2.67	59.75	2.5	23.9	21.2	46.3
II	4.97	124.25	3.5	35.5	14.7	81.8
III	35.93	215.60	3.5	61.6	5.6	71.5
IV	10.82	108.20	2.0	54.1	8.7	67.8
V	24.33	146.00	4.0	36.5	114.4	55.7

[1]One cord of roundwood equals 85 feet or one 2,400-pound bone-dry chip unit.
[2]The ovendried weight per unit of chips expressed as a percent of the green weight.

Forest management practices have become more intensified in recent years to take advantage of basic land productivity. Thinning and salvage operations to improve the growth rates of residual stands are more commonplace. In the northern Rocky Mountain region, 20,000 to 30,000 acres are thinned each year at an average cost of about $36 per acre. Any net sum realized from chip sales would reduce the cost of thinning operations. Consequently, more acres could be thinned for the same fixed appropriation.

The burning of logging slash has two disadvantages: (1)fire can get out of control, an infrequent but costly occurrence; and (2)the burning of slash contributes to air pollution. When use of the debarker and the chipper is feasible, less burning of logging residue is necessary. In the northern Rocky Mountain region, the cost of burning averages about $20 per acre; so chipping (even if it were a negative-value operation) would cost less than burning.

In addition, debarking and chipping operations indirectly benefit forest soils. Plant nutrients are added to such soils when logging debris, unsuitable for chipping, is packed to the ground for more rapid decomposition, or when skidding exposes rich, mineral soil.

CONCLUSIONS

Results of this trial indicate that relatively large volumes of chips ready for pulping can be produced from thinned and logged-over areas by portable debarking and chipping machines. Chip productivity rates are affected by material size, stand volume per acre, skidding conditions, and topography. When the volume of chipping material per area is relatively high, the material should be skidded into place and fed directly to the machines. When the volume is relatively low, the material should be skidded and decked before the machines are moved into the area.

To summarize, use of portable debarking and chipping machines on appropriate areas would:

1. Reduce the cost of intensive forestry practices;
2. Produce clean, usable chips;
3. Improve timber utilization, which would reduce wastage and fire hazard;
4. Reduce the total volume of slash, slash disposal costs, and air pollution resulting from the burning of slash;
5. Improve conditions that favor regeneration, either natural or artificial.

Research Note

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FERTILIZING TO IMPROVE ELK WINTER RANGE IN MONTANA

Joseph V. Basile[1]

ABSTRACT

Six fertilizer treatments were applied to a low-producing site and to a high-producing site to determine fertilizer benefits. The forage yields of both were checked for two growing seasons following application. Of the fertilizers tested, the 200-0-0 fertilizer seems most appropriate for the low-producing site. This treatment resulted in a 2½-fold gain in forage yields the first and second years, and produced a significant change in the grass-forb ratio. The high-producing site responded to fertilizers with a 50-percent gain in yield the first year, but treatment responses did not differ significantly from the response on the controls the second year. Grass-forb ratios were unchanged on the high-producing site. Fertilizing may be a valuable restorative measure on low-producing range sites, when it complements a sound herd management program.

The winter range of the Upper Gallatin elk herd in southwestern Montana straddles lands administered by the USDA Forest Service, the National Park Service, and the Montana Fish and Game Department. Historical evidence and range surveys show that range condition has been trending downward since the end of the last century.[2] This downward trend prompted the Forest Service to curtail livestock grazing on part of the area as early as 1908, to halt such grazing on the entire elk winter range east of the Gallatin River in 1919 and on the range west of the river in 1932. Despite the livestock ban, it was apparent by the mid-1920's that range condition was still deteriorating.

In 1965, the three agencies adopted a coordinated management program to balance the elk herd and its winter forage supply. To accomplish this they set a tentative wintering population figure (1,000 elk). This program may improve forage conditions on part of the winter range. However, a deteriorated condition is common on ridgetops and south-facing slopes, where several exclosures (20-plus years of age) show little recovery to date from protection alone. Though low in productivity, many of these sites still support residual vegetation of sufficient density and tenacity to suggest

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[1]Range Scientist, stationed in Bozeman, Montana, at the Forestry Sciences Laboratory, maintained in cooperation with Montana State University.

[2]Allen Lovaas. Gallatin big game studies. Montana Fish and Game Dep. Job Completion Rep., Proj. W-98-R-4, 5 p. 1965.

that fertilizing may be a restorative measure, provided it is coordinated with a herd management program. For example, 12 years after receiving a single application of nitrogen (rate unknown), an unfenced plot on this winter range produced 2½ times more dry matter than the surrounding untreated area. The increases in plant vigor, crown area, and litter that usually accompany production gains of this magnitude help to stabilize soil and to improve range condition.

This interim report on continuing research describes the initial responses of study sites to fertilizers and the second-year residual effects of fertilizers on forage production. The interest, services, and cooperation of the Montana Fish and Game Department and of Glennis O. Boatwright, Agricultural Research Service, are gratefully acknowledged.

THE STUDY AREA

The winter range is a complex of intermontane valleys that range in elevation from 6,000 to 8,000 feet. Mean annual precipitation is estimated at 15 to 18 inches.

The study sites are at an elevation of about 6,400 feet. Vegetation is predominantly a grass-forb mixture and a scattering of shrubs, mainly fringed sagebrush (*Artemisia frigida*), rabbitbrush (*Chrysothamnus viscidiflorus*), and gray horsebrush (*Tetradymia canescens*). Dominant grasses are: bluebunch wheatgrass (*Agropyron spicatum*); thickspike wheatgrass (*A. dasystachyum*); Idaho fescue (*Festuca idahoensis*); bluegrass (*Poa* spp.); and prairie junegrass (*Koeleria cristata*). Common forbs include: yarrow (*Achillea millefolium*); pussytoes (*Antennaria* spp.); ballhead sandwort (*Arenaria congesta*); fernleaf fleabane (*Erigeron compositus*); sulfur eriogonum (*Eriogonum umbellatum*); and lupines (*Lupinus* spp.)

METHODS

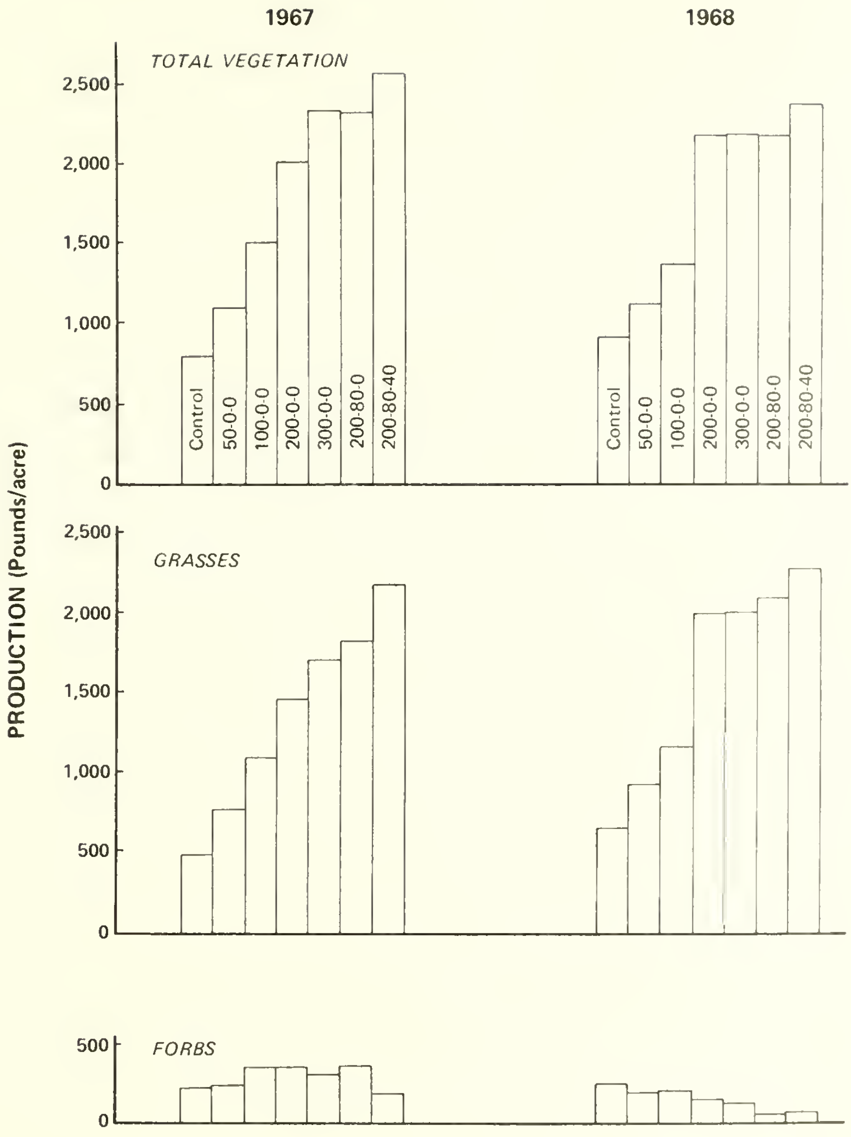
In September 1966, seven treatments in three replicates were applied to 21 contiguous strips in each of two locations--one a low-producing, heavily-grazed ridgetop, the other a high-producing, lightly-to-moderately grazed benchland. Each ridgetop strip was 6 by 20 feet, each benchland strip, 10 by 40 feet. Ammonium nitrate (33-0-0), treble superphosphate (0-45-0), and potassium chloride (0-0-63) were broadcast at the following rates:

N	P	K
	(Lbs./acre)	
0	0	0
50	0	0
100	0	0
200	0	0
300	0	0
200	80	0
200	80	40

The two sites then were fenced to exclude elk.

In early August of 1967 and 1968, all current-year vegetation was clipped at ground level from 1- by 4.8-foot plots, kept at 60°C. for 24 hours, and dried weight determined. Each year, four plots per strip were clipped on the ridgetop site, and five plots per strip were clipped on the benchland site. Random location of plots differed the second year to avoid the influence of previous clipping. Moreover, buffer zones along the sides of each strip precluded the possibility of sampling from areas of overlapping fertilizer effects.

Figure 1.--First- and second-year responses to fertilization of a low-producing site on elk winter range in Montana.



RESULTS

Because of their low density and small contribution to overall production, shrubs are not considered separately in the following discussion. However, shrub yields are included in the values for total vegetal production.

Ridgetop Site

On the poorer site, initial (1967) and residual (1968) responses were of essentially the same pattern and magnitude (fig. 1), an indication that the effects of fertilizer treatments carried over through the second growing season. Sequential tests of differences between means showed the following:

N-P-K	Responses 1967		Responses 1968	
0-0-0			]	
50-0-0			]	]
100-0-0				]
200-0-0	]		]	
300-0-0	]	]	]	
200-80-0		]	]	
200-80-40		]	]	

where lines connect treatments whose means did not differ significantly from each other.

The 200-0-0 fertilizer seems most appropriate for the ridgetop site. This rate of nitrogen application produced an initial response that was significantly greater than, or equal to, those produced by other rates of nitrogen application. Furthermore, the response was not statistically different from that resulting from the 200-pound rate with phosphorus added. The initial response to the 200-0-0 fertilizer was exceeded by that of the 200-80-40 fertilizer, but residual responses to these two fertilizers did not differ significantly.

In addition to the impressive initial production that resulted from the 200-0-0 treatment, the site's best second-year production response was to the same fertilizer. When compared to total forage yields on control strips, 1968 production attributed to the 200-0-0 fertilizer stayed close to the 2½-fold increase obtained in 1967. Production response to all other fertilizers tested showed a considerably larger drop between years. Aside from a few exceptions, this was true for grasses and forbs as well as for total vegetation.

In both years, grass production on all fertilized strips was markedly greater than grass production on the controls. Forb production increased moderately on most fertilized strips the first year, but decreased on all strips the second. These opposite trends in the production responses of grasses and forbs to fertilizers resulted in appreciable changes in grass-forb ratios (table 1)--particularly apparent when nitrogen, alone or combined with phosphorus and potassium, was applied at the higher rates.

Table 1.--Grass-forb ratios on fertilized strips the first and second years after treatment

	Treatment						
	Control	50-0-0	100-0-0	200-0-0	300-0-0	200-80-0	200-80-40
	Ratio[1]						
Ridgetop site							
1967	2.2	3.3	3.3	4.3	5.5	5.1	11.8
1968	2.6	4.8	5.7	12.9	16.3	38.9	36.2
Benchland site							
1967	1.1	1.5	1.2	2.0	1.2	1.4	1.4
1968	1.5	1.2	1.4	1.6	1.3	1.3	1.5

[1]Grass production as a multiple of forb production.

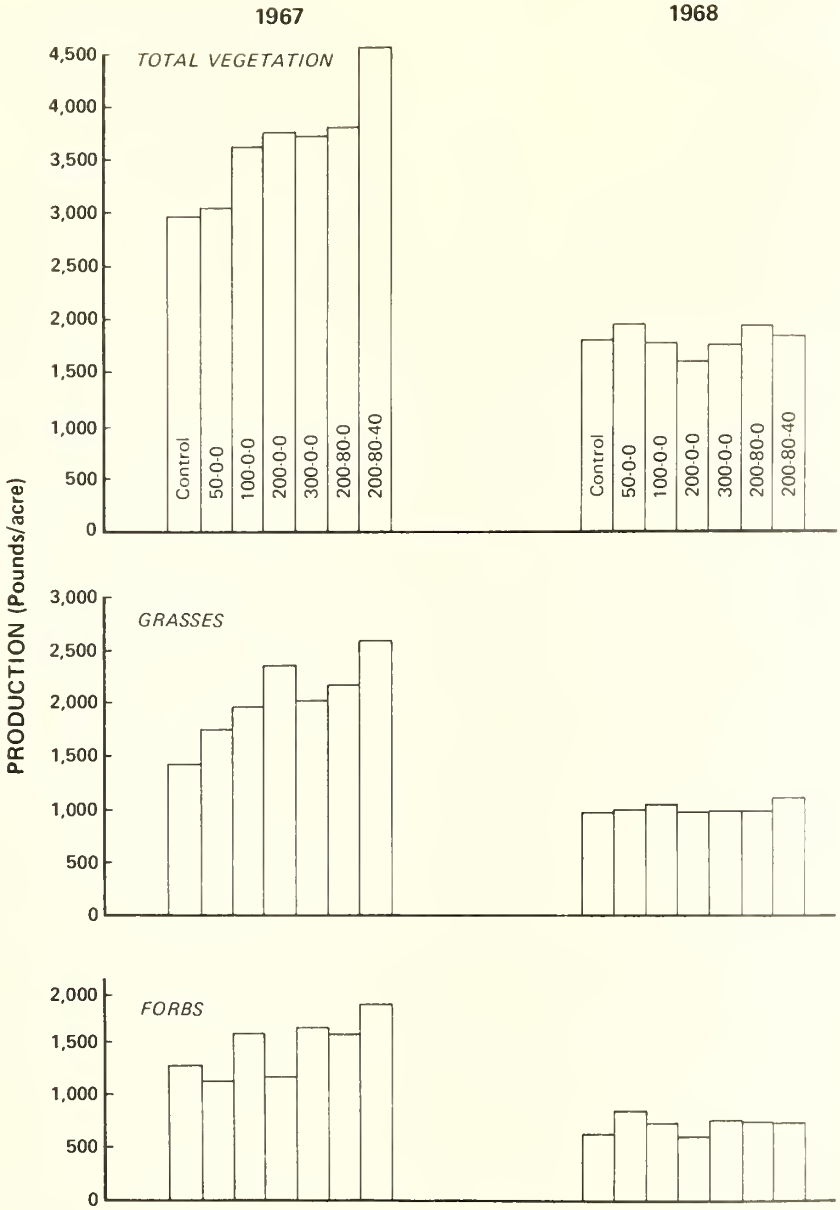


Figure 2.--First- and second-year responses to fertilization of a high-producing site on elk winter range in Montana.

Benchland Site

Initial results on this high-producing site suggest two populations of response, one of which includes the control and 50-0-0 nitrogen treatment, the second, all other treatments. Fertilizer effects were short lived, however; no significant differences were detected between treatment responses and responses on controls the second year (fig. 2).

When compared with production on the controls, modest first-year increases in grass production were erased the second year, and forb production was essentially the same both years. Consequently, grass-forb ratios (table 1) were virtually unchanged.

CONCLUSIONS

Murie[3] reported that elk eat approximately 10 pounds of forage per day (average for bulls, cows, and 8- to 9-month-old calves). On the ridgetop site, total production on the strips treated with 200-0-0 exceeded that on the controls by 1,221 pounds per acre in 1967 and by 1,262 pounds per acre in 1968. Thus, carrying capacity for a 5-month season appears to have increased approximately 0.8 elk per acre. The best response to treatment on the benchland site shows an apparent increase in carrying capacity of about one elk per acre the first year, but none at all, the second.

Such *apparent* gains in carrying capacity should not be construed to mean that the elk population could be increased 0.8 animal (or by any amount) for every acre fertilized. Poor range conditions dictate against any increase in herd size. The gain in carrying capacity merely reflects, to some degree, reduced grazing pressure exerted by existing elk numbers. Quite simply, the value of fertilizing lies in its potential for assisting range recovery *when used in conjunction with a sound program of herd management.*

Use of fertilizers on high-producing, good condition range sites appears to be unwarranted, but results on the harsher ridgetop site were so encouraging that fertilizer trials were extended in September 1968 to three other low-producing, poor conditio sites. Should the residual response on the ridgetop remain satisfactory for one or more years, and should the performance on the new test sites approximate that on the ridgetop, then fertilizing may be a valuable complement to the current herd management program on this winter range.

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[3]Olaus J. Murie. The elk of North America. 376 p., illus. Harrisburg, Pa. The Stackpole Company. 1951.

Research Note

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EFFECTS OF DICAMBA AND PICLORAM ON SOME NORTHERN IDAHO SHRUBS AND TREES

Russell A. Ryker[1]

ABSTRACT

Two recently developed herbicides, dicamba and picloram, used alone and in mixture with 2,4-D, gave promising results in tests on six shrub species common to northern Idaho brushfields. The treatments damaged conifers, and so apparently are unsuitable for broadcast spraying to release established trees from shrub competition.

Shrub species are ever present in the understory vegetation of northern Idaho forests. They are aggressive and can quickly dominate a site if the forest cover is partially or totally removed by cutting, fire, or pests. A heavy cover of shrubs makes it difficult to regenerate a forest, particularly with less tolerant species. Even more shade-tolerant species, such as Rocky Mountain Douglas-fir [*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco] and grand fir [*Abies grandis* (Dougl.) Lindl.]--which eventually will replace shrubs--may grow slowly, lengthening the time needed for seedlings to attain harvestable size.

We have used various means (e.g., machine scarification, fire, and herbicides) to remove or to control the spread of shrubs prior to planting trees. Of these, machine scarification probably has been most successful, but is not suited to steep terrain. In steep country, we have relied on fire--sometimes preceded by herbicide application. Upon occasion, however, subsequent herbicide treatment has been called for because shrubs often recover rapidly during the first growing season following a burn.

If a highly successful herbicide were available, it might be the only site preparation treatment needed on some areas. Elimination of a second treatment, such as burning, would reduce reforestation costs. Herbicides also have a use in brushfields where an adequate number of trees have become established beneath the shrubs. If these areas could be chemically treated without damaging conifers, such trees could be released from excessive shrub competition.

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[1]Silviculturist, stationed in Boise, Idaho.

With these needs in mind, we compared the performances of picloram mixed with 2,4-D,[2] dicamba,[3] and dicamba mixed with 2,4-D.[4] Two of these, dicamba and picloram, only recently have been developed for shrub control; the other, 2,4-D, has been used extensively for years. We tested the herbicides[5] on six shrub species in a northern Idaho brushfield area and on seven tree species planted in pots and grown under partly protected conditions. While they varied in their effectiveness on different species of shrubs, all damaged conifers. Consequently, we question their suitability for broadcast spraying to release established trees. However, these herbicides should be tested further for use in reducing shrub vegetation prior to planting trees.

METHOD

The shrubs tested during this study were growing in brushfield areas on the St. Joe National Forest. Thirty individuals[6] of each of the following species were selected: menziesia (*Menziesia ferruginea* Sm.); mountain maple (*Acer glabrum* Torr.); ninebark [*Physocarpus malvaceus* (Greene) Kuntze]; oceanspray [*Holodiscus discolor* (Pursh) Maxim.]; redstem ceanothus (*Ceanothus sanguineus* Pursh); willow (*Salix scouleriana* Barratt). Shrubs selected ranged in height from about 2 to 12 feet.

Five individual plants were assigned randomly to each of six treatments. Treatments were:

No. 1, dicamba (2 pounds)[7];
No. 2, dicamba (8 pounds);
No. 3, dicamba (1 pound) + 2,4-D (2 pounds);
No. 4, dicamba (4 pounds) + 2,4-D (8 pounds);
No. 5, picloram (1/2 pound) + 2,4-D (2 pounds);
No. 6, control (no spray).

Since we had used picloram successfully prior to this study,[8] we decided to stay with the application level recommended by the manufacturer. Little information was available about dicamba effects on shrubs; so we decided to try the herbicide alone and in mixture with 2,4-D at different concentrations.

Using a 4-gallon hand sprayer, we applied the chemical solutions to the foliage of individual plants until dripping started. Shrub condition and height were recorded at the time of treatment in July 1966, and on two other occasions, in August 1966 and again in August 1967.

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[2]This formulation contains 1/2 pound per gallon of 4-amino-3,5,6-trichloropicolinic acid (picloram) and 2 pounds per gallon of 2,4-D, both in the form of triisopropanolamine salt. It is sold by Dow Chemical Company under the registered trademark "Tordon-101." (Mention of trade names herein does not necessarily imply endorsement by the USDA Forest Service.)

[3]This formulation contains the equivalent of 4 pounds per gallon of 2-methoxy-3, 6-dichlorobenzoic acid, in the form of dimethylamine (DMA) salt. It is sold by the Velsicol Chemical Corporation under the registered trademark "Banvel."

[4]One pound per gallon of the DMA salt of dicamba plus 2 pounds per gallon of the DMA salt of 2,4-D.

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

[6]An individual plant is defined for this study as having one stem or several stems if no more than 6 inches separate any one stem from others at ground line.

[7]Amount of chemical per 100 gallons of aqueous solution.

[8]R. A. Ryker, Herbicides fail to insure success of a brushfield prescribed burn. U.S. Forest Serv. Res. Note INT-55, 7 p., illus. 1966.

Sixty 2-year-old conifer seedlings of the following species were obtained from nearby Forest Service nurseries: Rocky Mountain Douglas-fir; Engelmann spruce (*Picea engelmannii* Parry); grand fir; lodgepole pine (*Pinus contorta* Dougl.); ponderosa pine (*Pinus ponderosa* Laws.); western white pine (*Pinus monticola* Dougl.); western redcedar (*Thuja plicata* Donn). Ten trees for each species were selected for each treatment; 10 others, the control group, were untreated.

Trees were planted in pots in May 1966. They were kept in a lathhouse, except for the winter of 1966-1967 when anticipation of cold weather prompted us to move them into a greenhouse. Conditions inside the greenhouse were regulated to maintain dormancy. We treated the trees during the period July 6-11, 1966, and measured them in August 1966 and again in August 1967, recording leader elongation and plant condition.

RESULTS

SHRUBS

We evaluated the effects of herbicides on shrub growth by means of a 5-point rating system described by Gantz and Laning[9] (table 1).

For each species-herbicide combination five observations were made. Because of this low number of observations, comparisons using proportions drawn from the five response categories would give little indication of differences among species-herbicide combinations.

Since the scores assigned to the rating categories increase in magnitude as the severity of the response increases, these scores were used as criteria in an analysis of variance model. The analysis revealed a highly significant species-treatment interaction. Though the analytical results agree with field evaluation and with data summaries, we cannot be sure that scores are proportional to differences in response. Consequently, the analysis may not be valid. For this reason, we derived the following information from the data summary table.

Mountain maple resisted all treatments (table 1). Even the high-concentration treatment of dicamba plus 2,4-D (No. 4), which killed nearly 100 percent of the plants of other species, was ineffective against maple.

Dicamba was more effective when mixed with 2,4-D than when used alone. Even the highly concentrated treatment No. 2 was little better than treatment No. 3, for which a small amount of dicamba was mixed with 2,4-D. When used alone, the low concentration of dicamba was the least effective of all treatments.

Effects of the two treatments most comparable in formulation and concentration, Nos. 3 and 5, did not differ greatly among species. However, picloram (No. 5) seemed a little better for controlling ninebark, oceanspray, and redstem ceanothus than dicamba (No. 3), which was more effective on willow.

The degree of reduction in shrub height also reflects differences in species susceptibility to different treatments (table 2). Live stem height was reduced most in menziesia (94 percent) and willow (90 percent). Somewhat less reduction was obtained in ninebark (85 percent), oceanspray (76 percent), and redstem ceanothus (84 percent). Mountain maple, which was little affected, showed only a 31-percent reduction.

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[9] R. L. Gantz and E. R. Laning, Jr. Tordon for the control of woody rangeland species in the western United States. Down to Earth 19(3): 10-13. 1963.

Table 1.--Mean condition values[1] for shrubs in August of the second growing season after treatment

Shrub species	Treatment						No treatment (control)
	Dicamba (2 lbs.)	Dicamba (8 lbs.)	Dicamba (1 lb.) + 2,4-D (2 lbs.)	Dicamba (4 lbs.) + 2,4-D (8 lbs.)	Picloram (1/2 lb.) + 2,4-D (2 lbs.)	Mean	
Menziesia	3.6	4.8	5.0	5.0	5.0	4.7	1.0
Mountain maple	2.0	3.4	1.8	3.2	2.4	2.6	1.0
Ninebark	4.0	4.6	4.2	5.0	4.6	4.5	1.0
Ocean spray	2.6	4.4	4.4	5.0	4.6	4.2	1.0
Redstem ceanothus	4.2	4.4	4.4	5.0	4.8	4.6	1.0
Willow	4.6	5.0	4.8	4.8	4.4	4.7	1.0
Treatment means	3.5	4.4	4.1	4.7	4.3		1.0

[1]Each treatment-species value represents the mean condition class of five plants. The condition class of each plant was evaluated as follows:

Value	Condition class
1	Little or no effect
2	Fifty percent or less of top growth killed
3	Over 50 percent of top growth killed
4	Complete top kill; sprouts from root collar or lateral roots
5	Complete top kill; no sprouting

Table 2.--Shrub heights[1] in August of the second growing season after treatment

Shrub species	Treatment						No treatment (control)
	Dicamba (2 lbs.)	Dicamba (8 lbs.)	Dicamba (1 lb.) + 2,4-D (2 lbs.)	Dicamba (4 lbs.) + 2,4-D (8 lbs.)	Picloram (1/2 lb.) + 2,4-D (2 lbs.)	Mean	
	Percent						
Menziesia	29	2	0	0	0	6	107
Mountain maple	84	37	97	46	81	69	121
Ninebark	30	12	20	0	14	15	104
Ocean-spray	68	18	19	0	13	24	129
Redstem ceanothus	20	25	18	0	16	16	136
Willow	20	0	2	7	21	10	121
Treatment means	42	16	27	9	24		120

[1]Percent of before-treatment height.

CONIFERS

On August 19 of the first growing season, the effects of treatments on different species varied widely. Douglas-fir appeared to be the only species resisting all treatments, except the high-concentration mixture of dicamba and 2,4-D (treatment No.4). September 8, Douglas-fir still showed little damage, but the other six species were dying. By November, even the Douglas-fir showed discoloration. In August of the second growing season, most treated plants were dead (table 3); a few lodgepole pine, Douglas-fir, and western redcedar trees were still alive, but they were in poor condition and were not growing in height.

DISCUSSION AND CONCLUSIONS

At the end of the first growing season (approximately 1-1/2 months after treatment), dicamba appeared to be more effective than picloram. For example, dicamba treatments apparently had killed all ninebark plants while picloram treatments had not. However, the following year, some of the ninebark plants treated with dicamba sprouted, but most of those treated with picloram died. By the end of that growing season, picloram seemed to be the better of the two herbicides for controlling ninebark.

Menziesia showed little damage from any treatment during the first growing season; a few leaves died and fell from branch tips, but this was the only visible sign. However, the next year, all plants died back to the ground. Moreover, no sprouting followed treatment Nos. 3, 4, and 5. Treatments with dicamba alone (Nos. 1 and 2) were not as effective.

Because of their toxicity to the coniferous species, none of the herbicide treatments seems to have promise for use as a spray to release established trees from competing vegetation.

Because of their effectiveness at relatively low concentrations, two of the treatments, No. 3 (1 pound dicamba plus 2 pounds 2,4-D) and No. 5 (1/2 pound picloram plus 2 pounds 2,4-D), appear to deserve further study for use in brushfield spray projects where removal of shrubs is the primary objective. Although the two herbicides were similarly effective on the species studied, picloram was more effective on ninebark, oceanspray, and redstem ceanothus, while dicamba was better on willow. The choice of treatment for a specific area would depend on which species predominate and on prevailing chemical costs. However, more experimentation is needed before we can recommend use of these herbicides on anything other than a trial basis.

Table 3.--Mean condition values[1] for conifers in August of the second growing season

Tree species	Treatment: Dicamba (2 lbs.)	Dicamba (8 lbs.)	Dicamba (1 lb.) + 2,4-D (2 lbs.)	Dicamba (4 lbs.) + 2,4-D (8 lbs.)	Picloram (1/2 lb.) + 2,4-D (2 lbs.)	Mean	No treatment (control)
Engelmann spruce	5.0	5.0	5.0	5.0	5.0	5.0	1.0
Grand fir	5.0	5.0	5.0	5.0	4.9	5.0	1.0
Lodgepole pine	2.9	3.9	3.8	5.0	4.1	3.9	1.0
Ponderosa pine	5.0	5.0	5.0	5.0	5.0	5.0	1.0
Rocky Mountain Douglas-fir	3.2	4.2	3.2	5.0	3.8	3.9	1.6
Western redcedar	4.5	4.9	4.1	5.0	4.5	4.6	1.0
Western white pine	5.0	5.0	5.0	5.0	5.0	5.0	1.0
Treatment means	4.4	4.7	4.4	5.0	4.6		1.1

[1]Each treatment-species value represents the mean condition class of 10 trees. The condition class of each tree was evaluated as follows:

Value	Condition class
1	No observable damage
2	Foliage discolored and thin
3	Leader deformity
4	Tip killing only
5	Dead

Research Note

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1970

INFILTRATION IN CONTOUR TRENCHES IN THE SIERRA NEVADA

Norbert V. DeByle[1]

ABSTRACT

Infiltration rates for water ponded in the bottoms of contour trenches constructed in the Sierra Nevada were determined by means of double-ring infiltrometers. The average rate in coarse-textured soils derived from granite was 19.5 inches per hour, more than six times the 3-inch-per-hour rate measured in fine-textured soils derived from andesite. These widely differing rates should be considered when designing a trench network. The probable influence of contrasting infiltration rates on water yields is discussed.

Contour trenches have been used for more than three decades in the West to control erosion and to permit revegetation of damaged mountain watersheds.[2] They work; when properly constructed, they halt erosion. Nevertheless, their design and function are largely based on empirical tests and quantitative information about their hydrologic effects is lacking.

Since trenches pond surface runoff, the rate at which this ponded water infiltrates is an important facet of their hydrology and should be considered in the design of a trench network. Further, this infiltration rate probably will influence the timing and amount of water yields from the trenched watershed.

METHODS

An exploratory study of infiltration in contour trenches was conducted in 1963 on the east side of the Sierra Nevada near Reno, Nevada. About 110 lineal miles of contour trenches had been constructed on the burned area of the Dog Creek watershed after the 1960 Donner Ridge fire. These trenches were restricted to denuded slopes having gradients of approximately 30 to 60 percent. The trenches studied were in a small catchment on the west side of that watershed, where soils derived from both andesitic and granitic parent materials were available. The andesite had weathered into fine-textured soils that possessed relatively low infiltration capacities. Granitic soils,

[1]Plant Ecologist, stationed in Logan, Utah, at Forestry Sciences Laboratory, maintained in cooperation with Utah State University.

[2]Edward L. Noble. Sediment reduction through watershed rehabilitation. 29 p. Paper presented at the Fed. Interagency Sedimentation Conf., Jackson, Miss., Jan. 1963.

on the other hand, were coarse textured and the ponded water infiltrated readily. The sites used for studying infiltration in contour trenches were chosen from these two soil types.

Double-ring infiltrometers were used on six sites during the late summer of 1963, 1 year after trench construction. Each site consisted of two or three successive trenches, each divided into four test locations approximately 20 feet apart. Consequently, 8 or 12 tests were conducted per site. Sixty-four individual infiltrometer tests were made--24 on granitic soils, 40 on andesitic soils. Immediately before testing, a soil sample was taken from the bottom of each trench and its moisture content measured gravimetrically.

The inner (intake) infiltrometer rings were 9 inches in diameter; the outside (buffer) rings were about as large (21 inches in diameter) as would fit into the bottom of a typical trench. Before each test, an inner ring was driven 2 inches into the soil at the lowest point in the trench bottom and an outer ring was inserted deep enough to hold water. The water level in the inner ring was measured by means of a hook gage immediately after both rings were filled and at frequent intervals thereafter. Water levels in both rings were kept approximately equal; the head in each was allowed to vary between 8 and 2 inches. Whenever infiltration reduced the head in the inner ring to 2 inches, both rings were rapidly refilled to the 8-inch level.

Infiltration rates were based on the time required for 30 inches of water to infiltrate trench bottoms or for a 24-hour continuous test--whichever occurred first. However, tests were made throughout the daylight hours only; so if enough water infiltrated during the night to empty infiltrometers, infiltration periods could not be established. When this occurred, rates were determined from data recorded the previous day. If infiltrometers did not drain dry overnight, rates were based on 24-hour periods.

RESULTS

Most infiltration rates were much greater during the first few minutes of a test than after 10 to 30 minutes had passed. High initial rates probably were due in part to dry soils. Before testing, decomposed granite soils held only 4.4 percent and andesitic soils about 13.1 percent moisture by weight, percentages at or near their respective wilting points. A relatively constant infiltration rate usually was attained within the first 15 minutes. However, this rate varied somewhat with fluctuations in the head of water in the infiltrometer.

Infiltration rates and the time periods over which they were determined are summarized according to site in table 1. Site 4 (three trenches constructed in the fine-textured soil derived from andesite) had the slowest infiltration rate, only 0.61 inch per hour. Site 5 (three trenches constructed in the coarse-textured soil derived from granite) had the fastest rate, almost 23 inches per hour. Each of these rates is the average of 12 tests. As a matter of interest, of the 64 individual tests run, the slowest one (0.01 inch per hour) also was recorded on Site 4 and the most rapid (51.5 inches per hour) on Site 5. Note especially that the average infiltration rate in the bottom of trenches constructed in coarse granitic soils was approximately six times that in the bottoms of trenches constructed in the fine-textured andesitic soils; this is a highly significant difference.

The amounts of accumulated infiltration at selected time intervals (5, 10, 20, 40, and 80 minutes after testing began) were computed and tabulated. These data then were averaged by site and graphically portrayed in figure 1. Data from tests that extended beyond 80 minutes indicate a relatively constant rate of infiltration. In fact, in most instances, the rate is shown to be constant after the first 10 minutes.

Table 1.--Infiltration rate in contour trenches on six sites

Site no.	Soil	Average infiltration period	Infiltration rate: Average infiltration rate	Infiltration rate: Confidence limits at 0.05 level
		Minutes	------Inches per hour-----	
1	Andesitic	434	1.16	0.52- 1.81
2	Andesitic	257	1.32	.66- 1.99
3	Andesitic	210	7.67	3.67-11.68
4	Andesitic	974	.61	.21- 1.01
5	Granitic	88	22.99	15.46-30.51
6	Granitic	153	16.00	10.27-21.73
Sites 1-4	Andesitic	469	2.98	1.51- 4.46
Sites 5-6	Granitic	120	19.49	14.89-24.10

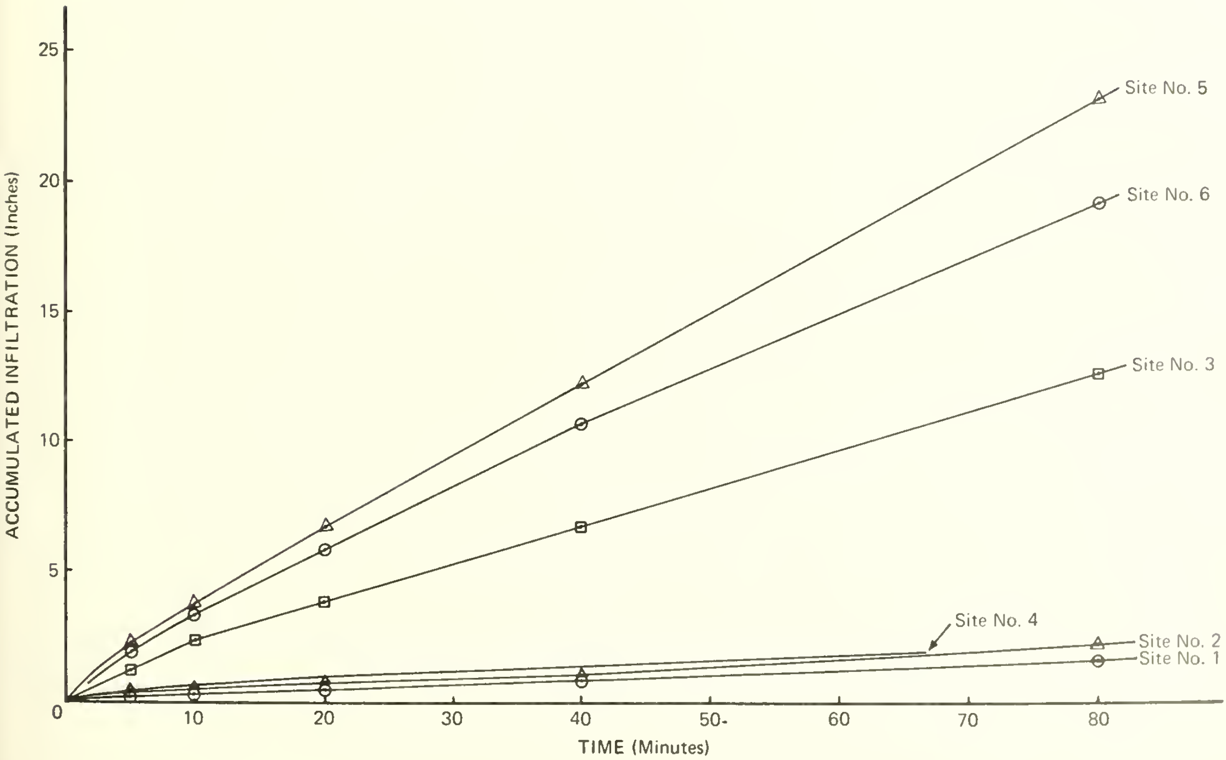

Figure 1.--Accumulated infiltration in contour trenches at six sites.

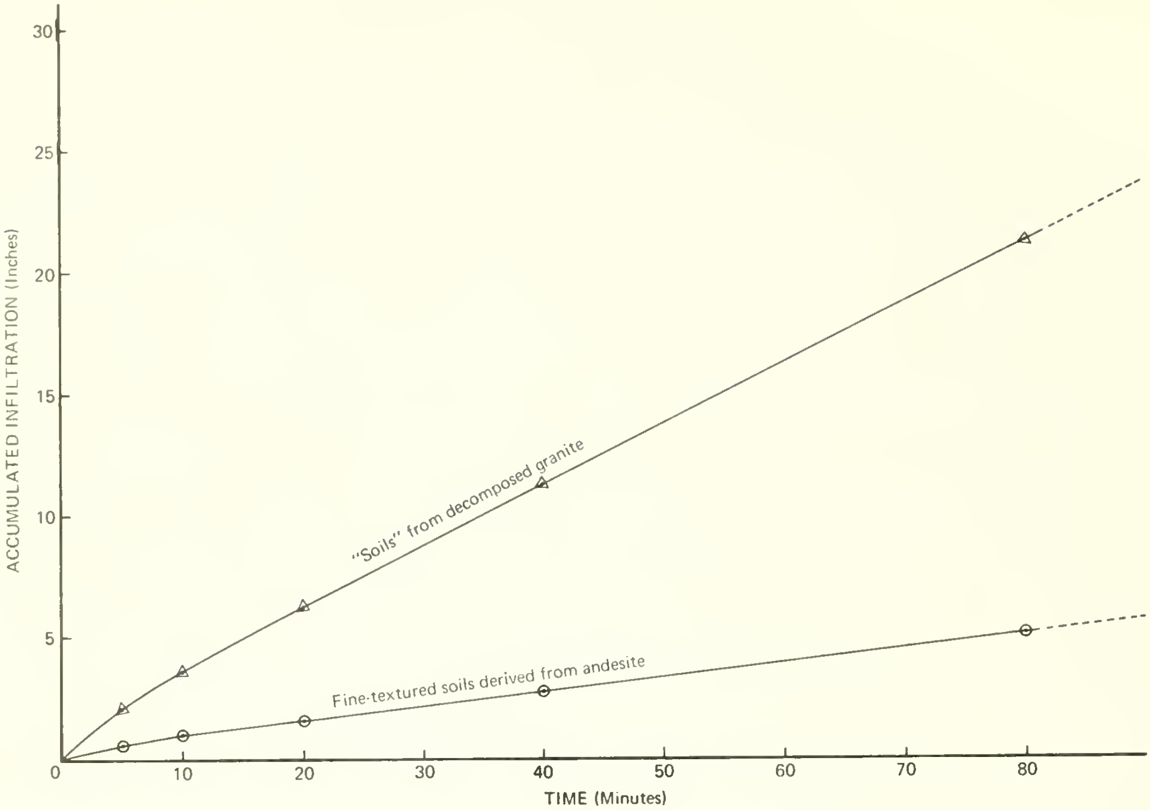

Figure 2.--Accumulated infiltration in contour trenches of decomposed granitic soils versus those of fine-textured, andesitic soils.

Sites 1, 2, and 4 have fine-textured soils derived from andesite; sites 5 and 6 have coarse-textured soils derived from decomposed granite. The soil on site 3 probably is a mixture of the two parent materials, but appeared to be of andesite origin primarily and so is included here with the andesite soils. Sites were grouped by soil parent material and the results from all tests on these sites averaged to derive the two curves of accumulated infiltration in figure 2. At the end of an hour, the graphed amount of infiltration for granitic soils was 16.3 inches and for andesitic soils 3.8 inches. These rates differ somewhat from those shown in table 1; probably because a constant (linear) rate of infiltration is assumed in table 1, whereas a curvilinear rate is shown in figure 2.

DISCUSSION

The results from 64 infiltrometer tests show a wide variation in the relative rates of infiltration in the bottoms of contour trenches constructed in the Sierra Nevada. Differences noted on individual sites show that infiltration rates can vary considerably on what appears to be a uniform soil type. Rate differences due to soil parent materials are even more striking. The hydrologic influence of contour trenches in decomposed granite would be unlike that of trenches constructed in fine-textured soils.

If all other design criteria are held constant, a contour trench system in decomposed granitic soils could successfully be designed with a smaller capacity for collecting and storing surface runoff than a system constructed in finer textured

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material. In reality, of course, all criteria cannot be held constant. For example, erosion within a trench system in decomposed granite usually is so great that more storage capacity must be built into the network initially.

Contour trenching of widely different soil types conceivably would have contrastive effects on water yields. Due to the large infiltration capacity of decomposed granite, contour trenches constructed in such material should have less influence on yields from the watershed than trenches constructed on finer material. Fine-textured soils cause water to pond in the trenches for considerable time, thus permitting it to evaporate or to be consumed by vegetation on the site. The timing of water yields also may be affected. The slow percolation of water from the bottoms of trenches in fine-textured materials may serve to delay streamflow and lower runoff peaks. On the other hand, contour trenches in decomposed granite probably would not alter the timing of water yields appreciably, except for trapping overland flow and reducing flash floods in the streams.

Contour trenches trap, pond, and dispose of overland flow in much the same manner as they dispose of water in double-ring infiltrometers. Under natural conditions, water usually is rapidly ponded. Then, under the pressure of a constantly decreasing head, it slowly soaks into the soil.

When these tests were conducted, the average trench in the Dog Creek watershed had a maximum depth of 2 feet and a cross-sectional capacity of 9.3 square feet. Since the trench cross section is a gentle, open V-shape, the average head would be about a foot--even if the trench were full. Trenches are seldom full, even after intense summer storms. Consequently, an average head of 8 inches (the maximum in the ring infiltrometers) would very likely exist in partially filled trenches.

Ring infiltrometers were used when soils (even in trench bottoms) were quite dry; so initial infiltration rates were rapid. The overland flow most frequently trapped in contour trenches originates from high-intensity summer rainstorms, which usually occur when the surface soils are dry. Consequently, dry surface soils and rapid initial infiltration rates also typify natural conditions.

Despite the similarities noted between natural and study conditions, ring infiltrometer tests have their shortcomings. Ring infiltrometers usually overestimate infiltration rates.[3] Hence, they are usually used to determine relative rates of infiltration under different conditions, as was done in this study. The large diameter, double-ring infiltrometers closely approximate actual infiltration. Consequently, the author can only hope that the infiltration rates cited in this paper approximate those that would occur under natural summer conditions.

Research is now being conducted in Utah on the infiltration capacity of contour trenches.[4] These Utah tests are being made in flooded trench sections; so actual infiltration rates are being measured. This research should answer questions that may arise concerning the validity and usefulness of data from the ring-infiltrometer tests in the Sierra Nevada. In the meantime, this report will provide watershed managers with a reasonable and useful first approximation of infiltration in contour trenches.

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[3]Herman Bouwer. A study of final infiltration rates from cylinder infiltrometers and irrigation furrows with an electrical resistance network. 7th Int. Congr. Soil Sci. Trans., Vol. I: 448-456. 1960.

[4]Paul E. Packer. Study plan INT-1603-312. Evaluation of soil and vegetation effects on the infiltration and sedimentation characteristics of contour trenches in Halfway Creek, Davis County Experimental Watershed, northern Utah. 36 p. Typescript on file, Intermountain Forest and Range Exp. Sta., Ogden, Utah. 1964.

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1970

TECHNIQUES FOR SECTIONING AND STAINING TISSUE CULTURES OF WESTERN WHITE PINE

J. Y. Woo[1]

ABSTRACT

*Using transparent tape, as a support, paraffin sections as thin as 5μ are microtomed from large, whole, and friable tissue cultures of western white pine (*Pinus monticola *Dougl.) and from pine cultures infected with the blister rust fungus* (Cronartium ribicola *J.C. Fisch. ex Rabenh.). Pathological differentiation is obtained with Conant's quadruple stain or safranin O-fast green stain, and cytological differentiation of the fungus is obtained with Heidenhain's hematoxylin stain or Flemming's triple stain.*

Plant tissue cultures provide a rather promising approach to a more thorough understanding of host-parasite interactions, particularly with obligate parasites. Tissue cultures of western white pine (*Pinus monticola* Dougl.) are being used in this laboratory to study the interactions between the plant host and blister rust fungus (*Cronartium ribicola* J.C. Fisch. ex Rabenh.) (Harvey 1967; Harvey and Grasham 1969 and 1970; Harvey and Woo 1969). It is difficult to microtome sections suitable for pathological and cytological study from these cultures because they are large (3/4 to 2 cm. diameter) and friable; they contain air pockets which render them difficult to infiltrate completely with paraffin; and their cells are loosely arranged with the middle lamella poorly developed. Physical disturbances that result from dividing these tissue cultures into smaller pieces convenient for microtoming often cause cells, or groups of cells, to separate from the tissue masses in the various solutions used prior to embedding. Killing and fixing solutions (or the first several solutions in the dehydration series, in which the water content is high) are particularly disruptive. The above problems are especially characteristic of the young, rapidly growing tissue cultures. As a result, it is desirable to cut these tissue cultures whole.

The above problems encountered in treatment of tissue cultures have not been resolved in the literature. Therefore, existing techniques had to be modified and the modifications are reported here.

[1]Biological Laboratory Technician, stationed in Moscow, Idaho at the Forestry Sciences Laboratory, which is maintained in cooperation with the University of Idaho.

Whole tissue cultures are taken from their culture media and carried intact through the processes of killing, fixing, and embedding. For pathological studies, the tissue cultures are killed and fixed in formalin-propiono-alcohol fluid (FPA) (Johansen 1940). For cytological studies, Randolph's modified Navashin fluid is used (Johansen 1940).

The tissue cultures are dehydrated by the tertiary butyl alcohol method (TBA) (Johansen 1940) and are embedded in paraffin (55 C mp.).

Sections of these tissue cultures are cut 5 to 25μ thick on the sliding microtome by using a modification of the cellulose tape method (Bonga 1961, Beckel 1959, Palmgren 1954). A paraffin block containing a tissue culture is trimmed to the desired place with the sliding microtome. The ends of a 4-inch strip of transparent tape, approximately the width of the paraffin block, are fastened together forming a circle with the adhesive surface facing outward (Figs. 1A and 1B). The adhesive surface of the tape is then attached to the cutting surface of the paraffin block, and the tape held up slightly by one finger (Fig. 1A), so that the part of the tape not adhering to the surface of the block will clear the knife during cutting. The cut sections will then adhere to the tape (Figs. 1A and 1B).

This procedure is repeated until the desired number of sections is obtained for one slide. If sections of different thicknesses are desired on the same slide, the feed mechanism is changed before cutting each section. The rotary microtome can be used also

After cutting is complete, the excess tape is removed and the part with the adhering sections is placed on a slide (adhesive side against slide) containing Haupt's adhesive and a 4% formalin solution (Fig. 1B). Two slides are then pressed together with the tape sides toward each other with a piece of absorbing paper of the same size as the slides placed between them. They are held in this position by five clothespins, two on one side and three on the other (Fig. 1B), to keep the pieces of tape containing the sections flattened while drying for 24 to 48 hrs. After drying, the slides are placed in xylene to dissolve the adhesive material of the tape, thus separating the tape from the slides but leaving the sections still attached. At the same time, the paraffin is also dissolved by the xylene. The time required for this process varied from 24 to 72 hrs.

For pathological studies, the sections are stained with Conant's quadruple stain or safranin O-fast green stain (Johansen 1940). For both staining schedules, slides are left in 0.5% safranin O-50% alcohol solution for 12 hrs. and differentiated in a very dilute HCl-95% alcohol solution (a few drops of HCl per staining jar of 95% alcohol and washed thoroughly in running tapwater. Also for both schedules, the staining time in 0.5% fast green-100% alcohol solution is 1 min. For Conant's quadruple stain schedule, the staining time in crystal violet (0.25% aqueous solution) is 3 min. The rust mycelium is stained purple by Conant's quadruple stain schedule and red by the safranin-fast green schedule.

For cytological studies, the sections are stained with Heidenhain's hematoxylin stain (Johansen 1940) or Flemming's triple stain (Sass 1958). In the Heidenhain's hematoxylin schedule, the sections are mordanted for 12 hrs. in a 1% solution of ferric ammonium sulfate and stained for 12 hrs. in a 0.25% solution of hematoxylin. For the triple stain schedule, the sections are left in a 0.5% safranin-50% alcohol solution for 12 hrs. The staining time in an aqueous crystal violet solution (0.25%) is 8 hrs. The nuclei are stained reddish-purple by the latter schedule.

As Bonga (1961) demonstrated with his method, microtomed sections showed little or no tearing or compression and can be maintained in series on tape if desired. In addition, the convenience of having sections of different thicknesses on the same slide is easily accomplished. When using tape as a support, it is possible to cut satisfactory sections from tissue cultures containing air pockets (which are sometimes difficult to completely infiltrate with paraffin) without tearing or compression. Specimens are well differentiated both cytologically and pathologically, with the staining schedules descri

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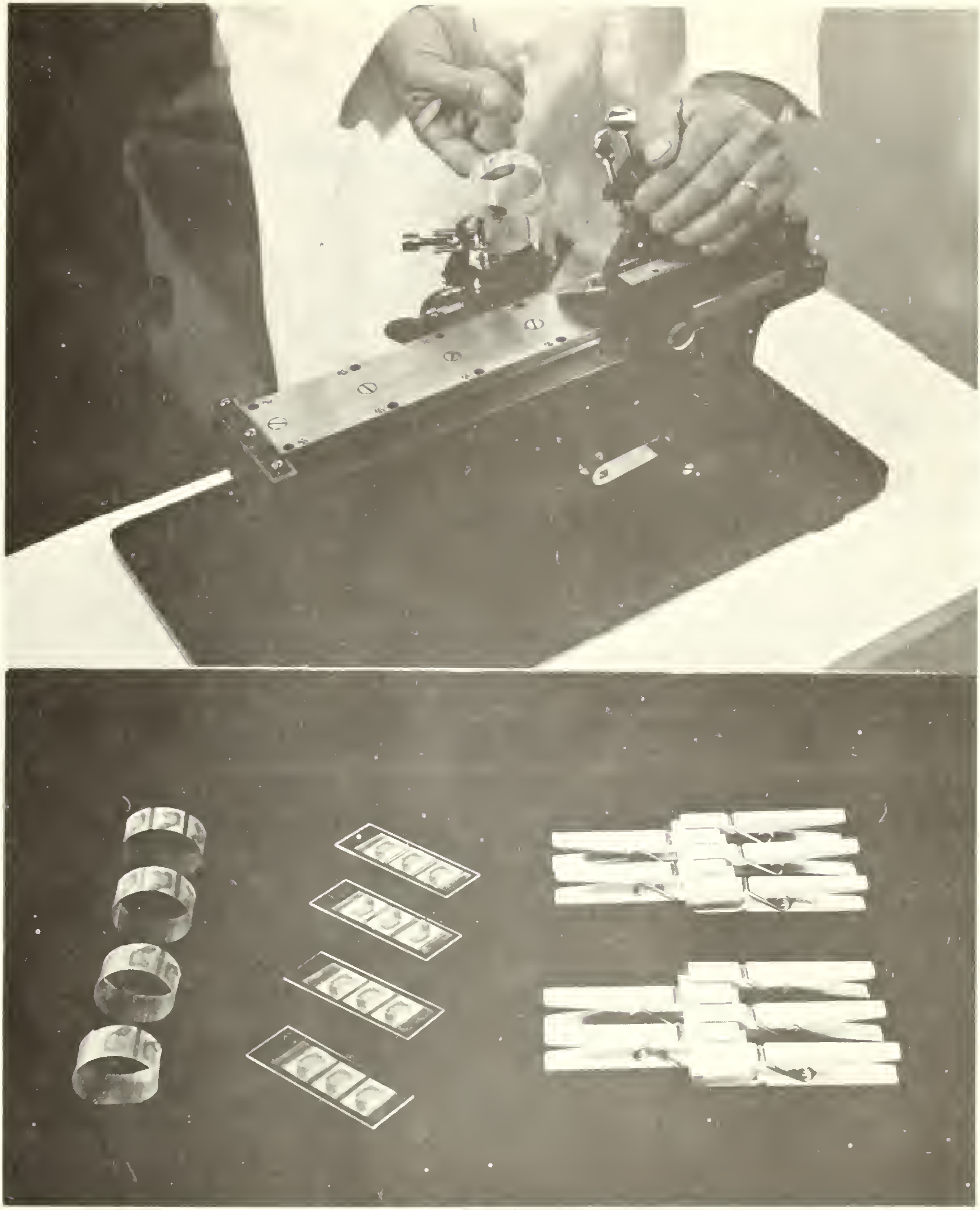

Figure 1.--(A) Sections of tissue cultures are cut by the transparent tape method on a sliding microtome (note the transparent tape must be held clear of knife). (B) Shown left to right are: sections on tapes; sections on slides containing Haupt's adhesive and formalin solution; and sections being flattened on slides by clothespins during the drying period.

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PREDICTING THE DURABILITY OF FOREST RECREATION SITES IN NORTHERN UTAH--PRELIMINARY RESULTS

Thomas J. Cieslinski and J. Alan Wagar[1]

ABSTRACT

By using a special roller, trampling was simulated in equal amounts on 40 small plots representing potential recreation sites throughout the Cache National Forest in northern Utah. Surviving vegetation was related to soil and topographic factors by multiple regression procedures. Resultant equations explained up to 64 percent of the variability in amounts of surviving vegetation, which suggests the possibility of predicting the durability of potential recreation sites. Site factors that can be measured on aerial photos explained approximately as much variability as factors requiring on-the-ground measurements.

One of the more serious problems facing recreation site managers today, particularly on campground and picnic areas, is that of maintaining adequate ground cover. This is an especially difficult task in semiarid regions such as the Intermountain West, where sites tend to support a sparse cover of ground-level vegetation. Because of different soil, moisture, and topographic conditions, some sites are much more durable than others in terms of the persistence of ground-cover vegetation. If we had tools for rating the durability of potential recreation sites, less durable sites either could be avoided or designed and managed in ways to increase their durability. Moreover, knowledge of the probable level of vegetation damage to a fragile site might allow managers to estimate any additional expenditures that may be needed if such a site is developed and used as a campground or picnic area.

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[1]This paper is based on the senior author's master's thesis accepted at Utah State University in 1968. The senior author is now Supervisor of Planning and Research for the Maine State Park and Recreation Commission. At the time this work was done, the junior author was leader of the Cooperative Recreation Research Unit maintained by the USDA Forest Service in cooperation with Utah State University at Logan. He is currently leader of a similar unit maintained at the University of Washington in Seattle by the Pacific Northwest Forest and Range Experiment Station, USDA Forest Service.

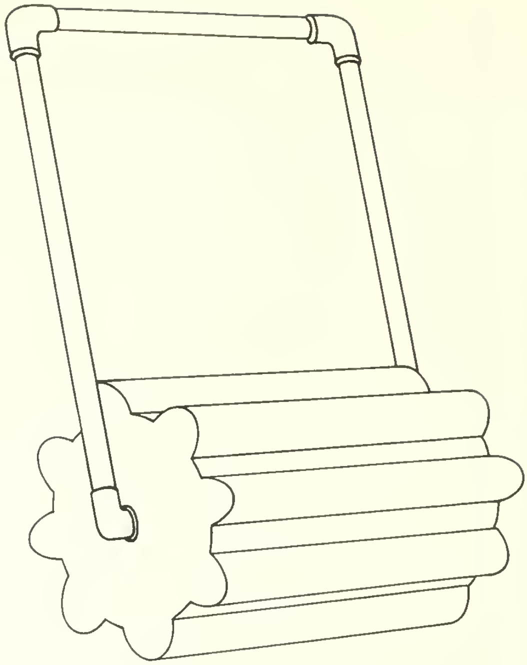


Figure 1.--Configurated roller used in the study to simulate trampling from recreation use.

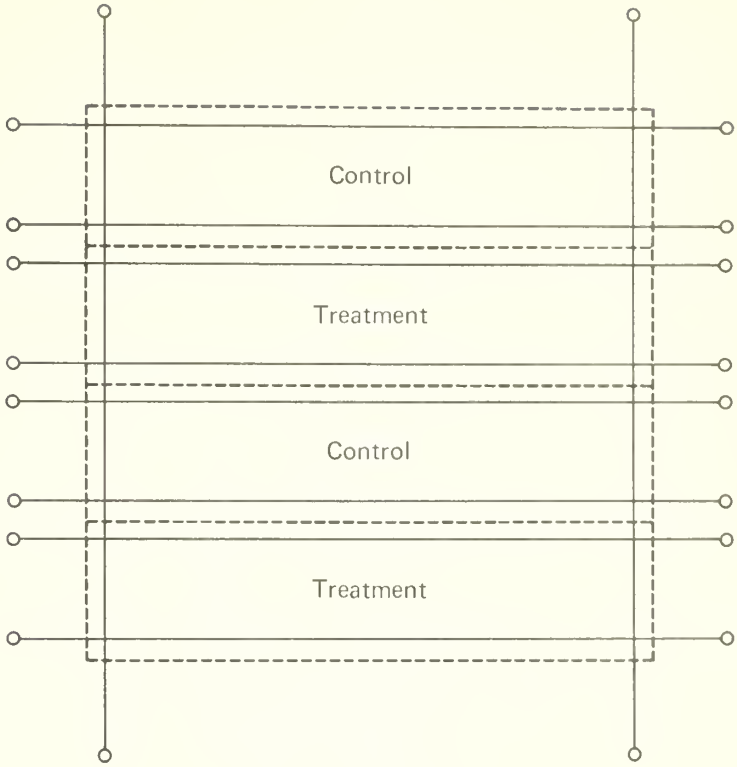
To provide procedures for rating the durability of site vegetation, a study was established on the Cache National Forest in northern Utah in 1965. A 100-lb. configurated cement roller (fig. 1) that applied a rolling pressure of about 6 lbs./in.[2] was used to simulate trampling on the 16- by 64-inch plots. Identical amounts of simulated trampling were applied to each plot in the study. Plots then could be arranged in order, according to resistance to damaging forces.

Whether the roller damage was greater or smaller than that resulting from human trampling is not known but probably is unimportant. We assumed that after moderate trampling the amount of vegetation surviving through one or more growing seasons would express site durability. Then, if amounts of surviving vegetation could be related to soil and topographic factors, the resulting relationships would enable us to predict site durability.

Because simulated trampling had been used in only one other study (Wagar 1964a), the 1965 growing season was used to test the effect of different intensities and timings of simulated use. On 48 plots--24 under a cover of lodgepole pine (*Pinus contorta* Dougl.) and 24 under a cover of aspen (*Populus tremuloides* Michx.)--we learned that plot vegetation responded quite differently to varying amounts of rolling, but little differently to the same amount of rolling applied with different timings. The response was about the same whether plots received two passes of the roller on 3 days of each week or the same amount of trampling applied as 12 passes of the roller once every other week. This seemed to justify the once-a-week rolling treatment that was planned for the second phase of the study.

Based on results from 1965, 40 sites were selected in May 1966. Sites represented the range of conditions judged suitable for recreation occupancy sites on the Cache National Forest. The sites chosen were concentrated on slopes ranging from 0 to 15 percent. To help us define the form of relationships, we included a few sites on steeper slopes (up to 30 percent). Sites represented overstory types ranging from lodgepole pine to aspen to maple to willow. The 40 plots selected included the following ranges of conditions: all aspects; elevations of from 5,100 to 8,400 ft.; soil pH values of

Figure 2.--Arrangement of 16- by 64-inch plots at each site location.



5.0 to 7.4; plot positions on the slope ranging from the bottom of the drainage to the top of the slope; a variety of soil textures in both the A and B soil horizons; percent stones in the soil (2 mm. and larger) from 6.9 to 64.8; season-long percentages of possible direct sunlight ranging from 1 to 40; and basal area of trees ranging from 26 to 313 $ft.^2$ per acre. Measurements were recorded for each of these site characteristics.[2] The most northerly plots and the most southerly plots were 52 airline miles apart.

The grass and forb species at the sites included the following: *Polygonum durslasia; Aconitum columbianum; Bromus marginata; Melica bulbosa; Aster engelmannii; Achillea lanulosa; Agropyron spicatum; Wyethia amplexicaulis; Thalictrum fendleri; Senecio serra; Lathyrus leucanthus; Agastacha urticifolia; Rudbeckia occidentalis; Delphinium barbeyi; Osmorhiza chilensis; Sidalacea neomexicana; Lupinus laxiflorus; Veronica campylopoda; Agoseris glauca; Arnica cordifolia; Taraxacum officinale; Hydrophyllum capitatum* var. *thompsonii;* and several *Carex* species.

At each site location, four 16- by 64-inch plots were placed in stands of ground-cover vegetation judged to be uniform. As shown in figure 2, two treatment plots were alternated with two control plots in each plot group. Beginning the latter half of June 1966, each treatment plot was rolled once a week with 12 passes of the roller. Treatments continued for 11 weeks. A 1-week interval between treatments provided sufficient time for all plot locations to be treated in a repetitive sequence and also allowed time for measurement of site variables at each location.

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[2]Aspect was coded as 1.0 plus the sine of the azimuth from southeast. This gave values ranging from 0.0 on cool northeastern exposures to 1.0 on moderate southeastern and northwestern exposures to 2.0 on hot southwestern exposures. Season-long percentage of possible direct sunlight was measured by using an insolation grid (Wagar 1964b). The point density procedure developed by Spurr (1962) was used to measure the basal area of trees.

During the growing season, plots at three locations were damaged so severely by livestock grazing that they could not be used in the analysis. Consequently, analysis was based on plots at only 37 locations.

At the end of the growing season (between September 10 and October 25) vegetation within a 12- by 60-inch zone in each plot was measured in two different ways. First, a 12- by 30-inch grid with two hundred 1.2- by 1.5-inch rectangles was placed over each half of the measurement zone and a count was taken of the number of stocked rectangles, i.e., rectangles having living vegetation anchored in them. This number then was expressed as a percentage of the total number of 400 rectangles and used as dependent variables Y_1 and Y_2. As a second measurement procedure, all plants from the measurement zone of each plot were clipped one-half inch above their root collars. Clippings then were ovendried and weighed for a measure of dependent variable Y_3.

Two other variables also were constructed and used to express results. Vegetation surviving on treated plots was expressed as a percentage of the vegetation surviving on adjacent control plots. This percentage was used as dependent variable Y_4 when based on clipping weights, and as dependent variable Y_5 when based on stocking measurements.

Multiple regression analysis procedures were used. Results for the five regression models tested are summarized in table 1.

In the equations for Y_1 and Y_2, approximately 60 percent of the variability was explained. It should be noted that the equation for Y_1 is limited to variables that either were or could have been measured from aerial photographs. From this we conclude that the possibility of determining site durability from aerial photos is promising. However, because this equation was based on measurements from only 29 plot groups,[3] results for this equation are not quite comparable to others.

In the equation for Y_1, most of the variability appeared to be due to topographic factors, and studies are being continued to determine whether site durability can be satisfactorily predicted from aerial photograph measurements.

Independent variables were examined for consistency from equation to equation and for statistical significance (defined as 5 or less percent probability that association with the Y variable was a chance occurrence). Variables that were both significant and consistent included slope percent, aspect, elevation, and the interaction between slope percent and aspect. Three additional variables, although not statistically significant, had no inconsistencies from one equation to another and occurred in the equation that had the best predictive value (lowest mean square error) for one or more of the models tested. These were percent clay at a soil depth of 1 to 4 inches, basal area of trees, and percent stones (>2 mm. in diameter) at a soil depth of 1 to 4 inches. Four variables were either inconsistent or explained too little variability to be included in the equations. These were pH of soil at a depth of 1 to 4 inches, position of plot on slope, season-long percentage of direct sunlight, and distance from drainage bottom to plot.

Within the narrow range of slopes studied, the steeper slopes showed greater durability than gentle slopes. This result was not expected and may be related to soil coarseness or some other factor associated with slope rather than slope itself.

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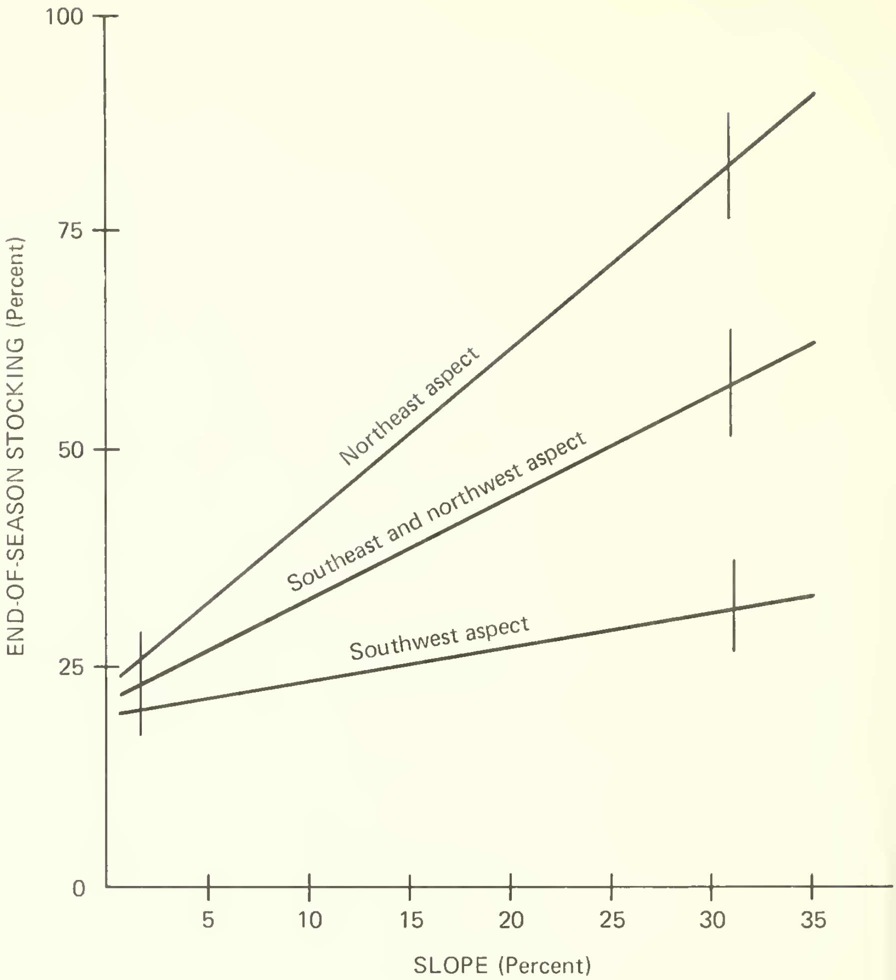
[3]At the time an expert photo interpreter was available, only 29 of the plot groups had been located on aerial photos. The authors are grateful to Karl E. Moessner of the Intermountain Forest and Range Experiment Station, USDA Forest Service, for making the aerial photograph measurements used in this study.

Table 1.--*Summary of results for five regression models. Study to predict the durability of potential recreation sites, 1966 data, Cache National Forest, northern Utah. Standard partial regression coefficients are shown in parentheses.*

		Constant a	Slope of plot, measured on ground (X_1) b_1 (b_1')	Slope of plot location measured on photos (X_2) b_2 (b_2')	Percent clay at soil depth of 1 to 4 inches (X_3) b_3 (b_3')	Aspect (X_4) b_4 (b_4')	Elevation (X_5) b_5 (b_5')	Soil pH at 1 to 4 inches (X_6) b_6 (b_6')	Plot position on slope, measured on ground (X_7) b_7 (b_7')	Plot position on slope, measured on photos (X_8) b_8 (b_8')	Percent stones (xmm) at soil depth of 1 to 4 inches (X_9) b_9 (b_9')	Basal area of trees (X_{10}) b_{10} (b_{10}')	Interaction of slope and aspect (X_1X_4) b_{11} (b_{11}')	Multiple regression coefficient R^2: With all X variables included	Multiple regression coefficient R^2: At lowest mean square error
End-of-season stocking	Y_1	740.96		6.54 (.45)**		-84.38 (-.52)**	-9.17 (-.62)**			1.04 (.22)				0.64	0.64
	Y_2	333.12	7.98 (.62)**		388.65 (.16)		-4.66 (-.33)*				222.32 (.27)	-.12 (-.14)	-3.23 (-.50)**	.60	.59
End-of-season clipping wt.	Y_3	-14.62	.26 (.38)**		36.45 (.29)	-4.37 (-.55)**		2.64 (.25)						.40	.38
Percent survival, based on clipping weights	Y_4	.60	.005 (.29)		.84 (.28)	-.04 (-.22)		-.09 (-.35)*	-.14 (-.21)					.31	.31
Percent survival based on stocking	Y_5	-.40	.014 (.52)*		1.55 (.31)			.11 (.26)					-.006 (-.46)	.34	.30

* Significant at 0.95. ** Significant at 0.99.

Figure 3.--The combined effects of slope and aspect on survival of trampled vegetation, 1966 data, Cache National Forest, northern Utah.



Trampled vegetation is vulnerable to severe heat and drying. Consequently, survival of vegetation was greatest on northeast (coolest) aspects and decreased as location approached the southwest (hottest) aspects. As shown in figure 3, this effect was accentuated by slope steepness.

The coefficients for elevation were negative (table 1), an indication that the amount of surviving vegetation decreased as elevation increased. Two factors may explain this decrease at higher elevations: the season was shorter than that at lower elevations and the vegetation less well developed at the start of trampling. Apparently the extra precipitation at higher elevations in the area studied did not offset the effects of a late season and low temperatures.

Although percent of clay at a soil depth of 1 to 4 inches was not significant, the coefficient for this variable was positive in all regression models in which it was tested. This indicates that, for the conditions studied, ground-cover vegetation survives best in soils that have a relatively high clay content.

CONCLUSIONS

Although results from a single growing season may not reflect the cumulative deterioration of vegetation in recreational areas over a period of years, several conclusions seem to be warranted:

1. It is possible to develop prediction equations for rating the durability of potential recreation sites. In fact, it may be possible to develop equations that will enable recreation managers to rate site durability from aerial photograph measurements alone. Such measurements would be much less expensive than on-the-ground evaluations. Lindsay (1969) reported that recreation areas could be accurately selected from aerial photos. He used seven criteria for selection. Durability would be an important additional criterion for selection.

2. In the development of equations for recreation site durability, end-of-season stocking seems to be a more effective dependent variable than the end-of-season weight of vegetation or than either the stocking or the clipping weight of treated plots expressed as a percentage of the same measurement for control plots. However, the reader should recognize that stocking measurements can be misleading, especially after a single season of treatment. Vegetation may be severely damaged and still give a high stocking percentage. If damaged plants disappear in subsequent seasons, first-year stocking measurements will not have given a valid indication of long-term site durability.

3. Use of a concrete roller to simulate trampling was effective. Simulation procedures permit the researcher to select the range of site conditions he wishes to examine and yet avoid the great variability associated with actual recreational use.

4. If simulated trampling is used to study areas grazed by livestock or wildlife, plots should be fenced.

5. Finally, it would be desirable to rate site durability under natural conditions and also under conditions of management. This is being done in a continuation of the study reported here.

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Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
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USDA Forest Service
Research Note INT-118

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NORTHERN IDAHO PONDEROSA PINE RACIAL VARIATION STUDY--50-YEAR RESULTS

R. J. Steinhoff[1]

ABSTRACT

Ponderosa pine trees from 19 geographic sources planted on a test area in northern Idaho have been measured 12, 20, 40, and 50 years after outplanting. From the 12th through the 50th years after outplanting, trees from one nonlocal source have been tallest. Trees from the local source now rank second in height, having risen from sixth during the last 10 years. In general, trees from sources close to the test area have performed better than those from more distant sources.

Studies of racial variation in ponderosa pine were begun on the Priest River Experimental Forest in northern Idaho in 1911. A single plantation consisting of 22 unreplicated plots representing as many provenances was established during the years from 1911 to 1917 using 2- or 3-year-old stock. The locations of 19 of the provenances represented in these plots are shown in figure 1; plots for the other three have been discarded for study because the stock was killed by freezing on one plot in 1924 and the source data for the trees on the other two plots are questionable.

In 15 of the 19 plots, which are 50 feet square, 100 trees were planted, while in the other plots, which are 25 by 50 feet, 50 trees were planted. All of these trees were planted using a spacing of 5 by 5 feet.

The trees have been measured four times during the course of the study. Data recorded at 12, 20, and 40 years after outplanting have been reported previously.[2 3 4] The most recent measurements were taken in 1966 when the ages of the trees ranged from 50 to 55 years: the data from these measurements are shown in table 1.

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[1]Associate Plant Geneticist, stationed in Moscow, Idaho, at the Forestry Sciences Laboratory, which is maintained in cooperation with the University of Idaho.

[2]G. Kempff. Non-indigenous western yellow pine plantations in northern Idaho. Northwest Sci. 2(2): 54-58. 1928.

[3]R. H. Weidman. Evidences of racial influence in a 25-year test of ponderosa pine J. Agr. Res. 59(12): 855-887. 1939.

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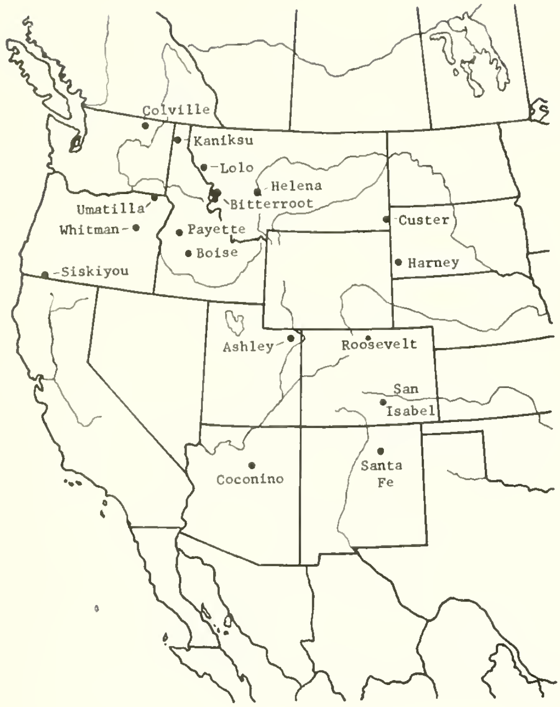

National Forest	Elevation (feet)	Latitude	Longitude
Siskiyou	2,000	42° 05'	123° 40'
Boise	5,500	43° 30'	115° 00'
Payette	5,000	44° 30'	116° 00'
Whitman	5,000	44° 38'	118° 25'
Umatilla	3,500	46° 00'	117° 30'
Bitterroot (1)	4,000	46° 00'	114° 20'
Bitterroot (2)	5,000	46° 00'	114° 20'
Bitterroot (3)	7,200	46° 00'	114° 20'
Lolo	3,000	47° 10'	114° 50'
Kaniksu	2,600	48° 20'	116° 50'
Colville	2,700	48° 40'	119° 00'
Coconino	7,100	35° 10'	111° 50'
Santa Fe	8,000	35° 40'	105° 30'
Roosevelt	8,000	40° 30'	105° 40'
Ashley	7,500	40° 40'	109° 40'
Custer	3,200	45° 30'	104° 00'
Helena	4,500	46° 30'	111° 50'
Harney	5,000	43° 40'	103° 30'
San Isabel	8,000	38° 00'	105° 00'

Figure 1.--Geographic locations of ponderosa pine seed sources represented in plantations on Priest River Experimental Forest (elevation 2,300-2,400 feet; latitude 48°20'; longitude 116°50').

METHODS

For trees over 50 years old, the values were adjusted to a 50-year base; to do this, we multiplied the mean annual height increment during the last 10 years by the number of years over 50 for each tree and subtracted these values from actual heights at time of measurement.

We also used only the tallest one-third of the trees on each plot in developing our analysis in keeping with the approach used by Squillace and Silen.[4] Consequently, among the data presented in figure 2, only those for the 50- and 40-year growth intervals have a common base. The data presented for the 20-year growth interval were based on the dominant trees,[3] while the data for the 12-year growth interval were based on all trees.

Mortality between the 40- and 50-year measurements has been fairly consistent. Death during this period on plots that previously had experienced high survival apparently can be attributed to crowding and suppression; death during this same period on plots that previously had experienced low survival apparently can be attributed to the continued effects of maladaptation.

Table 1.--Percentage of trees surviving and average height and diameter of trees on each plot in 1966

Seed source (National Forest)	Survival[1]	Average height[2]	Average diameter
	Percent	Feet	Inches
Siskiyou	4	64.4	12.2
Boise	16	64.3	11.5
Payette	4	52.5	9.8
Whitman	20	63.8	12.1
Umatilla	36	68.7	11.7
Bitterroot (1)	14	60.4	9.7
Bitterroot (2)	24	62.8	8.8
Bitterroot (3)	4	63.0	11.2
Lolo	14	76.4	13.1
Kaniksu	25	69.6	11.8
Colville	29	64.5	11.1
Coconino	10	49.8	10.1
Santa Fe	4	40.3	7.9
Roosevelt	12	41.4	7.4
Ashley	6	41.3	7.4
Custer	17	66.7	12.0
Helena	22	58.4	7.1
Harney	5	42.1	6.4
San Isabel	14	51.3	8.4

[1]For the Whitman, Umatilla, Roosevelt, and San Isabel sources, value is twice the number of trees surviving; for the other sources, value equals the number surviving.

[2]Average of the tallest one-third of the trees (at least two trees).

RESULTS AND DISCUSSION

About half of the trees have maintained their same relative height ranking throughout the period from 12 years after outplanting to the present. For example, the Lolo source has been the tallest throughout this period, while the Santa Fe and Ashley sources have consistently been the shortest. Changes in rank of only one or two positions are probably of little significance because of the low numbers of trees surviving on some plots.

The Coconino source was a fast starter: Kempff reported that it was tallest during the first 6 years, however, it slipped to 11th at 12 years;[2] and it is now 15th. The local Kaniksu source was about average during the first 20 years, but its growth since then has exceeded that of all but the Lolo source, and the Kaniksu source is now the second tallest.

The Custer and Harney sources grew similarly during the first 20 years, starting slightly above the median and then dropping a little below. However, the Harney source then dropped to near the bottom where it has remained, while the Custer source moved up during the period between the 20- and 40-year measurements, and it is now fourth.

The only surviving coastal source, Siskiyou, started slowly, then did well up to 40 years, but has fallen off slightly in the last 10 years.

Three of the sources that ranked in the top five at 12 years are still in the top five, but only two that ranked in the top five after 20 years still rank there. Only four of the sources in the top five at 40 years are still in the top five at 50 years;

Ranking of sources by height at various times after outplanting.

50 years	6	7	13	8	3	5	2	1	11	10	9	15	19	12	4	16	17	14	18
40 years	2	10	13	11	3	5	6	1	6	8	9	15	18	12	4	17	16	14	19
20 years	4	6	13	11	10	3	9	1	2	4	6	16	19	8	14	12	17	15	18
12 years	13	14	12	17	2	5	9	1	3	6	10	11	18	4	7	8	16	15	19

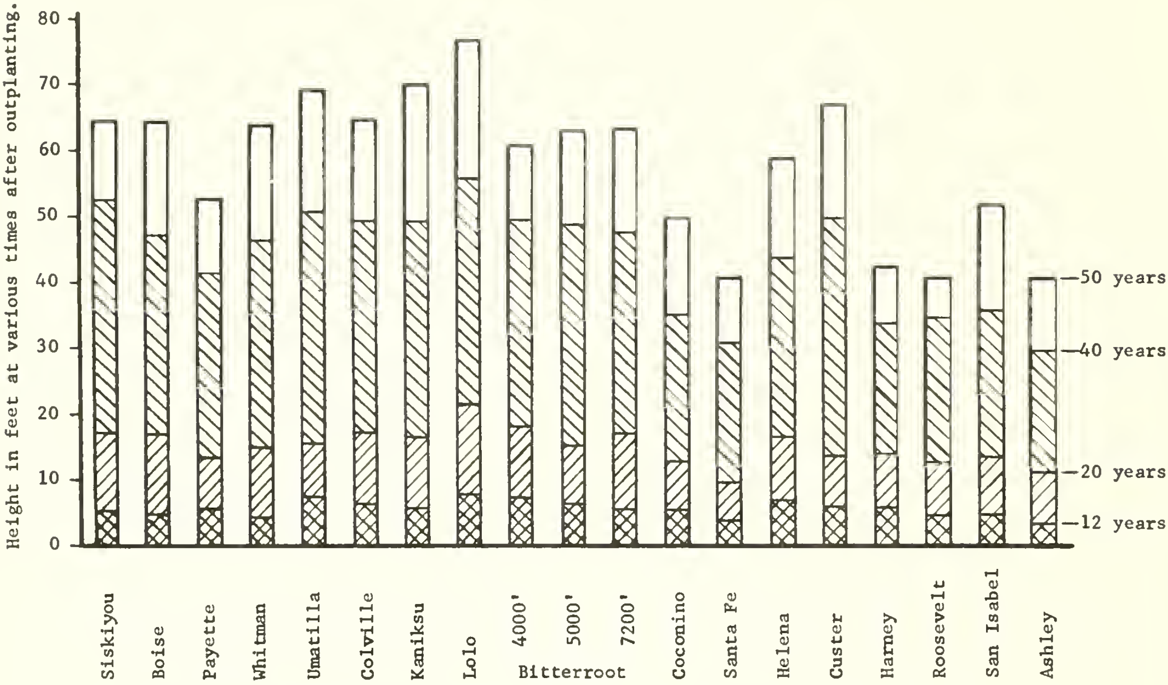

Figure 2.--Height of sources (bar graph) and ranking by height (tabulation above) at various points in time after outplanting.

the number 2 source at 40 years has dropped to sixth and another (Kaniksu), which was tied for sixth at 40 years, has moved to second.

Trees of the tallest source (Lolo) also have the largest diameters. The trees of the taller sources and the taller trees within sources generally have larger diameters than the trees of shorter sources or the shorter trees within sources.

CONCLUSIONS

Evaluation of the data with regard to the ever-present question of the importance of local, as opposed to introduced seed, is not as clearcut as it may seem. The lack of replication precludes separation of variation due to the experimental conditions from that due to inherent differences among sources. Even the Kaniksu source, although local in the usual geographic sense, may not be adapted to the particular site. While the nonlocal Lolo source has produced the largest trees so far, the positions could change by the time of harvest. We have no way of knowing whether some other local collection might do as well as or even better than the Lolo source. However, the Lolo source has been consistently best and has increased its height superiority during the past 10 years and may truly be more productive than any local source.

Because of the differences in survival between plots, the Kaniksu plot contains a larger volume of timber than the Lolo plot even though the individual trees on the Kaniksu plot are smaller than those on the Lolo plot. However, the Umatilla plot is the most productive because it contains more trees of approximately the same size than does the Kaniksu plot.

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
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SHADE INCREASES FIRST-YEAR SURVIVAL OF DOUGLAS-FIR SEEDLINGS

Russell A. Ryker and Dale R. Potter[1]

ABSTRACT

On a clearcut area of the Boise National Forest in Idaho, shading doubled first-year percent survival of Rocky Mountain Douglas-fir [Pseudotsuga menziesii *var.* glauca *(Beissn.) Franco*]. *The mortality rate among seedlings on unshaded plots was relatively constant throughout the growing season, but among seedlings on shaded plots, dropped sharply by mid-August.*

SEEDLING DISTRIBUTION SUGGESTS NEED FOR SHADE

In an effort to define regeneration problems of Rocky Mountain Douglas-fir [*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco], the senior author has examined numerous clearcut areas (1-15 years of age) throughout the National Forests of central and southern Idaho and Utah. In every case, acceptable numbers of Douglas-fir seedlings grew only within the partially shaded area at the timber's edge. No seedlings were found elsewhere on these openings, unless they were protected by shrubs and residual trees, by considerable amounts of logging debris, and/or by standing dead trees. This generality held regardless of aspect, but was less pronounced on steep north-facing slopes.

Similar findings have been reported for the Pacific Coast Douglas-fir [*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco]. Sprague and Hansen[2] found Douglas-fir reproduction concentrated on the northeast sides of scattered oak trees growing on a southwest slope in Oregon. According to these men, clumps of reproduction are well defined; only an occasional seedling grows beyond the area shaded by a tree during the hottest part of the afternoon. Isaac[3] stated that regeneration of Pacific Coast Douglas-fir is benefited by light vegetative cover (up to 25 percent), impaired by cover greater than 25 percent, and practically prohibited by cover exceeding 80 percent. He also observed more natural restocking within shadow lines along the southerly edges of clearcut areas.

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[1] The senior author is a Silviculturist, stationed at Boise, Idaho; the junior author is now a Forestry Research Scientist for the Pacific Northwest Forest and Range Experiment Station and is stationed in Seattle, Washington.

[2] F. LeRoy Sprague and Henry P. Hansen. Forest succession in the McDonald Forest, Willamette Valley, Oregon. Northwest Sci. 20(4): 89-98. 1946.

[3] Leo A. Isaac. Where do we stand with Douglas-fir natural regeneration research. Soc. Amer. Forest. Proc. 1955: 70-72. 1956.

Krauch[4] reported that Douglas-fir seedlings in Arizona and New Mexico require shade--especially during the first season. In a study evaluating cutting methods in Colorado, Roeser[5] found that shelterwood- and selection-cutting permitted more Douglas-fir seedlings to become established than clearcutting. Apparently, seedlings of both Douglas-fir varieties benefit from some shade during their early years, and this is probably true for transplanted trees as well.

The research upon which this note is based was initiated the summer of 1968 to determine the effect(s) of shade on the survival rate of young Douglas-fir trees through the first three growing seasons. We chose as our study plot a spot-seeded area on the Garden Valley Ranger District of the Boise National Forest in Idaho. Our objectives were to see whether shading contributed to seedling survival on that particular area and to establish the best time(s) of year to make reliable survival counts.

STUDY AREA

The 10-acre area selected for trial seeding and planting appeared to be one of the District's better sites for Douglas-fir. Before being clearcut and seeded, it supported a mixed stand of Douglas-fir, ponderosa pine, and grand fir. Willow, bitter-cherry, and maple dominated a heavy shrub understory. The soil, a sandy loam, was derived from granitic parent material. The seeded portion is on a southeast-facing, relatively uniform 40 percent slope.

PROCEDURES

Preparations for the seeding and planting trials began the summer of 1967. Slash was lopped and later burned and the study site stripped by tractor to mineral soil. Seeding was done during mid-October.

In July 1968, 80 seed spots were located and marked. These marked places--each of which supported 2 to 38 seedlings--represented 80 percent of the total population of recognizable seed spots.

Twenty randomly selected spots were covered by 2-foot-square lath screens that stood 1 foot above the ground surface and provided shade about 50 percent of the time (fig. 1). Also, all seed spots were kept weed-free during the remainder of the growing season to negate the influence of competition.

In order to evaluate the treatments' effects, we made seedling counts every 2 weeks from July 3 until September 12, 1968.

Four seed spots, to be used throughout the study, were randomly selected for soil tests. On each measurement day, samples from soils adjacent to these spots were taken from 4- to 6-inch and 8- to 10-inch depths. Soil moisture content was determined gravimetrically. In order to relate soil moisture content to the amount of moisture available to the trees, we determined the moisture-holding capacity of the soil at 15 atmospheres of tension by means of a pressure membrane apparatus.

We assumed that the major effect of shade would be to reduce soil surface temperatures. To determine the amount of reduction, we measured temperatures at four shaded spots by means of a thermistor probe and telethermometer (fig. 2). Soil surface temperatures were measured: (1) in the open, 1 foot from each screen; (2) on an unshaded strip beneath each lath screen; and (3) on a shaded strip beneath each screen. Temperature measurements were made during the early afternoon hours on clear days only. Consequently, we have data for only three of the six measurement dates.

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[5]Jacob Roeser, Jr. A study of Douglas-fir reproduction under various cutting methods. J. Agr. Res. 28: 1233-1242. 1924.

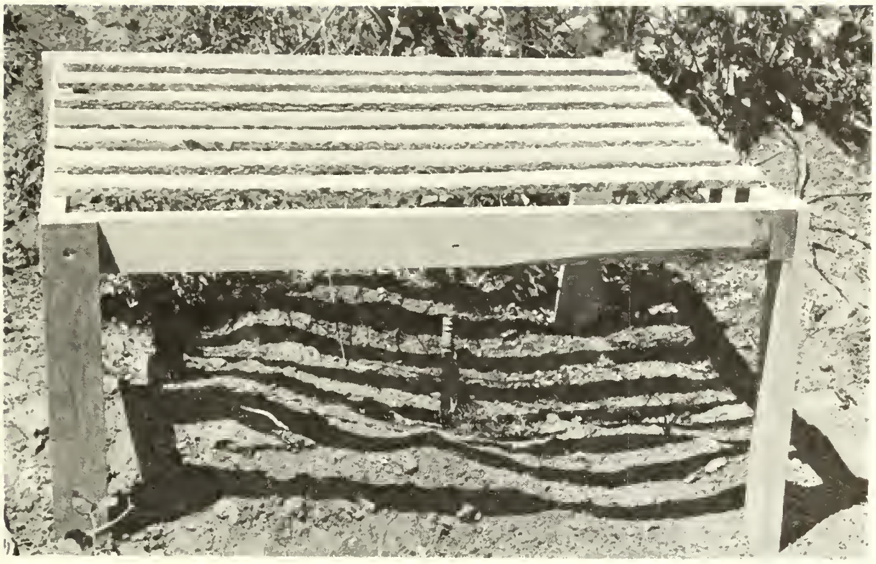

Figure 1.--Lath shade frames used for shading seed spots. Laths 1-1/2 inches wide were spaced 1-1/2 inches apart.

Figure 2.--Soil surface temperature is measured in the open next to a shade screen.

RESULTS

By mid-August, the mortality rate of shaded seedlings was close to zero, but (except for a 2-week rainy period) that of unshaded seedlings was relatively constant until mid-September. On September 12, 1968, percent survival of shaded seedlings was more than twice that of unshaded seedlings (fig. 3). The *t* test shows this difference to be highly significant.

Throughout the measurement period, soil moisture content remained well above the soil's moisture-holding capacity at 15 atmospheres of tension (fig. 4).

Shade screens effectively reduced soil surface temperatures (fig. 5). The day (August 1) that we obtained the highest readings, early-afternoon temperatures averaged 142°F. in the open, 126°F. on the unshaded strips, and 100°F. on the shaded strips beneath our screens.

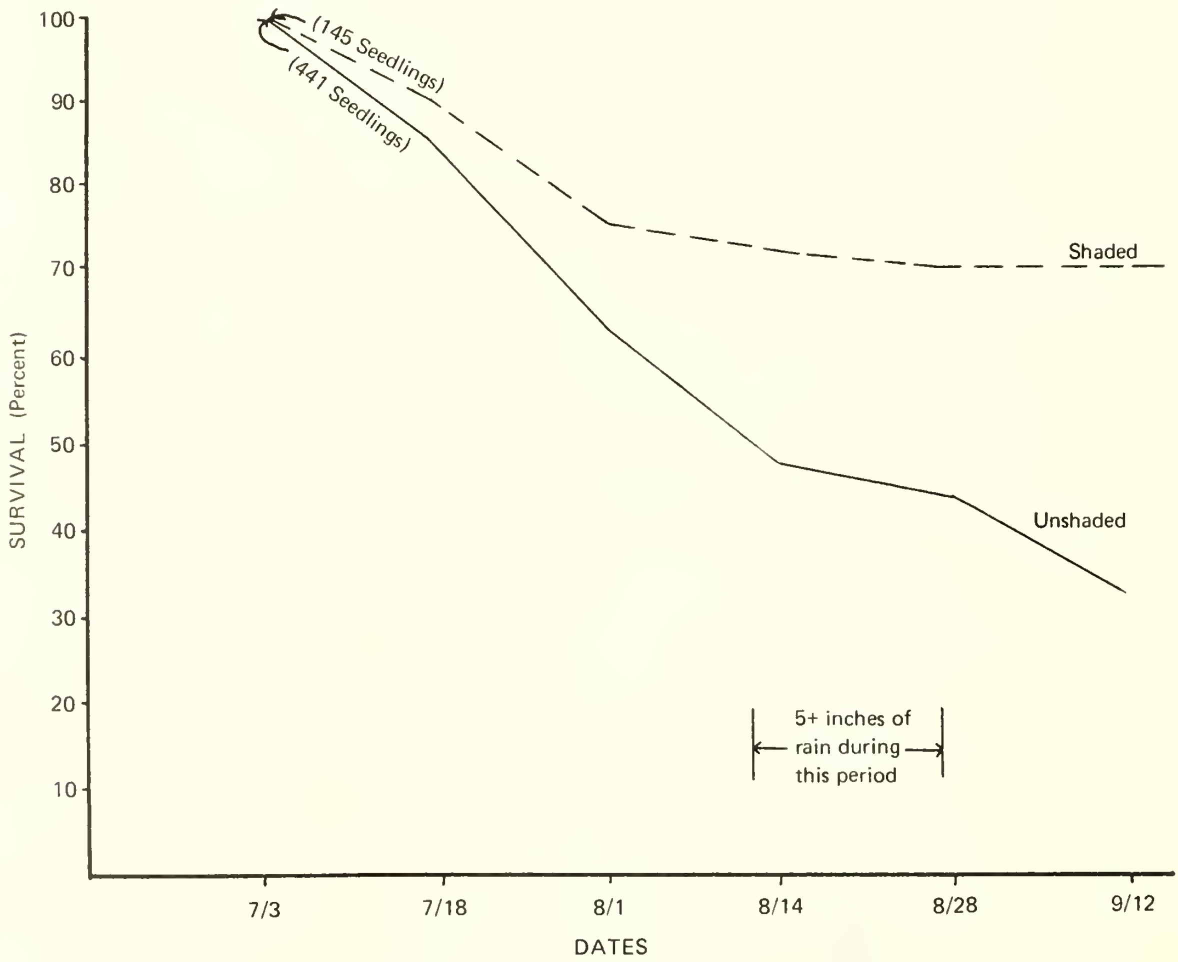

Figure 3.--Percent survival of shaded seedlings was almost twice that of unshaded seedlings late in the growing season (1968).

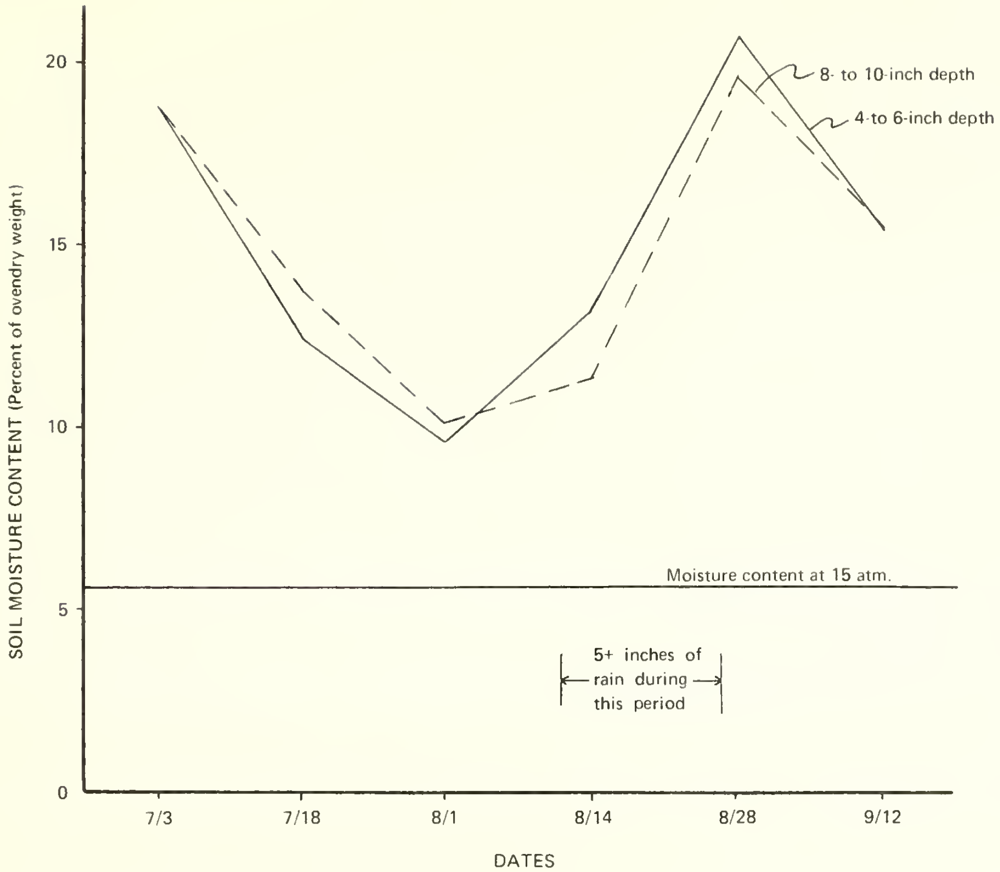

Figure 4.--Soil moisture content remained well above the moisture-holding capacity at 15-atmospheres tension.

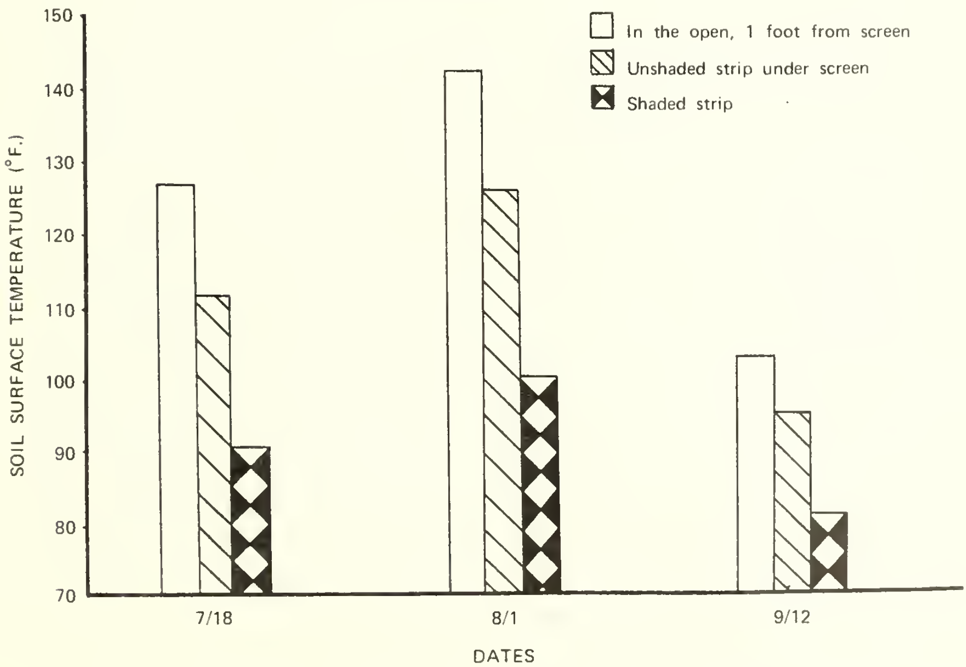

Figure 5.--Shading reduced surface temperatures.

CONCLUSIONS

Data obtained from this study support the contention that partial shade encourages establishment of Rocky Mountain Douglas-fir seedlings. Higher seedling survival rates attributed to shade probably did not result solely from reduced surface temperatures and soil moisture losses; unshaded seedling deaths continued at a relatively constant rate throughout the growing season, even though soil moisture content remained well above the 15-atmosphere level and surface temperatures decreased in early September.

Hodges and Scott[6] recently reported daily rates of net photosynthesis for seedlings of six conifer species. For four species (western hemlock, grand fir, sitka spruce, and West Coast Douglas-fir) these daily rates were highest in trees on the outer margin of the study stand. For the other two species (Scots pine and Noble fir), rates were highest in trees exposed to full sunlight.

It seems likely that a metabolic imbalance caused by internal moisture stress led to the high late-season mortality rate observed during the study reported here. Lath screens probably prevented a buildup of moisture stress in our seedlings and consequently bettered the likelihood of their survival. Shading evidently lowered leaf temperature relatively more than air temperature, thereby reducing water loss and the resultant moisture stress, and increasing net photosynthesis and probability of seedling survival.

Research is needed to determine the amount of shade required by Douglas-fir seedlings growing under various site conditions and to define the process by which shade affects seedling survival and growth.

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[6]John D. Hodges and David R. M. Scott. Photosynthesis in seedlings of six conifer species under natural environmental conditions. Ecology 49: 973-981. 1968.

Research Note

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SOME VARIATION OF TERPENES IN MONTANA LODGEPOLE PINE

James E. Lotan and N. Mason Joye, Jr.[1]

ABSTRACT

Intraspecific variation was found in the terpene fraction of oleoresin of Pinus contorta *near Bozeman, Montana. There was a tendency towards* P. banksiana-*type terpenes in 3 trees out of 11 sampled. In these trees α-pinene or β-pinene was the predominant terpene. The "typical" lodgepole pine terpene--β-phellandrene--varied from 8 to 83 percent among the 11 trees.*

Certain extraneous substances can be useful in understanding the origin, development, and relationships of species within a genus, and Mirov (1967) has been a leader in studying these relationships for the turpentine composition of the genus *Pinus*. However, sampling has been inadequate as he readily admitted. Population studies are needed to define "typical" compositions for the various species, subspecies, and varieties involved. Inadequate sampling can give an oversimplified picture of the chemical constituents of a taxon.

According to traditional concepts (Mirov 1948, 1961; Smith 1964, 1967b; Williams and Bannister 1962), the terpene fraction of lodgepole pine (*Pinus contorta* Dougl.) consists primarily of the monocyclic terpene, β-phellandrene. Smith had the advantage of using the gas chromatograph, therefore his work was more precise than the earlier work. Mirov, in his analysis, used steam distillation and the chemical procedures that were conventional at that time. However, there was general agreement in that most of the terpene composition for lodgepole pine was β-phellandrene. Other terpenes, such as

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α-pinene, Δ_3-carene, β-pinene, myrcene, and camphene, were usually never over 10 percent for any single component. Williams and Bannister (1962) had similar results for lodgepole pine grown in New Zealand.

Mirov (1961) reported that the turpentine of jack pine (*P. banksiana* Lamb.) is composed of mostly α-pinene and β-pinene. Further, he had reported earlier (Mirov 1956) that natural hybrids of *P. contorta* and *P. banksiana* tended to be intermediate in terpene chemistry. Smith (1967a) reported similar intermediate traits in artificial hybrids in California.

More recently, Zavarin, Critchfield, and Snajberk (1969), in comparing turpentine composition of *P. contorta* X *banksiana* hybrids with that of jack pine and lodgepole pine have shown evidence of possible introgression[2] of jack pine into lodgepole pine. Rocky Mountain lodgepole pine apparently has a tendency to deviate from "lodgepole pine" towards "jack pine" in turpentine composition.

Supporting evidence of this introgression can also be found in older studies. Mirov (1956) found that individual lodgepole pines, 30 to 50 miles outside the range of jack pine, possessed a range of physical properties of turpentine samples characteristic of both lodgepole pine and jack pine. Critchfield (1957) proposed the possibility of introgression in lodgepole pine based upon "jack pine-type" cone orientation in the northeastern part of the range of lodgepole pine.

We sampled 11 lodgepole pine trees in the northern Rocky Mountains in Montana using a technique similar to Smith's (1961) closed-face microtap. The samples were analyzed by gas chromatography and, in support of Zavarin, Critchfield, and Snajberk (1969), we found the terpene composition had a tendency to deviate from "typical" lodgepole pine among a relatively small number of trees. The percentage of β-phellandrene in the terpene fraction varied considerably more than that usually reported for *P. contorta*. When the β-phellandrene percentage was low, either α-pinene, β-pinene, or Δ_3-carene was high.

EXPERIMENTAL

Oleoresin was collected from the tree bole 4.5 feet above the ground with closed-face microtaps from 11 dominant or codominant lodgepole pine (*P. contorta* var. *latifolia* Engelm.) in Hyalite Canyon 10 miles south of Bozeman, Montana. Some of the trees were young and vigorous: trees 1-5 and 11 (20-38 years old, 3-6 inches d.b.h., and 16-46 feet tall). The others were mature or overmature: trees 6-10 (73-171 years old, 10-19" d.b.h., and 45-90' tall).

The freshly collected oleoresin was stored under an inert atmosphere at -5° C. The terpene analyses were run on two columns in order to separate all of the components:

(1) a 15-foot X 3/16-inch 10 percent Versamid 900 column at 115° C., and

(2) a 12-foot X 3/16-inch 20 percent Carbowax 20M column at 115° C.

Conditions for operation of the F and M Model 700 gas chromatograph were:

Injector temperature.	300° C.
Column temperature.	115° C.
Detector temperature.	300° C.
Helium flow	150 ml./min.
Sample size	0.5-3.0 μ liter
Solid support	60/80 mesh Diatoport S.

[2]The spread of genes away from an area of natural hybridization.

Table 1.--*Terpene composition of lodgepole pine oleoresin from Montana, 1970.*

Tree number	α-pinene	Camphene	Myrcene	β-pinene	Δ_3-carene	α-terpinene	Limonene	β-phellandrene	p-cymene	Allo-ocimene
	Percent									
1	[1]2	1	3	13	57*	4	1	8	4	9
2	9	[2]Tr	5	14	10	-	3	59*	Tr	-
3	4	1	4	8	17	-	-	64*	3	-
4	10	2	1	58*	7	-	2	20	2	-
5	7	Tr	3	28	27	-	2	32*	Tr	2
6	5	1	4	13	25	-	1	49*	2	-
7	2	Tr	3	7	3	2	1	83*	2	2
8	50*	Tr	3	6	27	Tr	1	11	Tr	-
9	5	Tr	1	13	10	Tr	2	65*	7	-
10	6	Tr	3	32	2	Tr	2	54*	-	-
11	9	Tr	2	52*	6	-	1	23	-	-
Average	10	Tr	3	22	17	Tr	1	42	2	1
Range	2-50	Tr-2	1-5	6-58	2-57	0-4	0-3	8-83	0-4	0-9

[1]The combined, corrected, or averaged values from both columns used.
[2]Trace values less than 1 percent.
* Major constituent.

Myrcene and Δ_3-carene do not separate on the Carbowax column so these were determined on the Versamid column. The Carbowax column was better than the Versamid column in separating β-pinene. Thus, both columns were used and the results were combined, corrected, and averaged.

RESULTS AND DISCUSSION

The major terpene constitutents of the trees sampled were β-phellandrene, Δ_3-carene, α-pinene, and β-pinene (table 1). The percentage of β-phellandrene (the "typical" lodgepole pine terpene) varied from 8 to 83 percent. In fact, for these samples, β-phellandrene was the major constituent in only 7 trees out of the 11. For the remainder, in 2 trees, the largest peak was β-pinene. In one it was α-pinene. In one it was Δ_3-carene. Other terpenes found in lesser amounts were camphene, myrcene, α-terpinene, limonene, p-cymene, and allo-ocimene; generally, these were on the order of a few percent when present.

This variation in terpene constituents, especially in trees 4, 8, and 11, supports the hypothesis of Zavarin, Critchfield, and Snajberk (1969), that the terpenes of lodgepole pine have been genetically influenced by jack pine at some distance from the zone of overlap. The range in percentage of β-phellandrene is considerable, and usually when β-phellandrene is low there is a corresponding rise in either Δ_3-carene, α-pinene, or β-pinene.

There is a difference in the way the data are presented here, and in the paper by Zavarin, Critchfield, and Snajberk (1969). These data are presented as a percent of the terpene fraction as compared to Zavarin's percent of total resin. However, one can readily see that here in the Montana trees we have α-pinene and β-pinene (the "jack pine" terpenes) showing up strongly in a lodgepole pine population some 600 miles from the nearest jack pine.

Zavarin, Critchfield, and Snajberk (1969) made an excellent review of current thinking on natural hybridization and introgression of these two interesting species. Apparently, our data support their thinking.

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PREDICTION OF HERBAGE YIELDS OF TALL BLUEBELL AND WHITE POLEMONIUM FROM HEIGHT OF AND NUMBER OF STEMS

W. A. Laycock[1]

ABSTRACT

Presents regression equations for predicting herbage yields of tall bluebell (Mertensia arizonica *var.* leonardi) *and white polemonium* (Polemonium foliosissimum) *using the interaction of height x number of stems. Equations are intended to serve as a guide for future studies, and not for use as predictive purposes generally, or for other species.*

In studies where individual plants are observed over several years, a method of assessing growth or production must be used that does not damage the plant and possibly influence future observations. A measurement of the total yearly production of herbaceous plants often is desired, but this is difficult to obtain accurately without clipping the plants. Visual estimates of weight can be made, but such a technique requires considerable training.

Methods of predicting yields, mainly of grasses, from easily measured plant characteristics, such as leaf or culm height, basal area, and number of culms, were summarized by Wright.[2] At the same time, he reported that individual plant weights of two bunchgrasses, *Stipa comata* and *Sitanion hystrix*, could be predicted accurately from the number of culms, leaf length, and the interaction between these two characteristics.

Study Procedures

The study was conducted in two forb-dominated openings in aspen rangeland at 8,300 feet elevation on the Uinta National Forest, Wasatch County, Utah. The annual precipitation for the area, based on short-term records, ranges between 27 and 39 inches, about 75 percent of which occurs as snow from October through May. Soils are about 5 feet deep with well developed silt loam A horizons.

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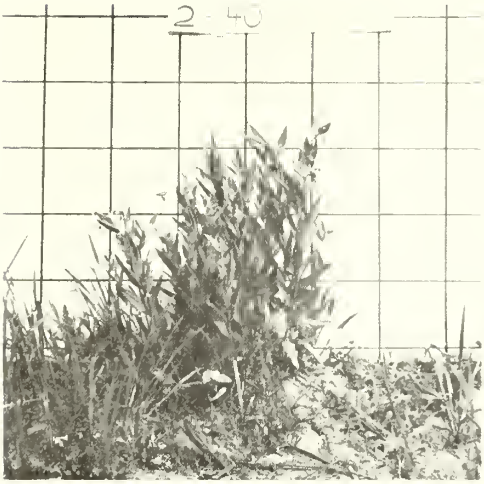
[1]Dr. Laycock is a Plant Ecologist, stationed in Logan, Utah, at the Forestry Sciences Laboratory, maintained in cooperation with Utah State University.

[2]Henry A. Wright. Predicting yields of two bunchgrass species. Crop Sci. 10: 232-235, illus. 1970.

Figure 1.--Growth of bluebell plants in 1967 showing high vigor and production of unclipped check plant (A) compared with lower production of those with 40 percent (B) and 70 percent (C) of the foliage removed in early flowering stage from 1963-1966.

A



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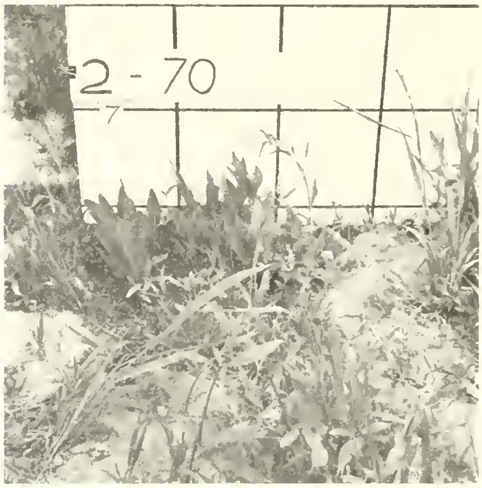

C

The species studied were tall bluebell (*Mertensia arizonica* var. *leonardi*) and white polemonium (*Polemonium foliosissimum*). Both are nonrhizomatous species in which a closely spaced cluster of flowering stems constitutes an easily identifiable plant. The plants were harvested in July 1967 at the termination of a clipping study in which the effects of time and intensity of foliage removal on production were reported.[3]

Fifty-two bluebell plants from the two sites were evaluated. Twelve were check plants that had not been clipped; the rest had been clipped at various levels for 4 consecutive years, 1963-1966. Nineteen polemonium plants from only one of the two sites were studied, six of which were unclipped check plants.

Depending upon the severity of the foliage removal, the clipped plants were lower in production and had fewer, shorter stems than the unclipped check plants (fig. 1). Plants that were so low in vigor that they produced only basal leaves and no definite stems were excluded.

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[3] W. A. Laycock and P. W. Conrad. How time and intensity of clipping affect tall bluebell. J. Range Manage. 22: 299-303. 1969.

In late July 1967, after the plants had attained full growth, the number of stems was counted and the average stem height was measured for each plant. For bluebell, the height of the third tallest stem was also measured to get the average stem height. There are usually one or two stems longer than the rest and the third tallest stem could be measured easier and more accurately in the field. Polemonium has fewer stems than bluebell and the average height can be determined easily. After these stems were counted and measured, the plants were cut at ground level and the green and ovendry weights were determined.

Data for each species were analyzed by stepwise multiple regression using ovendry weight as the dependent variable, while the number of stems, the average or third tallest stem height, and the linear interaction of these (height x number) were used as independent variables.

RESULTS

For both species, the simple interaction between stem height and number accounted for more than 90 percent of the variance in dry weight. For bluebell, the coefficient of determination (R^2) for the simple linear regression between weight and this interaction was 0.92. The addition of number and height of stems as independent variables only increased the value to 0.94. For polemonium, the coefficient of determination was 0.97 for the simple regression using the interaction variable and 0.98 when the stem number and height variables were added. For both species, the additional variables resulted in little or no reduction in the standard error.

Figure 2A shows the individual data points for bluebell at both sites. It also shows the regression line and the confidence limits at the 95-percent level for the mean and for individual observations. Initially, the regressions were calculated separately for the two different sites; however, the data were combined because the regression coefficients and formulae were similar:

Site 1: $\hat{Y} = 0.0661X - 22.61$; standard error of the predicted mean = 5.21

Site 2: $\hat{Y} = .0642X - 11.46$; standard error of the predicted mean = 2.98

Combined: $\hat{Y} = .0638X - 14.72$; standard error of the predicted mean = 2.94

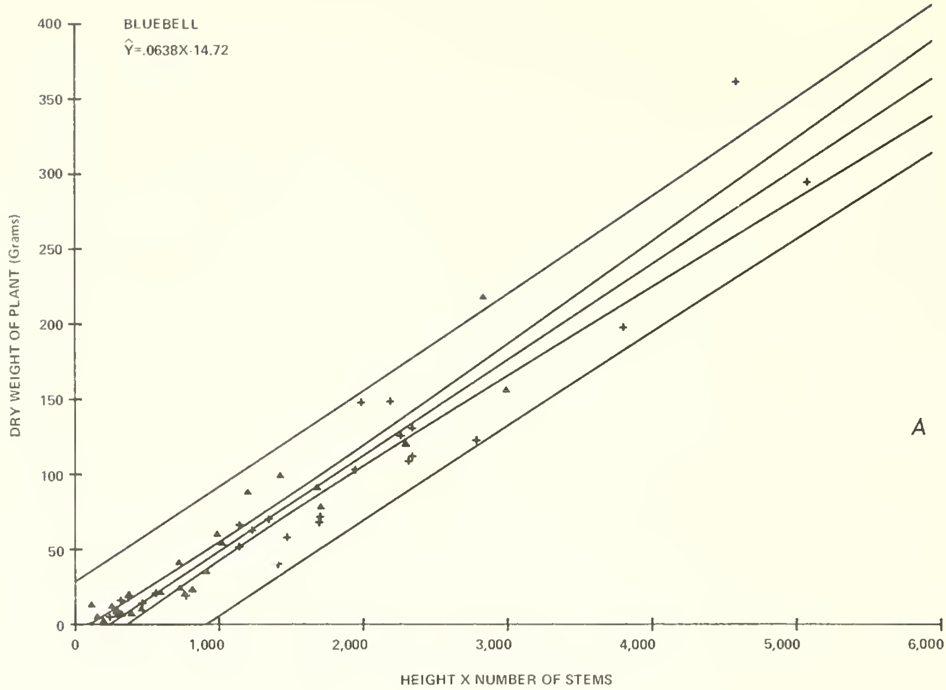
where: $\hat{Y}$ = predicted dry weight in grams and X = height of third tallest stem x number of stems.

Figure 2B shows the simple regression between dry weight and the interaction of stem height and number for polemonium. The presence of the three large plants shown by the points in the upper right portion of the figure obviously increased the degree of correlation. To determine the effect on the regression coefficient, the analysis was repeated without these three plants. The coefficient of determination (R^2) was reduced from 0.97 to 0.88 but the regression coefficient and formula remained essentially unchanged:

Original: $\hat{Y} = 0.1328X - 5.94$; standard error of the predicted mean = 1.22

Amended: $\hat{Y} = .1293X - 5.59$; standard error of the predicted mean = 1.02

The coefficients of determination and the confidence intervals are somewhat biased because of the skewed distribution of plants of various sizes in both species. Log transformation of the data resulted in a more normal distribution of plant sizes and lowered the coefficients of determination slightly ($R^2 = 0.90$ for bluebell and $R^2 = 0.94$ for polemonium).



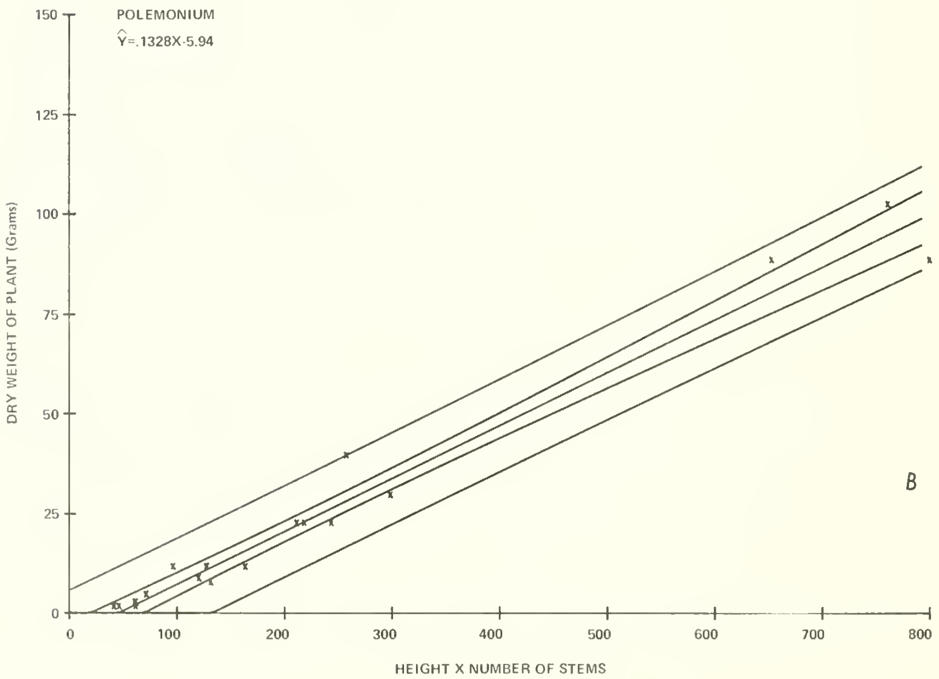


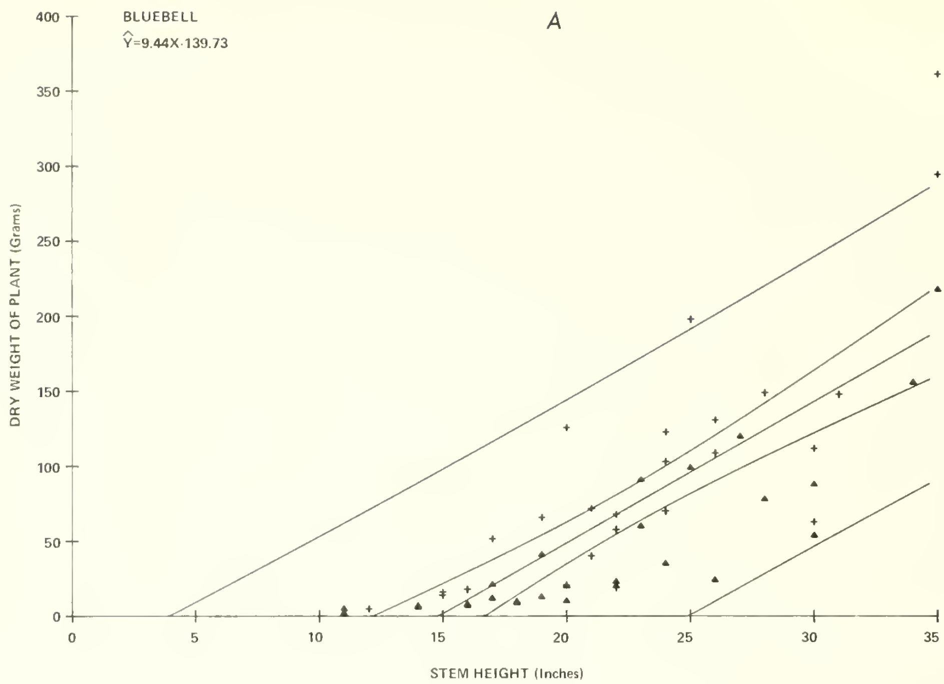
Figure 2.--Relation of plant weight to the linear interaction of stem height and number (height x number) for bluebell (A) and polemonium (B). Confidence limits at the 95-percent level are shown for the mean and for individual observations of plant weight for a given value of height x number.

Table 1.--*Simple correlation (r) between weight and stem height and number for tall bluebell and white polemonium; all are significant at the 99-percent level of probability*

Weight	Stem height	No. of stems	Height x number
		BLUEBELL	
Green	[1]0.81	0.84	0.94
Dry	[1].79	.87	.96
		POLEMONIUM	
Green	[2].76	.96	.99
Dry	[2].76	.97	.99

[1]Height of third tallest stem.
[2]Average height of all stems.

The relationships between height and weight and between number of stems and weight were investigated separately. The simple correlation coefficients were significant well beyond the 99-percent probability level for both species (table 1) but were not as high as the coefficients between weight and the interaction. In spite of the high linear correlation, it appears that the relationship between weight and stem height (fig. 3A), and perhaps between weight and number of stems (fig. 3B), may not be linear. However, further investigation of stem height or number as separate variables in a prediction equation seemed to be unnecessary because the predictive value of the height x number interaction was so great.



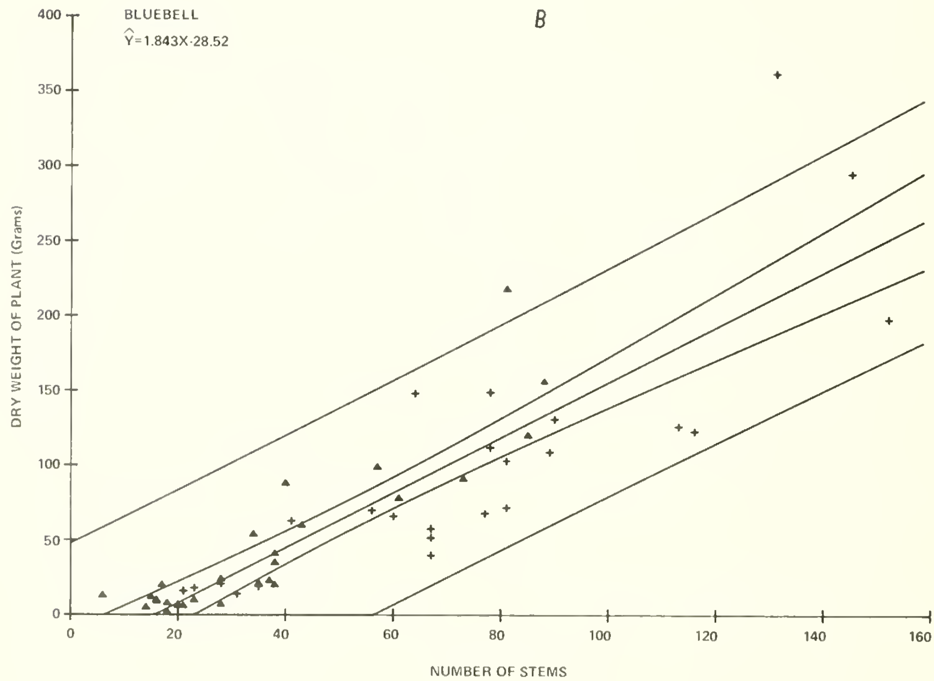


Figure 3.--Relation of plant weight of tall bluebell to stem height (A) and number of stems (B). Confidence limits at the 95-percent level are shown for the mean and for individual observations of plant weight for a given height or stem number.

DISCUSSION

Weights of bluebell and polemonium plants can be predicted with a high degree of accuracy using the interaction of height x number of stems in a regression equation. Weights of other species with similar growth forms undoubtedly could be studied in a similar fashion.

The equations presented in this paper are intended to be used solely as a guide to future research and are not intended to apply to the two species generally, or to other species. However, it is interesting to note that bluebell plants from two different sites yielded similar regression formulae.

Others using these techniques would have to develop predictive equations for the population of plants sampled. If the population consisted of all vigorous, high-producing plants with large numbers of tall stems, the equations would be quite different from those presented here because these were derived from a population of plants with wide ranges in production, height, and number of stems. If distribution of plant sizes were skewed, as in this study, a log or some other transformation might be desirable before attempting regression analyses. In addition, new formulae might have to be developed each year because production of plants differs from year to year as a result of climate. Wright[4] found that regression equations for predicting weight of two species of bunchgrass from numbers of culms and leaf length differed considerably in 2 consecutive years.

Caution must be used in application of such techniques. Even with a correlation as high as I found, the predicted weight of a single plant from its height and number of stems can be quite variable. At the mean value of height x number (1,337) the actual mean weight of a population of bluebell plants will be within 8 percent of the predicted mean (70.7 ± 5.9 grams) 95 percent of the time. However, the actual weight can vary as much as 61 percent from the predicted mean (70.7 ± 43.0 grams) for any one individual plant having the same combination of height and stem number. This means that height must be measured and stem number counted for several plants to get a reasonably accurate predicted weight. The number needed would depend upon the variability of the population sampled.

Use of other plant characteristics to determine weight might have applications in ecological studies beyond that of determining weight of specific plants over a period of years. For example, in autecological studies, growth curves usually are based on increase in height because height can be measured without destroying the plant. If height and number of stems were highly correlated with weight in different stages of growth, growth curves based on increase in dry matter over time would be possible.

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[4]See footnote 2.

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CONSTRUCTION OF A FINE FUEL IGNITION FURNACE

D. S. Stockstad and E. C. Lory[1]

ABSTRACT

A furnace capable of producing either spontaneous or pilot ignition and measuring temperatures at which these ignitions occur has been designed and constructed for use in ignition studies of fine forest fuels. One-inch-long sections of conifer needles, grass stems and leaves, and rotten wood represent the type of fuels capable of being ignited and tested in this furnace. Time-temperature relations for the ignition process of various fuels may be determined by using a three-channel plotter on which thermocouple traces for temperatures of the ignition chamber and fuel sample are recorded.

Determinations of total heat-flux output of the furnace and various methods of heat transfer were determined for an airflow of 5 liters per minute; convective heating contributed 55.4 percent and radiative heating contributed 44.6 percent.

Studies to investigate the ignition properties of fine forest fuels required the design and fabrication of an ignition-producing heat source. A review of research that has been conducted on the ignition of cellulosic materials revealed that a variety of ignition-producing devices were used by previous workers. These devices varied widely as to type of heat source utilized and manner in which ignition was accomplished.

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[1]Respectively, Research Forester, stationed in Missoula, Montana, at the Northern Forest Fire Laboratory; and Professor of Chemistry, University of Montana, Missoula.

The use of trade names herein is for identification only and does not imply endorsement by the USDA Forest Service.

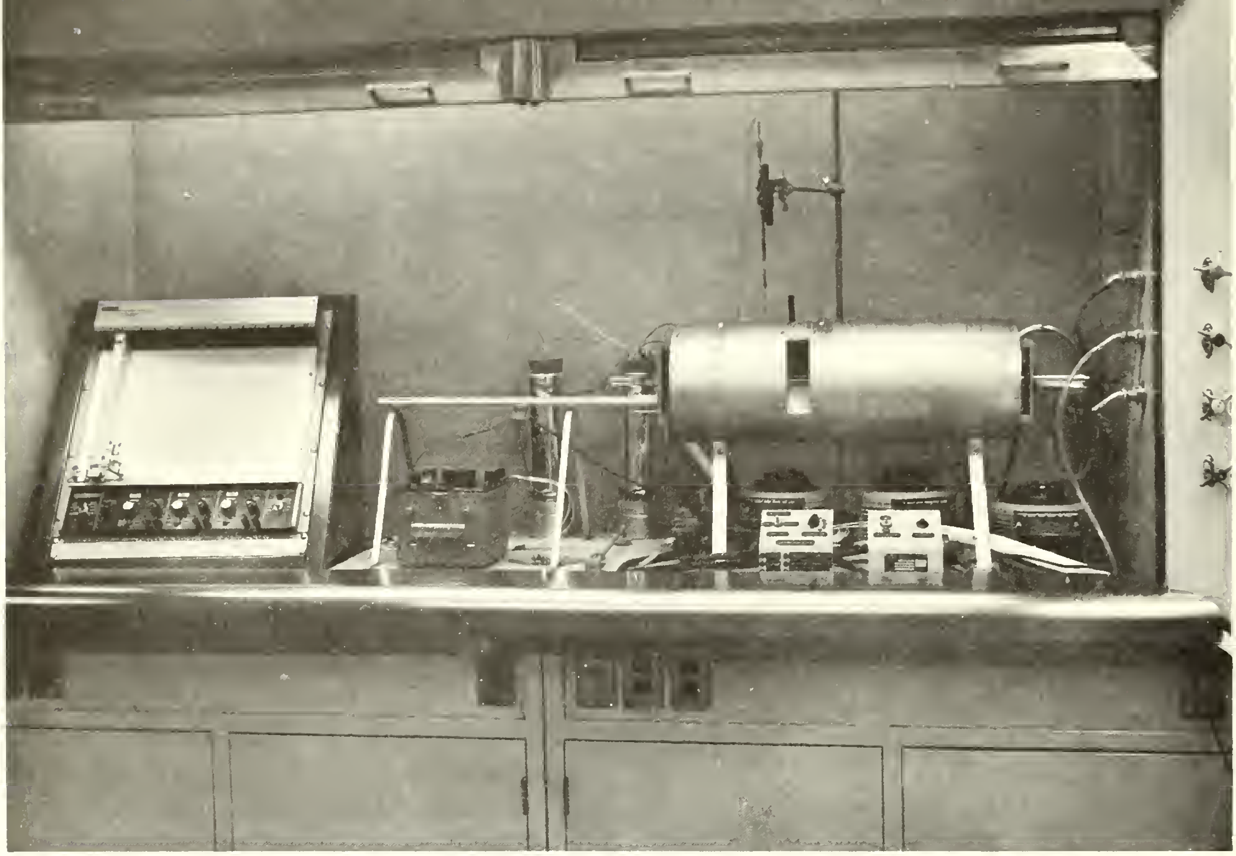

Figure 1.--Ignition furnace assembly.

Prince (1915) used an electric oven at various temperatures to drive volatiles from blocks of wood for ignition by a pilot flame. Doyle[2] and Space[3] used an electric hotplate as a heat source for their ignition studies. Wright (1932) used heated discs of metal dropped on the forest floor to determine ignition temperatures of forest floor duff. Brown[4] and VanKleeck[5] were two of the earlier workers who heated the sample in an airstream and attempted to measure the temperature of the sample at the time of ignition.

Early studies utilizing a radiative heat source were made in England by Lawson and Simms (1952). Also, the threat of possible use of thermonuclear weapons motivated a series of studies by Butler (1955), Martin (1958, 1959, 1963), Brown (1964), and others using a high-intensity carbon arc for ignition.

[2] I. S. Doyle. The inflammability and fire holding properties of various wood rots at different moisture content. 1926. (Unpublished thesis on file at School of Forestry, Univ. Idaho, Moscow.)

[3] J. W. Space. The inflammability of various kinds of needle duff at different moisture contents. 1927. (Unpublished thesis on file at School of Forestry, Univ.Idaho, Moscow.)

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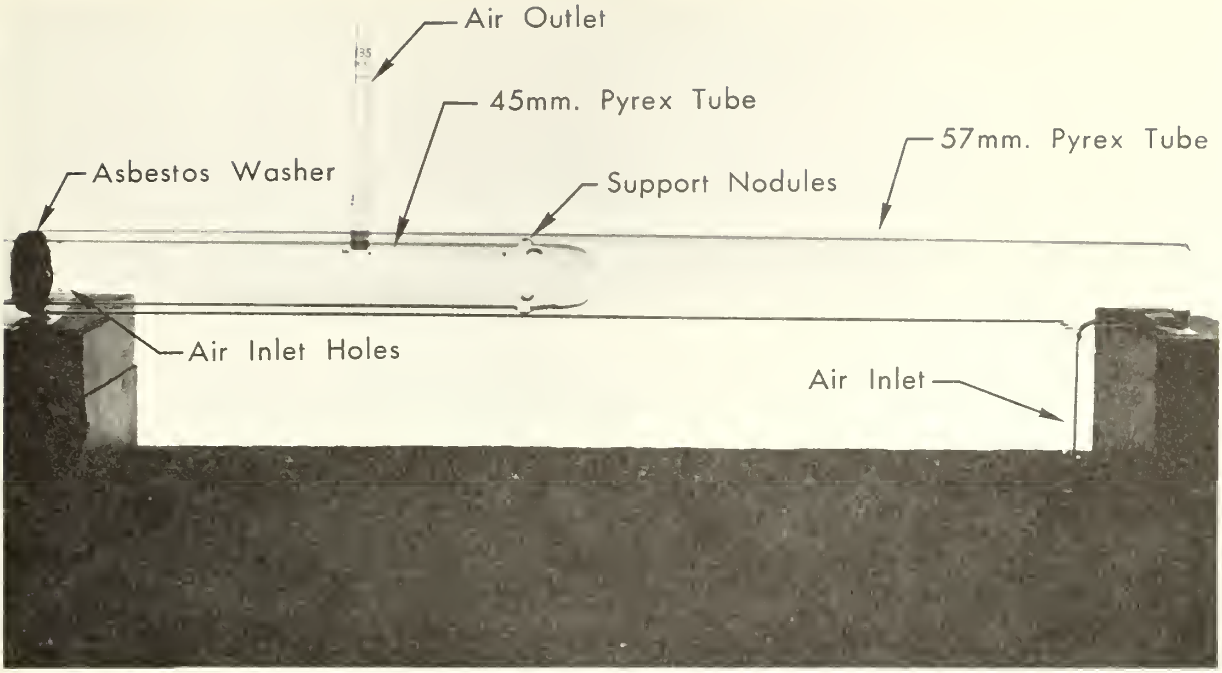

Figure 2.--Basic unit of ignition furnace.

VonDeichman (1960) and Mutch (1964) using a modified Jentzch ignition tester determined ignition time-temperature curves for various forest fuels that had been reduced to a common physical consistency.

Although extensive data have been reported in the literature, many of the reported results are inconclusive. The definition of ignition has varied widely in interpretation and the methods used to produce ignition have given widely diversified results. In addition, many of the studies have been theoretical in nature; while this has added to the knowledge, it has produced little of practical value.

A need has existed for an apparatus capable of igniting sections of wildland fuels under naturally occurring conditions. Since the relation between ignition time-temperature and heat intensity is highly dependent on the type of heat transfer mechanisms used to produce the ignition, this mechanism should be identified and quantified as precisely as possible. The researcher must know the proportions of heat transfer methods existing in the ignition device to correctly interpret test results. The apparatus also should be capable of producing and measuring temperatures for both spontaneous and pilot ignition.

A general view of the ignition furnace assembly is given in figure 1. The basic unit of the furnace consists of a 57 mm. O.D. Pyrex glass tube 32 inches long into which a 16-inch length of 45 mm. O.D. Pyrex glass tubing has been inserted, as shown in figure 2. The smaller tube was closed at one end and support nodules formed at four locations on this closed end before insertion into the larger tube. A washer was cut from 1/2-inch asbestos board to support the open end of the tube and to form a seal between the inner and outer tubes. Three holes 3/16-inch in diameter had previously been drilled

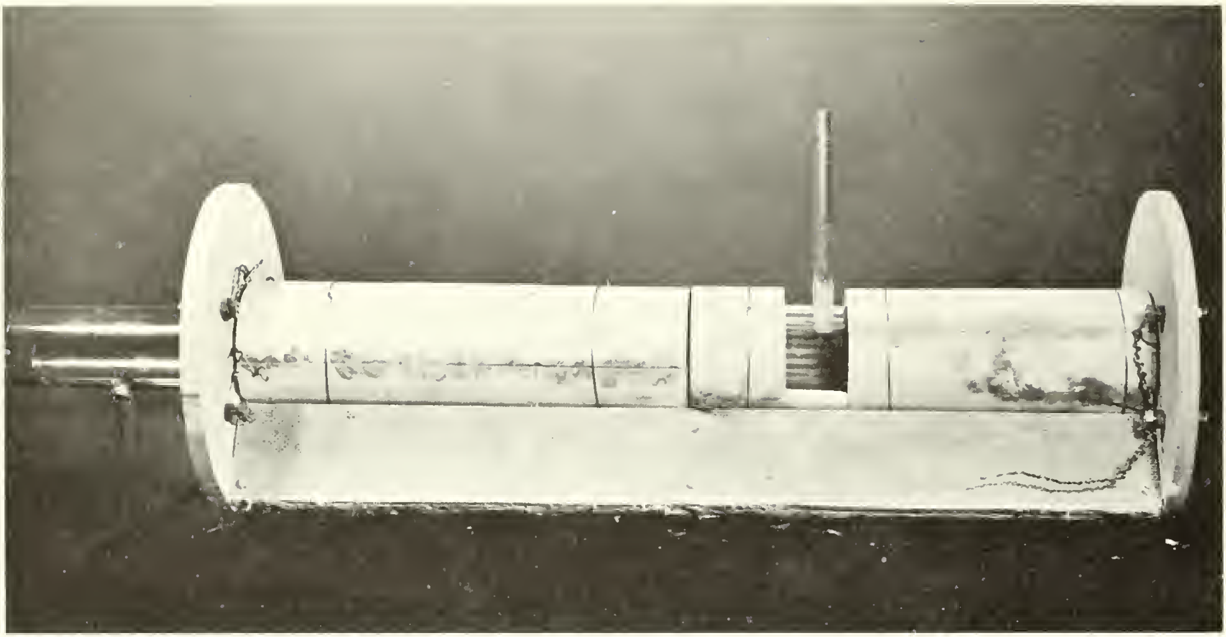

Figure 3.--Heater assembly of ignition furnace showing heating units, enclosed in ceramic, in place around the glass tube unit.

through the smaller tube at equidistant spacing on the circumference (figure 2). A number 10/30 ground-glass joint tube was fitted to the assembly by drilling holes of the proper size in both the inner and outer glass tubes a distance of 12 inches from the open ends of the tubes. The function of this ground-glass joint was to serve as an air outlet for the ignition chamber within the inner tube. An air inlet tube was then fused to the outer glass tube (figure 2).

Heat is supplied to the double tube assembly by three sets of Lindborg heating units (figure 3). Power to each set of units is controlled by a variable voltage transformer. The temperature of the tube assembly at each of the units is monitored by a 28-gage chromel-alumel thermocouple placed between the heating unit and the glass tube. The use of three separately controlled heating units provided a nearly constant temperature profile for the entire length of the furnace.

The entire tube and heater assembly was insulated with alumina wrap-around insulation (figure 4) with the exception of an observation port for the ignition chamber. The entire unit was covered with a sheet of 16-gage stainless steel fastened to the furnace assembly with No. 8 self-tapping screws (figure 5).

To insure adequate oxygen for combustion, compressed air is furnished the system through a flow meter; this air passes into the air inlet through a loosely-packed mass of stainless steel wool, and then flows through the 3/16-inch holes at the end of the smaller ignition tube assembly into the actual ignition chamber. The air is then exhausted through the ground-glass joint that is located directly above the ignition chamber.

The fuel sample is placed on an ignition boat assembly (figure 6) which is mounted on a slide mechanism to allow manual insertion into the ignition chamber. Insertion of this assembly into the chamber operates a microswitch that activates a three-channel

Figure 4.--Insulation of furnace tube and heater assembly.

Figure 5.--Stainless steel covering and support assembly of furnace.

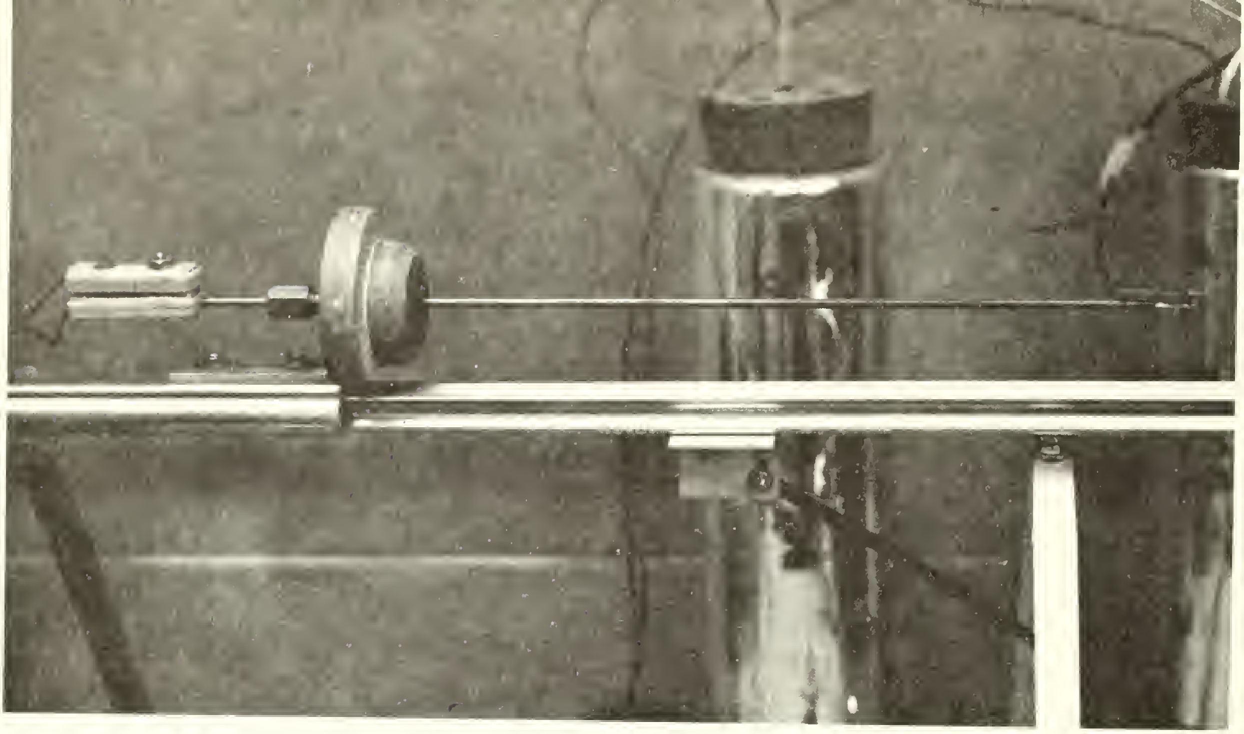

Figure 6.--Ignition boat assembly mounted on slide mechanism (thermocouple reference junctions are in background).

recorder. This recorder plots temperature of the ignition chamber and fuel sample's surface temperature against time. These two temperatures are obtained by two 0.003-inch chromel-alumel thermocouples on the ignition boat assembly (figure 7).

The necessary heat flux for producing spontaneous ignition is obtained by regulating the furnace temperature and volume of airflow. Pilot ignition is provided by inserting a small gas flame through the exhaust port into a position directly above the fuel sample being tested. This pilot flame is provided and accurately positioned by a hypodermic needle mounted on a modified microscope stage.

The entire ignition process may be observed through the furnace's observation port. An interrupter circuit to the recording pens marks the moment of glowing or flaming ignition. This allows comparison of visual identification of these points with the traces being recorded on the three-channel recorder.

The ignition boat assembly is designed to test small sections of forest fuels (figure 7). Trial-and-error testing has shown that a section of fuel approximately 1 inch in length and 1/8-inch in diameter is the optimum for a furnace of this size. Fuel sample dimensions are limited by the size of the ignition chamber. Conifer needles, grass stems and leaves, and sections of rotten wood have been tested in this furnace.

The types of heat transfer and total heat flux were determined for this furnace by using a 3/8-inch solid gold sphere instrumented with a thermocouple probe.[6] When using a constant airflow of 5 liters per minute the total heat flux input at the ignition chamber was 0.735 cal./cm.^{2}-sec. Of this amount, 55.4 percent was convective heating and 44.6 percent was radiative heating.

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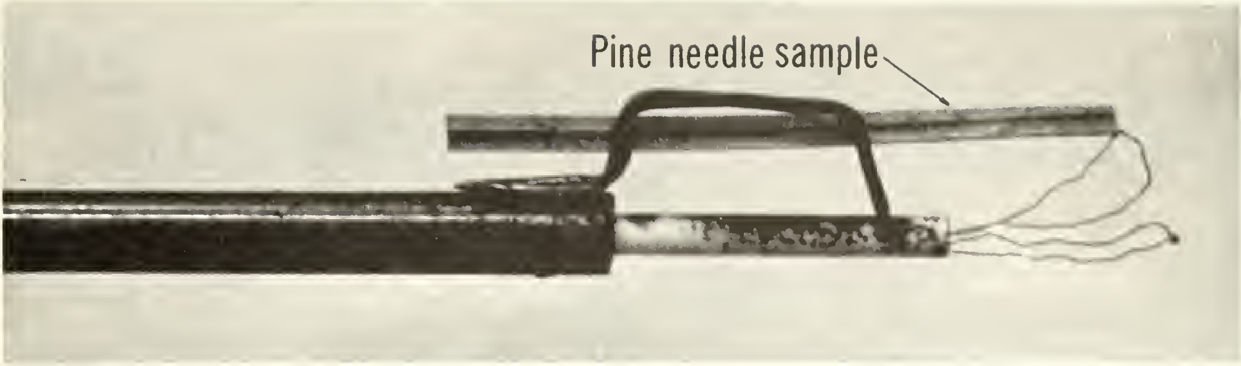

Figure 7.--Enlarged section of ignition boat with a 1-inch section of pine needle in test position. Note positions of air temperature thermocouple and surface temperature thermocouple.

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HEIGHT GROWTH IN WESTERN WHITE PINE PROGENIES

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ABSTRACT

Heights of 31 progenies of western white pines from four geographic localities and four crosses between localities were assessed on 14-year-old trees at two sites. Differences in height among individual progenies were detected but could not be related to localities or crosses between localities. Although differential effects of sites on tree height became apparent after age 9, differences among progenies were similar on both sites.

Assessment of genetic superiority and environmental adaptation in height growth of forest trees ultimately must be based on field tests over extended periods. Even though differences in height of 3- to 5-year-old progenies of western white pines (*Pinus monticola* Dougl.) varied in three natural environments (Squillace and Bingham 1958), the value of data involving juvenile performance depends on the correlation between performance at juvenile and mature ages. Whereas statistically significant correlations have been observed between height at age 5 and height at ages near 10 for *Pinus resinosa* Ait. (Lester and Barr 1966) and *P. ponderosa* Laws. (Callaham and Duffield 1962), the relative height of progenies of *P. ponderosa* (Callaham and Liddicoet 1961) and *Pseudotsuga menziesii* (Mirb.) Franco (Silen 1965) changed greatly after age 20. The present paper concerns variation in height of western white pine progenies up to 14 years of age.

[1]Research Plant Geneticists, stationed in Moscow, Idaho, at the Forestry Sciences Laboratory, maintained in cooperation with the University of Idaho.

MATERIALS AND METHODS

Data were taken from 31 progenies that had been field-planted in 1957 as 3-year-old seedlings. Field tests were established in northern Idaho on two sites: (1) a north aspect at an elevation of 3,650 feet on the Deception Creek Experimental Forest, Kootenai County; and (2) a northwest aspect at an elevation of 2,500 feet on the Priest River Experimental Forest, Bonner County.

The progenies represented four geographic locations in northern Idaho and four crosses between localities. Geographic localities included: (1) Crystal Creek, Benewah County, 2,850 feet elevation; (2) White Rock, Shoshone County, 5,000 feet elevation; (3) Gold Center, Shoshone County, 2,950 feet elevation; and (4) Elk Creek, Clearwater County, 3,000 feet elevation (figure 1, Squillace and Bingham 1958). Crosses between localities included Crystal Creek X White Rock, Gold Center, and Elk Creek; and White Rock X Elk Creek. A varying number of progenies were represented within localities and crosses between localities (table 1).

Table 1.--*Mean height of 14-year-old trees from individual progenies representative of interlocality or intralocality crosses*

Intralocality crosses: Maternal tree no.		Paternal tree no.	A[1]	B[2]	Interlocality crosses: Maternal tree no.		Paternal tree no.	A[1]	B[2]
			--Feet---					---Feet---	
Crystal Creek			7.09		Crystal Creek X White Rock			5.91	
15	X	wind[3]		6.23	54	X	19		5.73
15	X	20		6.67	63	X	20		6.31
18	X	wind		7.56	69	X	19		6.36
19	X	wind		7.32	69	X	20		6.05
20	X	wind		6.71	70	X	19		5.15
20	X	21		7.59	70	X	20		5.83
21	X	wind		7.79					
21	X	27		6.70	Gold Center X Crystal Creek			6.91	
25	X	wind		7.07					
25	X	18		6.82	23	X	20		6.91
58	X	wind		7.57					
					Elk Creek X Crystal Creek			6.93	
White Rock			5.97						
					62	X	19		6.51
54	X	wind		5.45	62	X	25		6.15
63	X	wind		5.99	62	X	58		7.94
69	X	wind		6.69	18	X	64		7.09
70	X	wind		5.75	19	X	59		6.97
Elk Creek			7.36		White Rock X Elk Creek			6.67	
59	X	wind		7.54	69	X	59		6.67
59	X	64		7.17					
Gold Center			6.57						
23	X	wind		6.57					

[1]Group means. [2]Progeny means. [3]Pollen carried by wind; paternal parentage unknown.

Height of all trees was measured at ages 4, 9, and 14. The following is the analysis of variance applied to the data:

Source of variation	*Symbol*	*Mean square code*	*Unweighted components expected in each mean square*	*Coded tester*
Sites	S	6	$\sigma^2_E + \sigma^2_{PB/S} + \sigma^2_{PS} + \sigma^2_{B/S} + \sigma^2_S$	5+3-2
Blocks within sites	B/S	5	$\sigma^2_E + \sigma^2_{PB/S} + \sigma^2_{B/S}$	2
Progenies	P	4	$\sigma^2_E + \sigma^2_{PB/S} + \sigma^2_{PS} + \sigma^2_P$	3
P X S	PS	3	$\sigma^2_E + \sigma^2_{PB/S} + \sigma^2_{PS}$	2
P X B/S	PB/S	2	$\sigma^2_E + \sigma^2_{PB/S}$	1
Within cells	E	1	σ^2_E	

RESULTS AND DISCUSSION

Analyses of variance for height at ages 9 and 14 and the analysis of covariance of height at age 14 on height at age 9 (table 2) indicate that the effects of sites on tree height became apparent after age 9; 14-year-old trees growing on the Priest River site averaged 1.5 feet taller than those growing at Deception Creek, but at age 9 essentially no differences separated trees growing on the two sites. By contrast, differences in height among progenies and the effects of blocks within sites on tree height were expressed before age 9 and remained relatively constant up to age 14. The meaning of interactions involving progenies is obscure, for significant effects indicated by one analysis of variance were not verified by the second, and the analysis of covariance indicated nonsignificant changes in the effects of these sources of variation over the 5-year interval. It is probable that these interactions are of negligible importance in this test.

Table 2.--*Results of analyses of variance of 9- and 14-year heights and the analysis of covariance of 14-year height on 9-year height*

Source of variation	Degrees of freedom	Mean square ratios: Analysis of variance, 9-year height	Mean square ratios: Analysis of variance, 14-year height	Mean square ratios: Analysis of covariance
Sites	1	0.18	[1]9.72*	275.61**
Blocks within sites	4	8.89**	6.44**	.96
Progenies	30	1.68*	2.09*	1.13
P X S	30	1.56*	1.11	1.39
P X B/S	120	.99	1.33*	1.09
Within cells	[2]554			

[1]Single (*) and double (**) asterisks, respectively, indicate significance at the 5- and 1-percent levels of probability.

[2]Degrees of freedom reduced by 1 for the statistically significant regression (1-percent level of probability) in the analysis of covariance.

Although mean height of trees representative of different localities or crosses between localities differed by as much as 1.4 feet (table 1), Scheffé's "S" test for multiple mean comparisons (Scheffé 1958) indicated that differences detected among progenies (table 2) were not related (5-percent level of probability) to either the elevation or locality of progeny origin. By contrast, western white pine seedlings fro localities of low and high elevations differed in height particularly in a high-elevati environment (about 4,400 feet) (Squillace and Bingham 1958). The divergent results of the present study may reflect an absence of a test site at a high elevation, for many o the same progenies were represented in both studies.

Despite a large variation in mean performance of individual progenies (table 1), differences were detected at only the 5-percent level of probability (table 2). Perfor ance of individual trees within progenies was thus highly variable; that this variation results primarily from large genetic heterogeneity of parental trees is consistent with conclusions of Hanover and Barnes (1969).

The consistency in mean growth of progenies between ages 9 and 14 is further eluci dated by correlation coefficients among mean height of progenies for ages 4, 9, and 14:

Tree ages *(Years)*	*Correlation coefficient (r)*
4 and 9	0.68
4 and 14	.61
9 and 14	.92

All coefficients are statistically significant at the 1-percent level of probability and suggest that observed differences in the height of progenies at age 14 were apparent not only at age 9 but probably at age 4, one year after the plantings were established. The possibility exists, however, that changes in height such as observed in *Pinus ponderosa* (Callaham and Liddicoet 1961) and *Pseudotsuga menziesii* (Silen 1965) may become apparent in later years.

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RESISTANCE TO *CRONARTIUM RIBICOLA* IN *PINUS MONTICOLA*: EARLY SHEDDING OF INFECTED NEEDLES

G. I. McDonald and R. J. Hoff[1]

ABSTRACT

Detailed analysis of symptom history provided information on the nature of resistance to Cronartium ribicola *J. C. Fisch. ex Rabenh. in* Pinus monticola *Dougl. seedlings. Two independent and sequential resistance factors appeared to be operative in seedling populations obtained from phenotypically resistant parents, but only one of these factors was present in seedling populations derived from phenotypically susceptible parents.*

The white pine blister rust disease, caused by *Cronartium ribicola* J. C. Fisch. ex Rabenh., has been a major forest management problem in the Western United States since the early 1920's (Ketcham, Wellner, and Evans 1968). A breeding program for development of resistance in *Pinus monticola* Dougl., western white pine, was initiated by the USDA Forest Service in 1950. The progress of this program was recently summarized by Bingham, Olson, Becker, and others (1969). The need for more detailed information on the mechanisms of resistance and their sites was stressed by Hoff and McDonald in August 1969 during a NATO-IUFRO Advanced Study Institute on Biology of Rust Resistance in Forest Trees at Moscow, Idaho (see Hoff and McDonald 1971).

The fungus enters both *Pinus strobus* L., eastern white pine, (Clinton and McCormick 1919; Patton 1967) and western white pine (Chapman 1934) through the stomata. It grows down the needle to become established in the bark within 1 to 2 years after penetrating the needle (Chapman 1934).

Any interference with the pathogen's growth down the needle or its penetration of the stem could prevent development of a canker, but not development of needle lesions. Occurrence of normal needle symptoms without the subsequent development of cankers (termed here "the needle-spots-only" reaction) has been observed in *P. strobus* (Riker, Kouba, Brener, and others. 1943; Hirt 1944); in white pine hybrids (Heimburger 1962; Patton 1966); and in *P. monticola* (Bingham 1954; Bingham, Squillace, and Wright 1960).

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Without elaborating, Riker, Kouba, Brener, and others (1943, p. 758) stated: "Many trees showed needle spots that were probably infections, but no stem cankers." Hirt (1944, p. 10) made one reference to the needle-spots-only phenomenon, when he said, "...occasionally needles had typical infection spots that failed to result in cankers." Heimburger (1962, p. 360) noted a moderately heavy needle infection in *P. griffithii* McClelland that "did not reach the stem before the needles were sloughed off." Patton (1966) reported that various hybrid white pine seedlings that had supported infected needles 1 year after inoculation were "disease-free" 2 years after inoculation.

Shedding of infected needles before the mycelium reaches the stem would be a discrete and effective mechanism of resistance. The needle-spots-only phenomenon suggests that such a system is operative in the white pines. This incomplete blister rust syndrome could also be explained in other ways; e.g., the mycelium could fail to reach or to penetrate the short shoot before characteristic shedding occurs or penetration of the short shoot could be followed by a reaction lethal to the fungus.

The objectives of the analysis presented here were to determine: (1) the percentage of seedlings supporting needle infections 9 months after inoculation; (2) the rate at which infected needles were shed; and (3) the effectiveness of shedding as a resistance mechanism.

MATERIALS AND METHODS

Disease-free western white pine were selected from areas exhibiting high levels of blister rust infection (Bingham, Olson, Becker, and others. 1969). These phenotypically resistant trees were subjected to a crossing program that produced many full-sib families. However, for purposes of this investigation, these families were combined into one group (termed here "resistant families").

Seed was obtained from several phenotypically susceptible, wind-pollinated trees or from squirrel caches in heavily infected stands. These seeds were bulked according to geographic source. Each of the 10 sources used was given a seed lot designation and handled as a full-sib family. Data from all control lots were combined into a second group ("susceptible families").

Seeds were planted at Moscow, Idaho, in early winter, 1964. The experimental design used was a randomized complete block consisting of 10 blocks, 475 plots per block, and 16 planting spots per plot. Each plot contained a full-sib family or a control. There was one replication (plot) per randomized block. Each block contained 383 separate full-sib families, 10 control lots, and some miscellaneous crosses. In order to make a manageable study, 116 full-sib families were chosen and only plots in blocks 4, 5, 6, and 7 were inspected. The 10 control lots in the same blocks also were examined. Two-year-old seedlings were inoculated between September 20 and 25, 1966 (Bingham, Olson, Becker, and others. 1969).

Seedlings were inspected three times over a 2-year period. The first inspection was begun June 15, 1967, and completed 15 days later. Five seedlings in each plot (family) selected from blocks 4, 5, 6, and 7 were examined for needle lesions caused by *C. ribicola*. The principal criterion was the yellow coloration typical of blister rust.

The second inspection was carried out between August 11 and September 28, 1967; blocks 5 and 6 were examined from August 11 to August 21 (the 11th-month measurement) and blocks 4 and 7, from August 22 to September 28 (the 12th-month measurement). Any evidence of *C. ribicola's* reaching the stem was recorded at the time of inspection. Yellow to orange discoloration, pycnia, and fusiform swelling were typical signs and symptoms encountered. Atypical symptoms, such as roughening of the bark, scaling of small bark patches at the base of the short shoot, and presence of small necrotic areas at the base of the short shoot, were also observed. If these atypical symptoms appeared on wood formed during the year of inoculation, they were interpreted as positive evidence that the fungus had reached the stem. All the above signs and symptoms associated with the stem were considered in judging whether or not the rust had penetrated the short shoot.

The third inspection was carried out between September 15 and October 31, 1968, 24 months after inoculation, to determine whether or not stem penetration had occurred. Seedlings were examined for typical symptoms and signs (swelling, discoloration, and pycnial scars) and atypical symptoms (swollen and roughened, necrotic and sunken, scaly, and deeply fissured bark). All indications of penetrations were labeled simply "stem symptoms."

Seedlings were classed according to parental phenotype and the presence or absence of stem symptoms 24 months after inoculation:

Class	Parental phenotype	Stem symptoms
I	Susceptible	Absent
II	Susceptible	Present
III	Resistant	Absent
IV	Resistant	Present

Seedlings were also classed according to the date of inspection; so each of the above classes consisted of seedlings inspected during the 9th, 11th, and 12th month after inoculation. The percentage of seedlings with needle infections was calculated for each class each of these inspection periods. These data provided a means of evaluating the relationships between the appearance of stem symptoms and the rate of needle shedding in susceptible and in resistant families. However, this arrangement does not provide information as to the effectiveness of shedding as a resistance mechanism. The effectiveness of shedding was evaluated by classifying the seedlings inspected during the 11th and 12th months after inoculation on the basis of the presence or absence of infected needles rather than on the presence or absence of stem symptoms. Chi-square values were calculated according to Snedecor (1956).

RESULTS

Results of the 9th-month inspection showed that from 97.4 to 100 percent of the seedlings supported needle infections (table 1); so it was assumed that none of the seedlings had escaped infection.

Performances of seedling classes II and IV were compared on the basis of the needle shedding rates of seedlings that developed stem symptoms within 2 years of inoculation. The population of seedlings from phenotypically resistant parents exhibited a faster shedding rate than the population of seedlings from phenotypically susceptible parents (table 1).

Comparison of the shedding rates of seedlings that exhibited the needle-spots-only reaction (no stem symptoms 24 months after inoculation) gave a different result. Seedling classes I and III showed the same shedding rate (table 1).

If infected needles had been shed by the end of the 11th month, contingency table chi-square analysis showed that parental phenotype had no significant effect on the percentage of seedlings in the needle-spots-only class (table 2). These data also indicated that *early shedding of infected needles was an efficient predictor of resistance* since 65 percent of the seedlings remained disease-free 13 months after their needles were shed.

Table 1.--Percentage of P. monticola *seedlings supporting* C. ribicola *needle lesions 9-12 months after inoculation*

Stem symptoms 24 months after inoculation	Parental phenotype	Seedlings inspected and inspection time					
		9 months		11 months		12 months	
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Present	Resistant (Class IV)[1]	1,636	99.8	2,338	97.1	2,255	84.2
	Susceptible (Class II)	180	100.0	310	98.7	271	93.4
Absent	Resistant (Class III)	465	97.4	558	74.6	801	47.2
	Susceptible (Class I)	13	92.3	35	77.1	17	47.1

[1]Seedling class in parentheses.

Table 2.--Percentage of P. monticola *seedlings exhibiting needle-spots-only reaction 24 months after inoculation, when needle infection is measured 11 months after inoculation*

Infected needles	Parent phenotype	Seedlings			Seedlings with needle-spots-only	χ^2	Probability of larger χ^2
		Stem symptoms present	Stem symptoms absent	Total			
		Number			*Percent*		
Absent	Resistant	67	124	191	65		
	Susceptible	4	8	12	67		
Total		71	132	203		.034	.60
Present	Resistant	2,271	416	2,687	15		
	Susceptible	306	27	333	8		
Total		2,577	443	3,020		43.46	.0005

On the other hand, the same analysis performed with seedlings retaining infected needles through the 11th month indicated that the effect of parental phenotype was highly significant and that low percentages of the seedlings remained free of stem symptoms (table 2).

The above analysis applied to seedlings from the same parents *but inspected 1 month later* had a very different outcome; *parental phenotype had no effect* if infected needles had been shed within 11 months of inoculation, but *a significant effect* if infected needles were not shed by that time (table 3, Infected needles, Absent). When the infected needles were retained through the 12th month (table 3, Infected needles, Present), the resistant families performed about the same as previously, but the susceptible families showed a decrease in the percentage of seedlings in the needle-spots-only class.

DISCUSSION

The results shown in table 1 have a particular bearing on the interpretation of these data. The high percentage of seedlings (all populations) supporting needle infections in June is the basis for an important assumption. Escape from and/or resistance to needle infection were so low that they could be disregarded and 100 percent infection assumed. The remote possibility that needle spots were caused by an agent other than *C. ribicola* was eliminated when histological examination revealed elements of the rust in 99 percent of 22,000 spots.[2]

This high level of needle infections in June also suggests a second important assumption. Seedlings that had needle spots in June but no needle spots in the 11th and 12th months must have shed diseased needles. Ninety-eight percent of the seedlings inspected had at least a few needles on the stem internode of the inoculation year.

The authors' interpretation of the relationship between the formation of stem symptoms and premature shedding of infected needles is based on the above assumptions and on the observation that all infected needles *eventually* are shed. At Moscow, Idaho, complete shedding generally occurs by the end of the second growing season, 22-23 months after inoculation in the nursery beds.

The reason for the increased rate of shedding exhibited by seedling class III (see page 3) is not immediately obvious. Early shedding may be related to a stem resistance factor because offspring of resistant parents have higher levels of stem-based resistance than those of susceptible parents (Bingham, Olson, Becker, and others. 1969). Also worth mentioning is the fact that seedlings were located in different blocks in the nursery. Consequently, the difference in shedding rates could be due to a block effect.

The equal needle shedding rates exhibited by seedlings that failed to develop stem symptoms may indicate that seedlings from resistant parents and those from susceptible parents were exhibiting the same resistance mechanism. Recessive genes controlling resistance could be present in both parental populations.

The data showed that seedlings expressing the needle-spots-only reaction tended to shed infected needles earlier than those that developed stem symptoms (table 1). Since some seedlings that had shed needles prematurely also showed stem symptoms and others retained infected needles into the 12th month but failed to produce stem symptoms, the effectiveness of early needle casting as a predictor of resistance was interpreted another way.

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[2]G. I. McDonald and R. J. Hoff. Variation in size and color of blister rust lesions on needles of western white pine. USDA Forest Serv., Intermountain Forest and Range Experiment Station, Ogden, Utah. (In preparation.)

Table 3.--*Percentage of* P. monticola *seedlings exhibiting needle-spots-only reaction 24 months after* C. ribicola *inoculation, when needle infection is measured 12 months after inoculation.*

Infected needles	Parent phenotype	Seedlings: Stem symptoms present	Seedlings: Stem symptoms absent	Seedlings: Total	Seedlings with needle-spots-only	χ^2	Probability of larger χ^2
		- - - - - *Number*	- - - - -		*Percent*		
Absent	Resistant	357	423	780	54		
	Susceptible	18	8	26	33		
Total		375	431	806		5.56	.025
Present	Resistant	1,898	378	2,276	17		
	Susceptible	253	9	262	3		
Total		2,151	387	2,538		31.32	.0005

The fate of every infected needle is death or casting. Hence, if premature casting prevents the formation of stem symptoms, then all or a high proportion of seedlings that exhibit premature needle shedding should fall into the needle-spots-only category. Furthermore, the size of this category should be much smaller proportionately at a later inspection time, because susceptible seedlings characteristically would swell the needles-absent category. Using this approach, the authors reinterpreted the data (tables 2 and 3).

The results presented in table 2 can be viewed in the following manner. Needle casting began some time during the 11th month. Of the seedlings that shed their infected needles during the 11th month, 65 percent were free of stem symptoms 24 months after inoculation *regardless of their parental phenotype*. Consequently, early dropping of infected needles appeared to be associated with resistance. A nonsignificant contingency table chi-square supports this conclusion, but the low number of observations in the seedling population obtained from phenotypically susceptible parents sheds some doubt on the statistical decision. Nevertheless, since a close decision was not involved, the statistical test should be valid (Snedecor 1956). On the other hand, if infected needles were retained through the 11th month, parental phenotype and appearance of stem symptoms were not independent (table 2).

When the same comparison was made from data collected during the 12th month after inoculation, an entirely different picture emerged. Parental phenotype and stem symptoms no longer were independent factors regardless of whether or not infected needles dropped (table 3). The statistical tests given in both tables should be valid since the correction for continuity was made and all cells contained more than five observations (Snedecor 1956).

The dependence on parental phenotype suggests: (1) that a second resistance mechanism is indicated by the tendency of some resistant seedlings to retain infected needles and (2) that susceptible families apparently did not possess this resistance mechanism, since only 3 percent of the control lot seedlings remained free of stem symptoms if infected needles were retained through the 12th month after inoculation (table 3).

CONCLUSIONS

The following generalizations can be made from this interpretation of the data. Early shedding of infected needles is implicated in resistance demonstrated by certain seedlings from both phenotypically resistant and susceptible parents. Seedlings from susceptible parents have only the mechanism for early shedding of infected needles. The data suggest that the needle-spots-only phenomenon is the result of two resistance mechanisms; the first is premature shedding of infected needles (needle-cast resistance), the second is failure to produce stem symptoms despite retention of infected needles 12 months after inoculation (needle-retention resistance). These mechanisms appear to be independent of one another and to function in a sequential manner.

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PLANTING METHOD AFFECTS HEIGHT GROWTH OF PONDEROSA PINE IN CENTRAL IDAHO

Dale O. Hall and James D. Curtis[1]

ABSTRACT

*Analyses of planting tests conducted over 5 years and of growth of ponderosa pine (*Pinus ponderosa *Laws.) seedlings over 10 years have shown that seedling survival and height growth are improved by careful handling and planting of stock in areas stripped of brush. When compared on a common age basis, 2-0 planting stock grows as tall as 2-1 stock. The study also showed that: (1) trees 2 to 3 feet from a cut bank grow taller than trees 6 to 7 feet from the bank; (2) height growth increases steadily for the first 10 years; (3) height variations increase with seedling age; and (4) site evaluations must take into account highly variable growth rates.*

Planting methods have long been known to affect the growth of ponderosa pine (*Pinus ponderosa* Laws.).[2] Methods that give greatest seedling survival generally result in best growth characteristics also. Ponderosa pine planting tests in central Idaho have shown that both percent survival and height growth can be increased if brush is removed from planting sites and nursery stock is carefully handled. These increases imply that reduced competition lessens the impact of natural selection and that site evaluations may be overly conservative as a consequence.

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[1]Respectively, Silviculturist, stationed in Boise, Idaho, and formerly Principal Silviculturist, stationed in Boise, presently retired.

[2]Harry C. Turner. The effect of planting method upon growth of western yellow pine. J. Forestry 16: 399-403. 1918.

THE TOWN CREEK PLANTATIONS

A 5-year planting test that incorporated three site preparations and three nursery stock-handling methods was initiated in 1954.[3] The test area was in the small Town Creek drainage, 11 miles northwest of Idaho City, Idaho, on the Boise National Forest. Within the Town Creek drainage, major slopes fall gently to the southeast, but tributaries form subbasins containing all aspects and slopes to 50 percent. Based on young growth in the vicinity, Site Quality IV[4] predominates.

The Town Creek drainage is within the 45,000 acres of the 1931 Quartzburg burn. Since the fire, the ground has supported little tree growth. Instead, it has sustained a broken to dense complex of brush species, dominated by snowbrush ceanothus (*Ceanothus velutinus* Dougl.).

SITE PREPARATION

Planting sites, three 8-foot-wide lanes, were contoured around the slopes. A D-7 Caterpillar[5] tractor was used to strip vegetation from two of the lanes. Two furrows made by Talledega plows were added to one of these lanes, but the third lane was left i its natural state; i.e., no brush was removed before planting.

NURSERY STOCK CLASSES

The three nursery stock-handling classes were known as: 2-1[6] "regular," 2-1 nursery stock transported by common carrier and planted by the slit method, a conventional forestry practice; 2-1 "special," 2-1 nursery stock transported by Forest Service truck and planted by the dug-hole method; and 2-0 "special," 2-0 nursery stock transported by truck and planted by the dug-hole method.

Thus, nine treatment combinations were compared. These treatments were randomly assigned to nine parallel lanes. Specified stock was planted in two rows 4 feet apart on each lane. Trees were spaced 6 feet apart in the rows. About 90 acres were restocked each spring from 1954 to 1958.

TREE HEIGHT SAMPLING

Tree heights on selected aspects were measured during the fall months of 1959 and 1968. In 1959, heights to the first and second whorls (after planting) were recorded for the five plantations and heights to the fifth whorl were recorded for the 1954 and 1955 plantations. In 1968, heights to the tenth whorl (after planting) were recorded for the five plantations. Different trees were used for each height period measurement

Sampling areas were carefully selected; areas in which soils were obviously shallo or height growth noticeably depressed were bypassed. Two aspects, easterly and westerly, were sampled in each of the five annual plantings. On each aspect, a starting line was arbitrarily specified that crossed the nine strips. The entire aspect was systematically sampled by measuring 15 trees on each lane.

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[3]James D. Curtis and Melvin A. Coonrod. The Town Creek ponderosa pine plantation. Soc. Amer. Forest. Proc. 1960: 21-25. 1961.

[4]Walter H. Meyer. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agr. Tech. Bull. 630, 59 p., illus. 1938. (Revised April 1961).

[5]Mention of trade names is solely for identification and does not necessarily imply endorsement by the USDA Forest Service.

[6]The first digit indicates the number of years stock has been in an initial nursery bed (a seeded bed), the second, the number of years in a transplant bed; e.g., a 2-1 seedling would be 3 years old.

A lack of randomness in the sampling precludes a rigorous statistical evaluation of height attainment. However, the breadth of sampling, the random assignment of treatments, and the measurement of all nine treatments at each sample location suggest that an analysis of variance for differences in height has some credibility. A 3 X 3 factorial design was used. Each analysis cell includes measurements from the five annual plantings on two selected aspects (15 trees per aspect, 150 tree heights).

The 1-year age difference between 2-0 and 2-1 stock implies a height difference. In some instances, in order to compare stock on a common base, we estimated height of the 2-0 stock 1 year after measurement. We calculated the periodic annual height growth for the measurement period and added it to the actual height. In every case but one, *careful planting and handling resulted in increased growth each period,* regardless of site preparation.

HEIGHT RELATIONSHIPS

Height evaluations were planned to take into account the influence of site preparation and of planting stock. Analysis of variance for common-base heights at 10 years indicates highly significant differences (p=.01) between all treatments:

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*	*F*
Site preparation (SP)	2	1063.4917	531.7458	236.668**
Planting stock (PS)	2	137.7035	68.8517	30.644**
SP X PS	4	16.1406	4.0351	1.796 NS
Error	1341	3013.0259	2.2468	
Total	1349	4230.3584		

** Significant at the .01 level.

NS Not significant at the .05 level.

The interaction term was not significant.

Turning now to a secondary analysis, growth conditions adjacent to cut banks differ from conditions at the soil surface or on fill areas. Height differences were compared by means of a t test for paired plots. Data are included to permit survival-height comparisons.

Site preparation.--No stock treatment nor site preparation method affected survival and height more than brush removal. Five years after planting, survival in brush was 42 percent or less, survival on stripped rows exceeded 71 percent. Ten years after planting, mean seedling heights were:

Treatment	*Mean heights (Feet)*
No site preparation	3.18
Stripped	5.06
Stripped and furrowed	5.05

Figure 1.--Contrast the height of a tree planted on an unprepared site (left) with that of a tree planted at the same time on stripped ground (right).

The range in mean heights for trees in brush was 2.86 to 3.54 feet and on stripped ground, 4.69 to 5.64 feet.[7] Height of trees in brush averaged 57 to 66 percent of the height of trees on stripped ground (fig. 1). Site preparation improved both survival and height growth.

Planting stock.--Stock that was carefully handled and planted grew taller, regardless of site preparation (Table 1). Tenth-year mean tree heights were:

Stock class	*Mean heights (Feet)*
2-0 "Special"	4.22
Common age base (est.)	(4.64)
2-1 "Special"	4.88
2-1 "Regular"	4.19

The mean annual height growth for the full life of the seedling was used as the basis for making comparisons of all treatments (table 2). At the last year measurement, the 2-1 "special" stock had shown the fastest growth rate, and the 2-0 "special" stock had grown as fast as or faster than the 2-1 "regular." The influence of stock handling and its importance are indicated by these two comparisons.

The increasing rate of height growth is apparent over the three growth periods (tables 2 and 3). The rate should stabilize in the next 10-year period.

Unfortunately, the performance of planting stock is contingent upon several factors that cannot be ignored. From an operational standpoint, the most important of these is the planting method. Production for the dug-hole method ranged between 160 and 180 trees per day, for the slit method, 340 to 400. Differences of this magnitude and the costs they represent would influence operational decisions. It was unfortunate the study design did not provide for direct comparison of planting methods.

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[7]Slight differences between means of the two treatments were not significant. (George W. Snedecor. P. 253 *in:* Statistical Methods. Ed. 5, 534 p., illus. Ames, Iowa: The Iowa State Coll. Press, 1956.)

Table 1.--*Periodic seedling heights and survival percents, Town Creek Plantations, Boise N.F.*

Nursery stock (Years since planted)	(Seedling age)	None: 2-0[1] special	None: 2-1 special	None: 2-1 regular	Stripped: 2-0 special	Stripped: 2-1 special	Stripped: 2-1 regular	Stripped and furrowed: 2-0 special	Stripped and furrowed: 2-1 special	Stripped and furrowed: 2-1 regular
		SEEDLING HEIGHTS[2]								
		Feet								
2	4	0.48			0.61			0.54		
	5	[3](0.60)	0.61	0.57	(0.76)	0.72	0.62	(0.67)	0.68	0.59
5	7	1.39			2.03			1.83		
	8	(1.59)	1.61	1.33	(2.31)	2.37	1.88	(2.09)	2.31	2.15
10	12	2.86			4.98			4.80		
	13	(3.10)	3.54	3.10	(5.39)	5.44	4.75	(5.20)	5.64	4.69
10-year range		0.5-5.5	0.5-7.0	0.9-6.0	0.9-9.4	1.4-10.0	0.9-9.1	1.0-8.9	1.4-10.3	0.4-8.8
		SEEDLING SURVIVAL[4]								
		Percent								
2	4	52.5			87.7			87.9		
	5		72.5	51.3		99.3	83.9		97.0	91.7
5	7	31.9			74.7			79.9		
	8		42.1	23.4		85.5	71.8		93.1	82.5
5-year range		16-42	39-59	12-35	72-88	82-91	71-76	79-80	90-95	79-83

[1]The first digit indicates the number of years stock has been in an initial nursery bed (a seeded bed), the second, the number of years in a transplant bed; e.g., a 2-1 seedling would be 3 years old.
[2]Basis: 150 trees in each cell.
[3]Parenthetical values are estimates calculated by adding the periodic annual increment to the height at the end of the period.
[4]Basis: 12.7M to 21M trees per cell.

Natural variation.--Ten years after planting, the treatment combination with the tallest trees had the greatest height range:

Mean heights (Feet)	*Height range (Feet)*
5.64	9.2
5.44	8.6
4.98	8.5
4.80	7.9
4.75	8.2
4.69	8.4
3.54	6.5
3.10	5.1
2.86	4.5

Parallel trends are evident. Apparently slow starters continued growing slowly; fast starters fast.

Table 2.--*Mean annual height growth 2, 5, and 10 years after planting, Town Creek Plantations, Boise N.F.*

Nursery Stock		Site Preparation								
(Years since planting)	(Seedling age)	None 2-0[1] special	None 2-1 special	None 2-1 regular	Stripped 2-0 special	Stripped 2-1 special	Stripped 2-1 regular	Stripped & furrowed 2-0 special	Stripped & furrowed 2-1 special	Stripped & furrowed 2-1 regular
		Feet								
2	4	0.120			0.152			0.135		
	5		0.122	0.114		0.144	0.124		0.136	0.118
5	7	.198			.290			.261		
	8		.201	.166		.296	.235		.289	.269
10	12	.238			.415			.400		
	13		.272	.238		.418	.365		.434	.361

[1]The first digit indicates the number of years stock has been in an initial nursery bed (a seeded bed), the second, the number of years in a transplant bed; e.g., a 2-1 seedling would be 3 years old.

Table 3.--*Periodic annual height growth 2, 5, and 10 years after planting, Town Creek Plantations, Boise N.F.*

Nursery Stock		Site Preparation								
(Years since planting)	(Seedling age)	None 2-0[1] special	None 2-1 special	None 2-1 regular	Stripped 2-0 special	Stripped 2-1 special	Stripped 2-1 regular	Stripped & furrowed 2-0 special	Stripped & furrowed 2-1 special	Stripped & furrowed 2-1 regular
		Feet								
2	4	0.120			0.152			0.135		
	5		0.122	0.114		0.144	0.124		0.136	0.118
5	7	.300			.473			.430		
	8		.333	.420		.550	.420		.543	.312
10	12	.294			.590			.594		
	13		.386	.574		.614	.574		.666	.508

[1]The first digit indicates the number of years stock has been in an initial nursery bed (a seeded bed), the second, the number of years in a transplant bed; e.g., a 2-1 seedling would be 3 years old.

Figure 2.--Cut bank, stripped of brush in 1954, is shown as it appeared in 1968.

Data show that variance increased with size, a well-documented phenomenon.[8] Seed from many stands growing under different environmental conditions probably were mixed together in the nursery each year. Additional mixing of genetic characteristics no doubt occurred in lifting, shipping, and planting. These factors suggest that the variation in heights at any given age should be greater than that found in natural stands.

In addition, a broader range of inherited growth capacities survive because improved conditions for regeneration and establishment reduce the impact of natural selection. When the stands are thinned, management selection can replace natural selection by keeping trees best adapted to these sites. At times, height growth may be only a partial indicator of a tree's adaptability and survival potential.

Cut banks.--Trees planted 2 or 3 feet from a cut bank of 1 or 2 feet in depth (fig. 2) may have different growth conditions than trees 6 or 7 feet from the bank. From a subsample of all treatment combinations on a 1957 planting, we found that 12-year-old trees in the row next to a bank averaged more than 0.3 foot taller (8.55 feet) than trees in the outside row (8.19 feet). This difference is significant at the 95 percent level.

Influence of competition.--It is logical to assume that competition between brush and ponderosa pine seedlings has an effect on seedling height similar to that observed in overdense stands. The height-retarding influence of overstocking and its effect on site index evaluations has been described by Lynch.[9] The Town Creek results appear to be consistent with Lynch's findings. However, we can expect height growth to accelerate soon after the crowns clear brush level and the trees become dominant.

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[8] Donald R. Gedney and Floyd A. Johnson. Weighting factors for computing the relation between tree volume and d.b.h. in the Pacific Northwest. U.S. Forest Serv., Pacific Northwest Forest and Range Exp. Sta. Res. Note 174, 5 p. 1959.

[9] D. W. Lynch. Effects of stocking on site measurement and yield of second-growth ponderosa pine in the Inland Empire. U.S. Forest Serv., Intermountain Forest and Range Exp. Sta. Res. Pap. 56, 36 p. 1958.

Cognizant of the potential for error in site index evaluations, let us consider the magnitude of such an error. Project a stand planted in brush to, say, the year 2000. Then consider a traditional site index evaluation based on total age and height. It is apparent that volume on a brush site would be underestimated when compared to that on stripped ground. Of course, the magnitude of the error is variable, but (we suspect) appreciable in many cases. A 2-foot difference in height value for 20-year-old ponderosa pine (S.I.=80) represents 4 to 5 index units--a 5 to 10 percent difference in estimates of cubic foot volume at 50 years.[10] Much of this potential error, the result of wide variation in juvenile conditions, can be removed by using age at breast height as a variable in developing site index curves.

WHAT WAS LEARNED

Land managers must frequently base decisions on incomplete or inadequate data. Before 1954, regeneration practices in the Intermountain Region gave little hope for success. By 1958, survival in the Town Creek Plantations had pointed the direction to successful plantings. An unanswered question was: How well will the seedlings grow? Thousands of acres required planting; so the Region managers moved ahead without waiting for this question to be answered. Stripping was the site preparation, 2-0 seedlings were given special handling, and the slit method was used for planting. Height growth results have supported their decisions.

As a result of this study, we conclude that:

1.--Brush competition restricts seedling height growth;

2.--Brush removal improves both seedling survival and height growth;

3.--Nursery stock that is carefully handled and planted grows taller;

4.--On a comparable age basis, 2-0 ponderosa pine stock grows about as well as 2-1 stock;

5.--Trees 2 to 3 feet from a cut bank grow taller than trees 6 or 7 feet from the bank; and

6.--The rate of seedling height growth increases steadily for the first 10 years.

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[10]Meyer, *op. cit.* p. 2.

Research Note

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PINUS CONTORTA X *BANKSIANA* HYBRIDS TESTED IN NORTHERN ROCKY MOUNTAINS

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ABSTRACT

*Between 1950 and 1955 hybrid progenies of lodgepole pine (*Pinus contorta *Dougl.) X jack pine (*Pinus banksiana *Lamb.) were tested to determine whether adaptation and performance in Montana and Idaho justified improvement of lodgepole pine by hybridization. Average heights, diameters, and survival rates of hybrids, of jack pines native to the Lake States, and of lodgepole pines native to Montana and Idaho were similar after 15 to 20 years of field tests. Poor growth and survival characterized progenies of California lodgepole pines, which represented the maternal parents of several hybrid groups. It was concluded that programs which rely on intraspecific variability are most feasible for the improvement of lodgepole pine in the northern Rocky Mountains.*

Pinus contorta X *banksiana* hybrids were first produced in 1939 (Righter and Stockwell 1949; Righter and Duffield 1951) to combine the fast growth of jack pine (*Pinus banksiana* Lamb.) with the good form of lodgepole pine (*P. contorta* Dougl.). Field tests conducted in California indicated that hybrid seedlings grew at a slightly slower rate than jack pine seedlings, but had the characteristic form of lodgepole pine (Righter and Duffield 1951; Righter and Stockwell 1949). At older ages, hybrids may even surpass jack pine in growth (Duffield and Righter 1953; Duffield and Snyder 1958).

Field tests of F_1 hybrids were established between 1950 and 1955 in Montana and Idaho to determine whether hybrid adaptation and performance justified hybridization

[1]Respectively, Plant Geneticist, stationed in Moscow, Idaho, at Forestry Sciences Laboratory, maintained in cooperation with University of Idaho; and Silviculturist, stationed in Bozeman, Montana, at Forestry Sciences Laboratory, maintained in cooperation with Montana State University.

as a means of improving lodgepole pine.[2] After 5 to 10 years of growth in the field, it was evident that hybrids were able to survive in Montana and Idaho but did not grow taller than lodgepole pines indigenous to Montana (Lotan 1967). The present paper reports hybrid performance after 15 to 20 years of field tests.

MATERIALS AND METHODS

Three series of tests involving hybrids of different origin were field-planted between 1950 and 1955 in Idaho and Montana. Tests I and II were established in 1950 and 1952, respectively, and involved hybrids developed in California; Test III was established in 1955 with progenies derived from lodgepole pines native to Idaho and Montana. The parental lines of hybrid progenies are listed in tables 1, 2, and 3.

Tests I and II were planted on three sites: Lewis and Clark National Forest in west central Montana, Lubrecht Experimental Forest in western Montana, and Priest River Experimental Forest in northern Idaho. Test III was established on the Lubrecht and Priest River Experimental Forests. The basic design specified that ten 2-year-old seedlings be spaced 5 feet apart in randomized complete blocks replicated twice on each site. Irregularities of design and methods of establishment have been discussed previously (Lotan 1967).

Data on tree height, diameter, crown width, and number of branches in the uppermost whorl were scored at intervals following establishment. In 1969, only height, diameter, and vigor were scored because crown competition and shoot injuries were prevalent. Moreover, a severe outbreak of western gall rust (*Peridermium harknessii* Moore) in Tests I and II at Priest River prevented meaningful height or diameter measurements. Thus, results are available for Test I after 20 years of field growth, for Test II after 18 years, and for Test III after 15 years.

Due to inequalities in survival and irregularities in experimental design an analysis of variance of tree height and diameter was made for each site; analyses of variance were calculated from data on survival (percent live trees) and vigor (percent nondefective[3] trees) from all sites. Arcsin transformations were used for all percentage data. Mean values for hybrids, jack pines, California lodgepole pines, and lodgepole pines indigenous to Montana and Idaho were compared by means of Scheffé's S test for multiple mean comparisons (Scheffé 1959).

RESULTS

Test I--1950 California Hybrids

After 20 years of field testing, the mean height of California lodgepole pines (table 1) was significantly less (1% level of probability) than that of hybrids, jack pines, and Montana lodgepole pines on the Lubrecht site. At the Lewis and Clark site, only indigenous trees were significantly taller (1% level) than California progenies. Lack of hybrid superiority over jack pines and indigenous lodgepole pines was also apparent; in fact, indigenous trees significantly surpassed (5% level) the height of hybrids on the Lewis and Clark site.

[2]This study was established by A. E. Squillace, now with the Southeastern Forest Experiment Station. Establishment of field tests was made with the cooperation of the Pacific Southwest Forest and Range Experiment Station, the University of Montana, and the Lewis and Clark National Forest. All hybrids developed in California and sources of jack pine pollen were supplied by the Institute of Forest Genetics, Placerville, California.

[3]Each defective tree was scored primarily on the basis of general health and of forkedness resulting from biotic and environmental injuries to the terminal shoot.

Table 1.--*Mean performance of 22-year-old trees in Test I*

Seed source	Pollen source	Survival (live trees)	Vigor (nondefective trees)	Diameter at root collar: Lewis & Clark	Diameter at root collar: Lubrecht	Height: Lewis & Clark	Height: Lubrecht
		- - - - *Percent* - - - -		- - - *Inches* - - -		- - - *Feet* - - -	
LP (Calif.)[1]	JP (Wis.)[2]	85.4	60.1	2.1	3.2	9.6	19.1
LP (Calif.)[3]	Wind	84.3	6.2	2.2	3.8	6.2	10.6
LP (Mont., Gallatin N.F.)[3]	Wind	98.7	75.8	3.9	4.3	17.6	19.2
LP (Mont., Lolo N.F.)[3]	Wind	98.8	73.3	3.1	3.9	12.1	18.9
JP (Minn.)[3]	Wind	52.8	37.7	2.6	4.0	13.8	20.7
JP (Wis.)[3]	Wind	--	--	--	3.8	--	21.0

[1]Represented by two or three trees; elevation 5,700-7,200 feet. LP = lodgepole pine.
[2]Represented by unknown number of trees. JP = jack pine.
[3]Probable stand collections.

Low mean values characterized survival and vigor of jack pines, vigor of California lodgepole pines, and diameter of hybrids. None of these values, however, deviated significantly (5% level) from corresponding values for other groups.

Test II--1952 California Hybrids

After 18 years of field testing, the mean height (table 2) of California trees was significantly less (1% level) than those of hybrids and jack pines on the Lubrecht site and of Montana lodgepole pines on both sites. No differences in performance could be detected between hybrids and indigenous trees. Moreover, diameters of California trees were significantly less than those of hybrids (1% level) on the Lubrecht site and of indigenous trees (5% level) on both sites. Survival and vigor of jack pines and F_2 materials were low, but the values were not significantly lower (5% level) than those of other progenies.

High survival values characterized hybrid and wind-pollinated progenies of one California lodgepole pine, Eld-10-1 (table 2). At the Priest River site, where western gall rust was prevalent, all uninfected trees were progenies of this tree; 40% of its hybrids and 80% of its wind-pollinated progenies were alive and uninfected. Tree Eld-10-1 may carry resistance to western gall rust.

Test III--1955 Montana and Idaho Hybrids

After 15 years of field tests, no differences (5% level) were detected in either height or diameter of hybrids and lodgepole pines native to Idaho and Montana (table 3). Survival and vigor were not analyzed because of the unbalanced design.

Table 2.--*Mean performance of 20-year-old trees in Test II*

Maternal tree	Pollen source	Survival (live trees)	Vigor (nondefective trees)	Diameter at root collar: Lewis & Clark	Diameter at root collar: Lubrecht	Height: Lewis & Clark	Height: Lubrecht
		Percent	*Percent*	*Inches*	*Inches*	*Feet*	*Feet*
LP(Calif., Eld-8-1, 7,300' elev.)[1]	JP(Mich.)[2]	85.2	35.5	2.8	4.0	10.7	16.9
LP(Calif., Eld-10-1, 6,500' elev.)[1]	JP(Mich.)[2]	99.4	70.0	2.6	3.9	10.2	16.6
F_1 LP(Calif., 5,700' elev.) X JP[3]	Wind	31.4	5.2	--	2.1	--	11.1
LP(Calif., Eld-9-1, 7,100' elev.)[4]	Wind	79.8	18.7	2.1	2.3	5.3	8.2
LP(Calif., Eld-10-1, 6,500' elev.)[4]	Wind	92.0	45.1	1.8	2.2	5.1	8.4
LP(Mont., Deer-lodge N.F.)[5]	Wind	87.2	52.2	3.4	3.4	14.0	15.6
LP(Mont., Lewis & Clark N.F.)[5]	Wind	85.4	45.2	3.7	4.1	15.4	16.0
JP(Minn., Superior N.F.)[5]	Wind	38.3	13.1	--	3.9	--	19.0

[1]Symbols refer to Eldorado County, the stand and the maternal tree as assigned by the Institute of Forest Genetics. LP = lodgepole pine.

[2]Represented by two trees from the same provenance. JP = jack pine.

[3]Seeds collected from several F_1 hybrids at Placerville, Calif.; progenies are F_2.

[4]Seeds collected from a single tree.

[5]Probable stand collections.

Table 3.--*Mean performance of 17-year-old trees in Test III*

Maternal tree	Pollen source	Diameter		Height	
		Priest River	Lubrecht	Priest River	Lubrecht
		Inches		*Feet*	
LP-1 (Mont., Lolo N.F.)	JP (Mich.)[1]	--	2.9	--	17.4
LP-1 (Mont., Lolo N.F.)[2]	Wind	3.7	3.3	20.6	15.6
LP-2 (Mont., Lolo N.F.)	JP (Mich.)[1]	--	3.4	--	18.0
LP-3 (Idaho, St. Joe N.F.)	JP (Mich.)[1]	4.1	--	21.0	--
LP-3 (Idaho, St. Joe N.F.)	Wind	4.0	--	21.4	--
LP-4 (Idaho, St. Joe N.F.)	JP (Mich.)[1]	3.2	3.1	20.9	15.7
LP (Mont., Missoula Co.)[3]	Wind	2.5	3.5	15.0	15.8
LP (Idaho, St. Joe N.F.)[3]	Wind	3.5	3.9	20.3	16.9

[1]Represented by two trees of different provenances. JP = jack pine.
[2]Seeds collected from a single tree. LP = lodgepole pine.
[3]Probable stand collections.

DISCUSSION

After 15 to 20 years of field testing, the growth of *P. contorta* X *banksiana* hybrids was similar to that of lodgepole pines native to Montana and Idaho. Moreover, the growth of jack pines from Minnesota and Wisconsin equaled that of hybrids and indigenous (Montana and Idaho) trees. However, growth of lodgepole pines from California was comparatively poor.

The present results are similar to those presented by Lotan (1967) after the test trees had completed 5 to 10 years of growth in the field. Furthermore, statistically significant (1% level) correlation coefficients of 0.54 to 0.65 related the heights of individual trees in 1969 (tree ages, 17 to 22 years) to heights at age 5; these coefficients increased up to 0.98 as the age interval decreased. Thus, the relative height of individual trees remained fairly constant from 12 to 17 years.

The progenies of lodgepole pine and jack pine included in this study undoubtedly represent small proportions of the genetic variability within each species. Nevertheless, the data pertained directly to the feasibility of improving lodgepole pine throug hybridization. In Tests I and II, growth of the California lodgepole pine progenies contrasted sharply with that of the jack pine progenies; hybrids performed admirably regardless of their genetic relationship to the California trees. It is not surprising that lodgepole pine from relatively southern latitudes but high elevations in California performed poorly in northern Idaho and Montana; such occurrences are common in provenance tests of forest trees. Moreover, the good growth of jack pines suggests that some progenies are preadapted to environmental conditions in Idaho and Montana. Surprisingly good growth of hybrids thus may result from: (1) complementary effects of two relatively foreign genetic systems; or (2) covering effects of an adapted genetic system over a maladapted system (see Clausen and Hiesey 1958, 1960; Clausen 1959; Hiesey 1964).

Although the results suggest a potential for improving lodgepole pine through hybridization with jack pine, interspecific hybridization does not appear to be warranted. If the potential is to be utilized, provenances must be screened for jack pines that exhibit high general ability to combine with lodgepole pines native to Montana and Idaho. Moreover, those hybrids in which preadapted genetic systems of jack pine are combined with adapted systems of indigenous trees should also be tested. On the other hand, superiority of hybrids over trees indigenous to Montana and Idaho has not been shown. Therefore, programs that rely on intraspecific variability appear to be most feasible for improvement of lodgepole pine in the northern Rocky Mountains.

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SOIL FREEZING DETERMINED WITH FOUR TYPES OF WATER-FILLED TUBES

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ABSTRACT

During two winters (1966-67 and 1967-68) periodic determinations were made of soil temperatures and ice column depths in four types of tubes inserted in the soil at three sites in northern Utah. The 0°C. isotherm varied in depth from the surface to 21 inches at lower elevation sites in Logan and to 41 inches on an exposed mountain ridge at 8,870 feet elevation. Steel tubing (1.55-inch inside diameter), commonly used as access tubes for neutron probes used in soil water measurements, proved to be as good as steel or plastic pipe as casings for water-filled frost meter tubes.

The depth, persistence, extent, and nature of soil frost are of biotic and hydrologic importance. The nature of soil frost can be determined only through laborious methods, such as digging or probing (Stoeckeler and Thames 1957). However, any temperature-sensing device can be installed and left in place for several years to sample depth, persistence, and extent of freezing temperatures in the soil. Thermistors or electrical soil moisture resistance blocks, buried at specified depths in the soil profile, are commonly used.

Frost meters, based on the freezing of a contained aqueous solution held in the soil, have been tested and used, too. Sartz (1967) checked one of these meters and concluded that it was not satisfactory. An even simpler instrument, the Danilin soil-freezing meter, a direct-reading, tube-type gage, has been used in the Soviet Union and is reported to be reasonably accurate (Molga 1962, pp. 91-92). However, Kapotov (1968) feels it may overestimate frost depth. Modifications of the Danilin meter have been made and tested on this continent. For example, Patric and Fridley (1969) used a water-filled plastic tube encased in a copper tube buried vertically in the soil.

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[1]Plant Ecologist, stationed in Logan, Utah, at the Forestry Sciences Laboratory, which is maintained in cooperation with Utah State University. The author acknowledges the assistance of E. Arlo Richardson, ESSA Weather Bureau, in instrumenting this research.

Currently, similar devices are being extensively tested by the U.S. Army Cold Regions Research and Engineering Laboratory (Brown and Rickard 1968) and by the North Central Forest Experiment Station (Harris 1970). Basically, they are working with sand- or liquid-filled tubes of transparent plastic encased in plastic tubes. They have found a dilute aqueous solution of fluorescein dye in a sand-filled tube to be most reliable, accurate, and easy to read. The fluorescein separates from the water as it freezes, leaving a distinct color change between the liquid and solid phases.

The tests I report here were made with modified Danilin frost meters filled with water. At the time, I was not aware that dilute aqueous dye solutions in sand might be better than distilled water columns; consequently, this paper can best serve as a comparison of different types of outer casings for frost tubes.

METHODS

Four frost meters and a stack of thermistors were installed at each of three sites before the soil froze in 1966. Two sites were in Logan, Utah, adjacent to one another on very stony alluvium. The surface foot of soil on these sites differed; on one it was black loam, on the other, sand. The third site was on a windswept mountain ridge at 8,870 feet elevation near Farmington, Utah.

A pit, approximately 3 by 5 feet by 6 feet deep, was dug at each site. The following casings were positioned vertically at maximum distances from each other: a 5/8-inch (inside diameter) galvanized iron pipe, a 5/8-inch black iron pipe, a 5/8-inch black plastic pipe, and a 1.55-inch black steel soil moisture access tube. The bottoms of the pipes and the access tube were sealed. Thermistors, calibrated through the range of soi temperatures expected, were installed at least a foot lateral distance from any casing and at selected depths (2, 6, 12, 18, 24, and 36 inches in Logan; plus 42, 54, and 66 inches on the mountain). After the soil had been packed back into the pit, the protruding casings were painted white to minimize absorption of solar radiation. These protruding ends varied in length from 8 to 50 inches, depending upon the site and the year.

The access casings for frost meters in Logan extended 50 inches above the sandy soil and 18 inches above the loam soil during the first winter. The 50-inch extensions were shortened to 8 inches during the second winter. Snow was removed from the Logan sites the first winter but allowed to accumulate during the second. Casings extended 24 inches above the soil throughout both winters on the mountain site; so, depending on snow depth, 5 to 24 inches of tubing was exposed to solar radiation during the season of soil freezing.

The outside diameter of the frost meter, a 4-foot length of clear, flexible, plastic tubing, measured 7/16 inch in the small casings and $1\frac{1}{4}$ inches in the soil moisture access tubes. Each meter was fabricated as shown in figure 1. Plastic plugs were glued into both ends of the tube. A string was run through the tube, left fairly slack, and glued to these plugs. The string effectively held the ice column at the depth of its formation. The tube was filled with distilled water to within 6 inches of its top; the upper air space allowed for expansion or contraction of water volume due to temperature changes or to freezing. The tube was graduated from the water level downward. The top of the water column was placed at ground level by adjusting the length of chain between the pipe cap and the top of the tube. A stiff wire would have been better than the chain; it would have allowed the frost meter to be pushed to the proper depth against the friction on the inside of the casing.

Periodic readings were taken at each site during the winters of 1966-67 and 1967-68 (fig. 2). Soil temperatures (from thermistor readings) and depth of frost (indicated by depth of ice column in the frost meters) were recorded. The depth of freezing temperatures (0° C. isotherm) was estimated by interpolation of readings between thermistors.

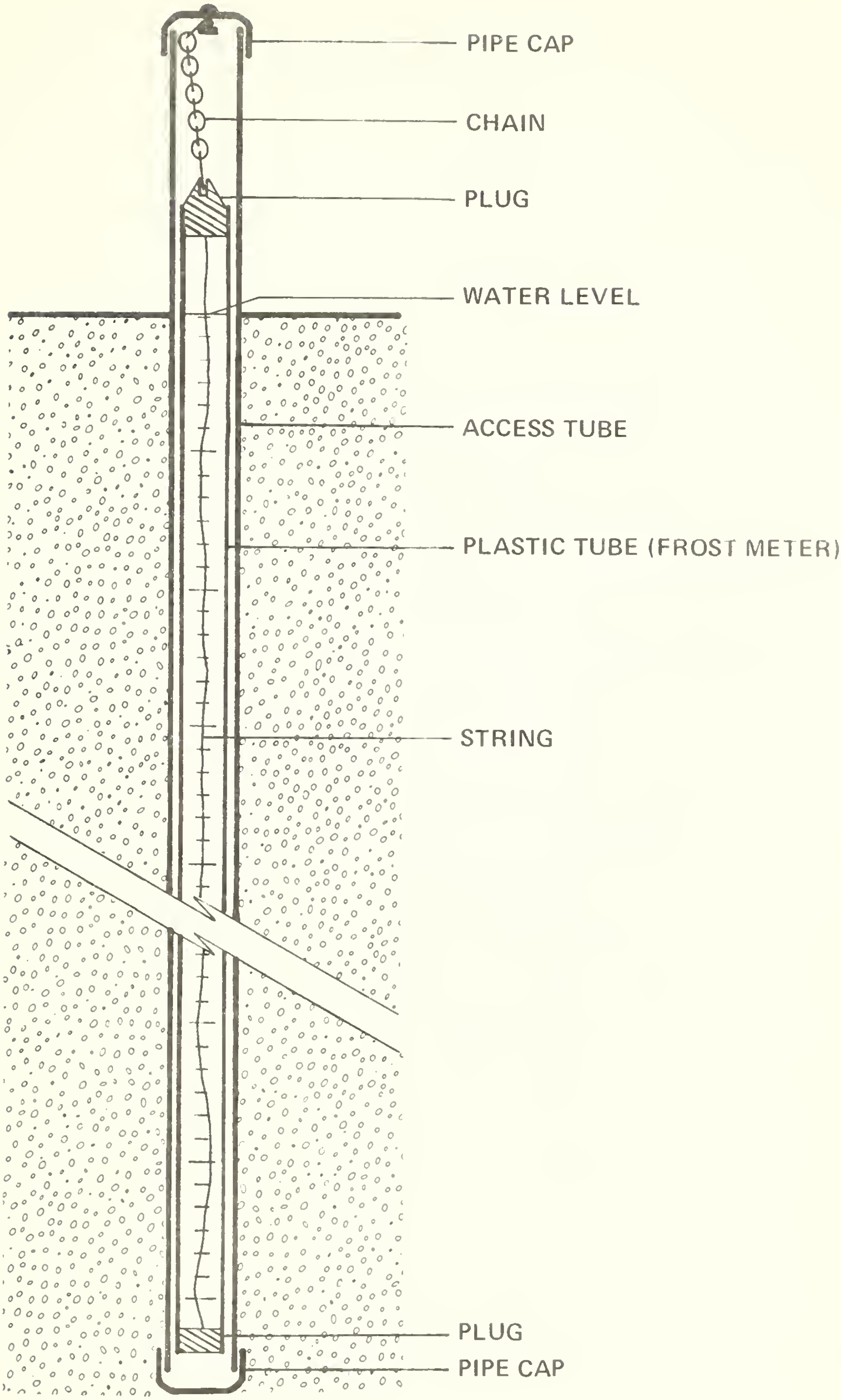

Figure 1.--Modified Danilin frost meter.

Figure 2.--Gathering data from a frost-meter site in Logan.

RESULTS

During the first winter, when snow was removed from the Logan sites, freezing temperatures on January 11 extended to their maximum depths: 10.3 and 17.5 inches beneath loam and sandy soils, respectively. At that time, there were freezing temperatures to at least the 30-inch depth on the mountain ridge, where snow depths seldom exceeded a foot. The maximum freezing depth, 40.6 inches, was recorded March 7 on the mountain. Midwinter mild weather thawed the soil in Logan, and all thermistor readings after January 16 were above 0° C. The 0° C. isotherm was at the 18-inch depth on the mountain April 18, and readings were all above freezing by May 16.

During the second winter, maximum freezing temperatures in Logan extended to 18.0 and 21.4 inches in the loam and sandy soils, respectively. These measurements were made on January 23 under 4 inches of snow. Only one reading was taken on the mountain that winter; on February 1, freezing temperatures extended 24.8 inches into the soil, which was then buried under a 16-inch snowpack.

Wide differences in exposed casing lengths produced no detectable effect on ice depth in frost tubes. Apparently, tubes, painted white and as much as 50 inches long, conduct an insignificant net amount of solar radiation into the frozen soil. Unfortunately, limited data preclude a thorough statistical analysis of this important feature. However, this observation is supported by earlier research, in which access tubes were found to have no influence on soil temperatures under the severe winter climate of Montana (Dickey, Ferguson, and Brown 1964).

Several linear regression analyses were run to determine relationships between depth of ice in the various types of frost meter tubes and depth of the 0° C. isotherm in the soil. One analysis involved all 72 observations; the ice column depth was compared with the independent, concomitant depth of the 0° C. isotherm in the soil at the respective site. The equation was $\hat{Y} = 5.3579 + 1.0052X$, with an r^2 of 0.65. This relationship was highly significant; some 65 percent of the variance in ice column depth could be explained by soil temperature. In another analysis, 20 observations of ice depth in meters encased in soil moisture access tubes were compared to concomitant 0° C. isotherm determinations. The resultant equation was $\hat{Y} = 6.7836 + 0.9594X$, with an r^2 of 0.60.

Both analyses revealed a major disadvantage in the use of water-filled frost tubes. The spread of data, indicated by r^2 values of 0.65 and 0.60, was caused by a lag in frost meter response to soil temperature changes. Ice remained in the meters during thaw periods for some time after the soil temperature exceeded 0° C. For example, the 0° C. soil isotherm on the mountain had reached 18 inches April 18, but some 41 inches of ice remained in the meter within the soil moisture access tube. By May 16, there were still 36 inches of ice in that meter, although soil was entirely above freezing. In Logan, a similar lag existed during the midwinter thaw; some 14 inches of ice remained in meters of the above type after soil thermistors gave above-freezing readings.

There is an intolerable lag in response from these frost meters, at least during the thaw season. Coarse-textured, well-drained soils warm and thaw well before ice melts in such meters. But, before the soil moisture access tubes are condemned as casings for frost meters, let's compare them to the other casings.

The depths of ice in the frost meters encased in access tubes (dependent variable) were compared to depths of ice in the frost meters encased in plastic pipes on the same site at the same time (fig. 3). This regression yielded an r^2 value of 0.98. Obviously, the access tube casing was just as good as the smaller-diameter, plastic tube casing for the modified Danilin frost meter. If one is rejected as being unsatisfactory for accurate soil-frost measurements, both must be rejected.

Three other regressions compared the different casings. In the first, galvanized iron pipe (dependent) was compared to black iron pipe (independent). Despite the similarity in materials, especially when both were painted white, the r^2 value was not as great as when access tubes and plastic pipes were compared. Fourteen observations were used; they produced an r^2 of 0.92 and the following regression equation:

$$\hat{Y} = -0.2425 + 0.9495X.$$

In the next regression, black iron pipe (dependent) was compared to plastic pipe (independent). Twenty-one observations were used. The r^2 value was 0.97 and the equation:

$$\hat{Y} = 0.2115 + 1.0274X.$$

Finally, access tubing (dependent) was compared with black iron pipe (independent). Twenty observations resulted in an r^2 of 0.95 and the following equation:

$$\hat{Y} = 1.219 + 0.9366X.$$

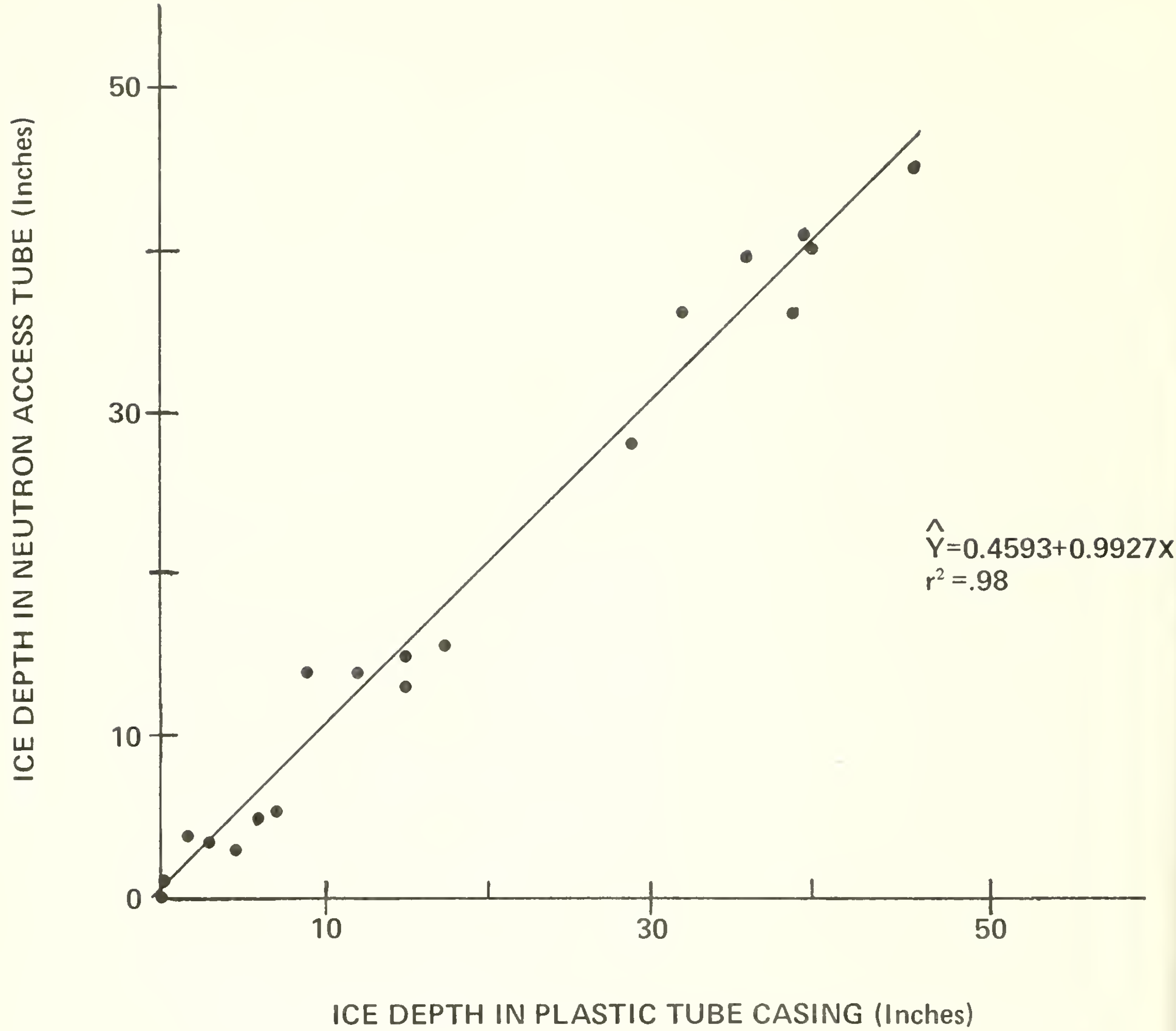

Figure 3.--Regression of data from frost meters with neutron access tube casings on data from meters with plastic pipe casings.

DISCUSSION AND CONCLUSIONS

Rather simple, easy-to-read frost meters can be used as an index of soil freezing. All modifications tested had about the same degree of accuracy; comparisons among them resulted in r^2 values that ranged from 0.92 to 0.98. However, the accuracy of all could be challenged when these data were compared to soil thermistor data and an r^2 value of only 0.65 resulted. The lag time in frost-meter response, especially during melt periods, accounted for much of the inaccuracy. Perhaps, the large quantity of water or ice in the frost meter tube plus the insulating effect of the air-space in its casing caused this delayed response. In any event, it was no worse in casings of soil moisture access tubes than in any other type of casing tested.

So, if frost meter tubes are accepted as adequate for soil frost measurements--as the sand-filled modifications being developed by Brown and Rickard (1968) perhaps are--it may make little difference whether these tubes are inserted in specially installed plastic casings, in pipe, or in already installed soil moisture access tubes. Certainly, if soil moisture access tubes can be used as acceptable casings for frost meters, their usefulness can be doubled. One installation could be utilized for soil water measurements in the frost-free season and for soil frost measurements during the remainder of the year. On sites that have appreciable snowpacks, plastic extensions probably would have to be added to the access tubes in the autumn when meters are inserted. These extensions and the frost meters could easily be removed in the spring prior to taking soil water readings with the neutron probe.

This proposed dual use (soil water plus soil frost metering) of an installation would not only save installation costs in many cases, but have other advantages as well:

1.--Neither use is destructive to the site;

2.--The thawing of frost in the spring may indicate the need to begin soil water readings at that site;

3.--Soil profile characteristics, usually determined at sites of soil water measurements, can also be used to explain soil frost conditions;

4.--If concomitant data on soil frost and soil water content are desired, the same microsites (holes) may be used; merely remove the frost meter from the access tube casing, read it, take the neutron soil water readings at the desired depths in the hole, and replace the meter. This would contribute to the ease and precision of some research, such as that conducted by Sartz (1969a, 1969b).

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CONTROLLED FELLING OF LARGE TREES TO PREVENT BREAKAGE

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ABSTRACT

Occasionally large trees need to be felled in a manner which prevents breakage and subsequent disruption of components of the crown and stem. Controlled felling of large trees in high use areas also is frequently needed to prevent damage to neighboring trees. Procedures employing a system of letdown ropes, pulleys, and manpower are described to fulfill these needs. This system provides near maximum safety, entails a minimum cost, and can be used in a wide variety of forested environments.

Occasionally for experimental purposes, large trees need to be felled so that, when brought to the ground, their limbs, foliage, and stem remain intact. There are also many other situations for which a simple, controlled felling procedure could be advantageously employed to remove undesirable large trees; e.g., in residential or administrative areas, near utility lines, or in campgrounds and other recreational units, where heavy equipment cannot be operated and where damage to surrounding trees and property should be avoided.

When one of our studies was terminated in 1968 on the Priest River Experimental Forest, various components of crowns and stems of 27 trees of western white pine (*Pinus monticola* Dougl.) had to be measured and weighed (fig. 1). Ranges in characteristics of these trees were:

Total above-ground fresh weight: <550 to 4,630 pounds
Live crown length: 16 to 99 feet
Total height: 52 to 138 feet
Diameter at 1.6-foot stump: 4 to 20 inches

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Figure 1.--Representative western white pine trees later felled by procedures described here. The numbered trees were felled in the direction toward the lower right corner of the shelter which was dismantled prior to felling. Diameters of trees here, at 1.6-foot stump, ranged from 5.5 (No. 1) to 18 inches (No. 8).

Our experience in piecing together the crowns of some of the taller trees after they had "free fallen" forced us to find a system of lowering the remaining trees to the ground to prevent considerable stem and branch breakage and crown disruption and to maintain accuracy of component sampling. That system is reported subsequently with the belief that it can be utilized in similar or other situations with appropriate modifications.

PROCEDURES

The steps that we found through trial and error to be most efficient and conducive to the safety of the operation are listed here in the recommended sequence.

1. The pathway along which the tree is to be laid down is cleared of debris, brush, trees, etc. This pathway can often be used for several sample trees when taken from small clusters.

2. The sample tree is climbed to the lower limit of the live crown. Dead limbs are removed flush with the bole during climbing. In order to prevent inadvertent loss of any live crown, we rarely went above its lower edge.

Material needed for step 3 may be carried with the climber or raised with a drop rope. For steps 3 through 6, refer to figure 2 as appropriate.

3. At the lower limit of the live crown, a 7/8- to 1-inch heavy link chain is double looped around the stem and fastened so that one loop drops below the other. A single block pulley, threaded with the let-down rope, is secured to the lower loop. A rope[2] is fastened just below the pulley attachment to provide equally trailing ends (two ropes of equal lengths would substitute adequately). The latter ropes serve as guides to keep the sample tree descending in the direction intended and are played out accordingly and in concert with the let-down rope.

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[2]All ropes were secured with bowline knots which were readily untied even after the loads exerted here.

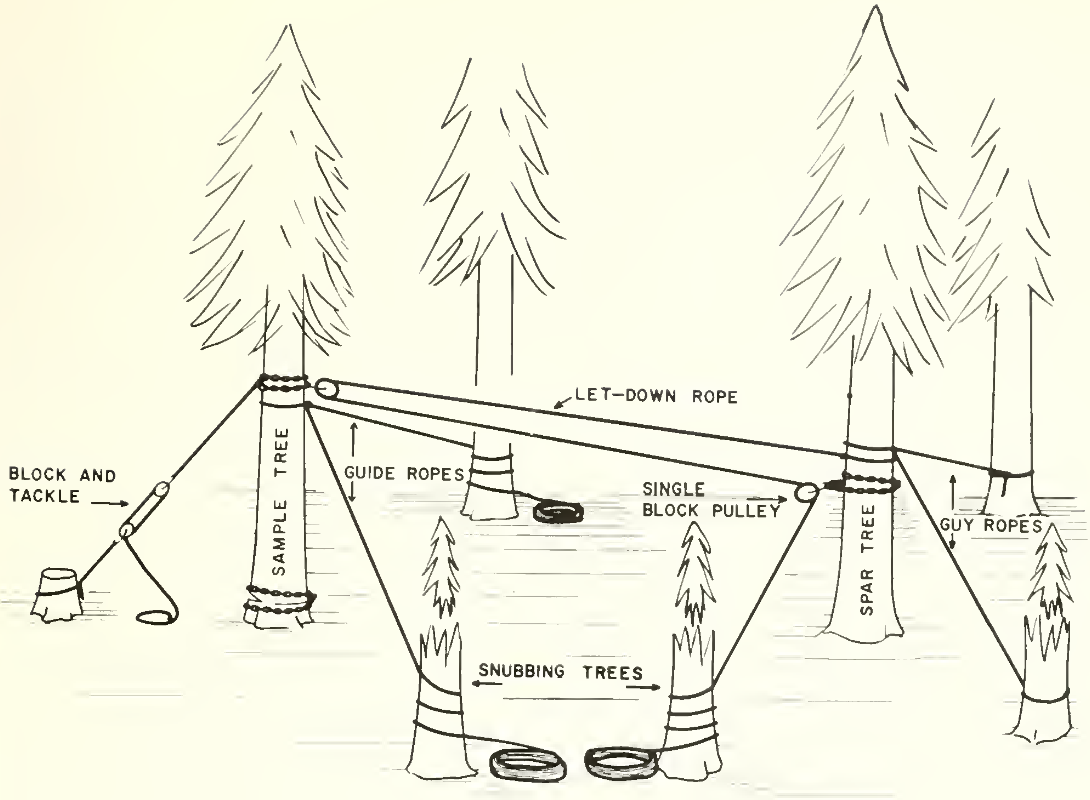

Figure 2.--Diagram of rigging for felling large sample trees.

4. A "spar" tree is selected behind and as near in line with the sample tree and its direction of descent as possible. One end of the let-down rope from the pulley on the sample tree is tied to the spar tree and the other end is run through a pulley, which is secured just below it and in the same manner as the one on the sample tree. The trailing end of this rope is then quadruple-looped around the base of a nearby large "snubbing" tree and coiled so that it can be played out without interference as the sample tree is lowered. Each trailing end of the guide ropes can at this point be likewise secured to sturdy snubbing trees located 45° to 90° from the let-down rope between the pulleys. Guy ropes are secured to the spar tree above the tied end of the let-down rope and to snubbing trees opposite the direction of intended fall.

5. A block-and-tackle or come-along is attached to the chain (preferably at step 3) holding the pulley on the sample tree and snubbed to a solid object toward the direction of tree fall. This arrangement will assure the tree starting in the direction intended and counteracts the weight and pull of the ropes and pulleys toward the opposite direction.

6. An undercut is made either as a downcut or an uppercut on the side of intended fall. We found the latter to be satisfactory, but the former may be safer; i.e., reduce stump jumping. The back cut is then made so that it comes within 2 to 2-1/2 inches of the undercut and approximately parallels it; a much wider uncut strip often results in a "barber chair" while a narrower strip is likely to break loose and, thus, eliminate the desired fulcrum effect. This 2-inch strip of uncut wood provides adequate stability as the tree is lowered and is usually of sufficient strength to prevent the tree from jumping off the stump. This latter possibility is insured against or at least controlled by a chain fastened around the stump and the tree butt after the back cut is made.

After this chain is fastened, the block-and-tackle is tightened until the tree leans sufficiently to descend alone. The tree may then be lowered under controlled release of the guide ropes by gradual release of the let-down rope. Some damage to snubbing trees, particularly by the let-down rope, may happen when its friction removes underlying bark. In no case did we expose living bark or cambium since we snubbed to thick-bark species, such as western larch (*Larix occidentalis* Nutt.), but thin-bark trees would be damaged.

SAFETY PRECAUTIONS

The above procedures can be used relatively safely provided certain precautions are taken. The ropes, chains, and pulleys must provide a safety load factor beyond their rated ones for the weights of trees lowered. While load ratings can easily be obtained for these materials, it is unfortunate that few data are available to obtain very accurate estimates of tree weights for all sizes and species of trees. Young and his coworkers have been most active in providing complete tree data (e.g., Young and Carpenter 1967; Young, Strand, and Altenberger 1964); but, from these data and others (Fahnestock 1960) that provide partial information, one should be able to reasonably estimate tree weights. A safety factor of at least one time greater than the estimated load should probably be used as a guide in procuring equipment.

The let-down rope should not be twisted between the sample and spar trees, and its trailing end and those of the guide ropes should be coiled so that they play out freely. The number of loops around snubbing trees, especially for the former rope, should be at least four in number to provide necessary friction for gradual playout. The number of loops required will vary with the size and bark characteristics (coefficient of friction of the snubbing tree, the diameter of the rope, and the force required at the trailing end of the let-down rope. The first experience will guide subsequent felling operations

The spar tree should be sound and at least as large as the sample tree. It should be securely anchored by guy ropes, as illustrated (fig. 2). When the spar tree pulley is located approximately 20 feet above ground as was our usual practice, the sample tree may free fall any time after its top is within about 20 feet of the ground, but little crown damage will occur. Our reason for placing this pulley so low was to avoid chances of spar tree breakage or tip over. Higher placement of the pulley would have provided better control over the final stages of let down but also would have increased costs of spar tree preparation including its anchoring. Worth mentioning in this respect is one incident where we used a slightly smaller spar than sample tree and anchored it with only one guy rope. When the sample tree was at about 45° in descent, the guy rope slipped up its snubbing tree. This caused the spar tree to lean. This lean along with the slightly upward force exerted toward the sample tree pulley caused the spar pulley, its holding chain, and the secured end of the let-down rope to slide up the spar tree when the bark failed and slipped on the woody cylinder at the points of attachment. (White pine, and other species, peel very readily in the spring, the time of our operation.) The result of these successive failures was a more rapid than desirable descent of the sample tree and breakage of the sound, though smaller, spar tree at about 35 feet above ground.

Each sample tree usually required a new spar tree in order to achieve reasonable alinement with the let-down area. We also advise the let-down crews (usually numbering about two men on each rope) to be clear of direct snapback of the ropes they are handling and to be shielded by trees from all of these ropes as well as from the pulleys and the spar tree. As indicated above, alertness to all phases of the operation by all crews is a prerequisite since all systems are "go" once the sample tree is in descent.

CONCLUSIONS

Obviously, more elaborate systems of tree let-down have been used (Young, Gammon, and Hoar 1963; Young and Chase 1965), but we found the above procedures easy to employ, cheap, manageable, and safe as long as the above precautions were adhered to. All equipment described here can be moved rather easily over any terrain to any forested sample point. Small trees, weighing perhaps less than 750 pounds, could literally be hand lowered with let-down ropes. The time involved to rig and fell even the largest trees rarely exceeded one hour, but these trees required a total of six to eight men during the actual let-down to man the ropes and to direct operations. However, it took more than 10 man-days to piece together a large, free-fallen tree, and uncertainty still prevailed over exact relocation as well as completeness of the sample components, such as foliage.

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Research Note

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ECONOMICS AND MANAGEMENT IMPLICATIONS OF CAMPGROUND IRRIGATION--A CASE STUDY

Wendell G. Beardsley and Roscoe B. Herrington[1]

ABSTRACT

Irrigation of campgrounds can aid in establishing and maintaining ground-cover vegetation; however, it introduces new administrative problems and increases costs of campground construction and maintenance. At Point Campground in central Idaho, costs of irrigation were $0.26 per visitor-day; benefits must be subjectively evaluated. Improved campground design can reduce the costs and minimize problems of administration.

In some campgrounds, irrigation will be considered as a means for facilitating revegetation. Managers must examine (1) the cost and anticipated benefits of an appropriate system of irrigation, and (2) the problems of accommodating campground visitors to the system. As is frequently the case in investment for recreational uses, the benefits of vegetation improvements are primarily esthetic. Although costs can be quantified fairly easily, managers must subjectively decide whether such investments are justified.

Using a case study to provide insight into the questions of benefit and cost, this paper describes an irrigation system in a redesigned and reconstructed campground. Additionally, the study suggests many problems which may be encountered elsewhere during campground irrigation, together with possible alternative solutions.

THE STUDY AREA

Point Campground in the Sawtooth National Forest, Idaho, is a 17-family unit campground that occupies a 12-acre peninsula on Redfish Lake near the Sawtooth Primitive Area. It has been a very popular "destination campground" since first being opened in 1935. In 1969 it received 6,200 visitor-days' use. The climate at this 6,500-foot elevation is cool and dry; 10 frost-free days are considered normal; average rainfall during the summer season is 7 inches. Although congenial for summer recreation, the climate is not conducive to luxuriant vegetation. Moreover, the short season available for effective plant growth coincides with the season of heavy tourist use.

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Native vegetation consists of several grasses and forbs as well as bitterbrush, lodgepole pine, and some Douglas-fir and aspen. After 30 years of camping and picnicking use, less than 15 percent of the ground surface area was covered with vegetation. Although no records were available, the site originally must have supported closer to 70 percent ground cover judging from the present condition of undeveloped areas adjacent to the campground.

SITE RECONSTRUCTION

Point Campground was closed and completely redesigned and rehabilitated from 1965 through 1967 and reopened for use in July 1968. An adequate supply of water is piped 2,500 feet through a single pipe from Fishook Creek to the campground. There, culinary water is diverted for minor chlorination treatment and piped to drinking hydrants and washrooms. Untreated irrigation water is delivered to a "rainbird" sprinkling head at each family unit. The capacity and pressure of the system delivers 6 gallons per minute to each of the 17 sprinkling heads, each of which waters an area 110 feet in diameter (fig. 1).

For experimental purposes, only eight family units are currently receiving water in a study designed to test the effectiveness of water, fertilizer, and seed in establishing and maintaining adequate ground cover vegetation on an old and worn site.[2]

COSTS OF THE IRRIGATION SYSTEM

The campground irrigation system represents an addition to the basic water system required for delivery of water for culinary use by campers and for a flush toilet facility. Without the irrigation system, the pipeline, hydrants, treatment equipment, and toilet facilities would have cost $45,600. Irrigation required additional investment at several points: larger capacity pipe from the water source to the campground, pipe for delivery of water to each family unit, underground valves and sprinkler heads. These added costs were $11,400, or $670 per unit.

Irrigation of the campground necessitated added costs for operation and maintenance of the system during the growing season. Weekly operating costs, from mid-June to mid-September, were estimated to be $35, or $420 per season. Annual maintenance of the system costs approximately $280. Therefore, total annual operation and maintenance costs were about $700, or $41 per unit.

The irrigation system should have a useful physical life of at least 20 years. Over this period, the annual cost of the system would be $915 per year, assuming an interest rate of 5 percent on the initial ($11,400) investment. Per family unit, the costs would be $54 per year.

Therefore, the total annual cost of capital investment in the system, operation, and maintenance, expressed on a per family unit basis is $95. Based on the 1969 season use-level (365 visitor-days per unit), this cost is $0.26 per visitor-day.[3] This amounts to approximately $1 per night for a family of four persons.

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[2]Roscoe B. Herrington and Wendell G. Beardsley. Improvement and maintenance of campground vegetation. USDA Forest Serv. Res. Pap. INT-87, 9 p. 1970.

[3]Although only eight units (randomly located) were actually watered, additional costs incurred to water all 17 units would be negligible. The irrigation system already extends to the other units. The additional labor required to turn on nine extra sprinklers would be minimal and would be accomplished while walking between the currently watered units.

Figure 1.--A "rainbird" sprinkler was used to irrigate a family unit at Point Campground, Sawtooth National Forest, Idaho.

One further (but less obvious) cost which cannot be ignored is the loss of campground capacity necessitated by irrigating Point Campground. All visitors were excluded Tuesday afternoon and night of each week to permit sprinkling. Therefore, as much as one-seventh of the annual benefits of visitor-use would have been lost had the camp been fully occupied. If a daily overnight fee for use were charged, as much as one-seventh of total revenues would be lost because of the irrigation program. While the magnitude of these costs at Point Campground cannot be quantitatively expressed, they should be considered along with many of the immeasurable benefits of the irrigation system.

BENEFITS OF IRRIGATION

Although the costs of providing irrigation in campgrounds are for the most part readily assembled, the benefits resulting from this activity cannot be evaluated in monetary terms. Most of the benefits generated accrue directly to individual campground users as increased satisfaction from the camping experience. Some benefits may flow to the campground managers in the form of reduced maintenance costs. For example, the more succulent vegetation may reduce fire risk, or cleanup cost may be reduced if the neater, fresher appearance of the campground induces less littering by visitors.

The benefits from irrigating Point Campground include: (1) esthetic benefits to visitors from increased grass, herb, and shrub cover around family units, (2) decreased dust and mud conditions, (3) decreased ground fire hazard, and (4) the weekly cleansing effect of the water on the table and grill facilities and surrounding area. After 2 years of treatment, the campground seems generally greener and cleaner. Units receiving water, fertilizer, and seed had 49 percent grass, herb, and shrub cover; units receiving fertilizer and seed only had 17 percent cover.[4] These and other benefits of increased vegetative cover must be subjectively evaluated at each campground for use in investment decisions.

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[4]Herrington and Beardsley, op. cit.

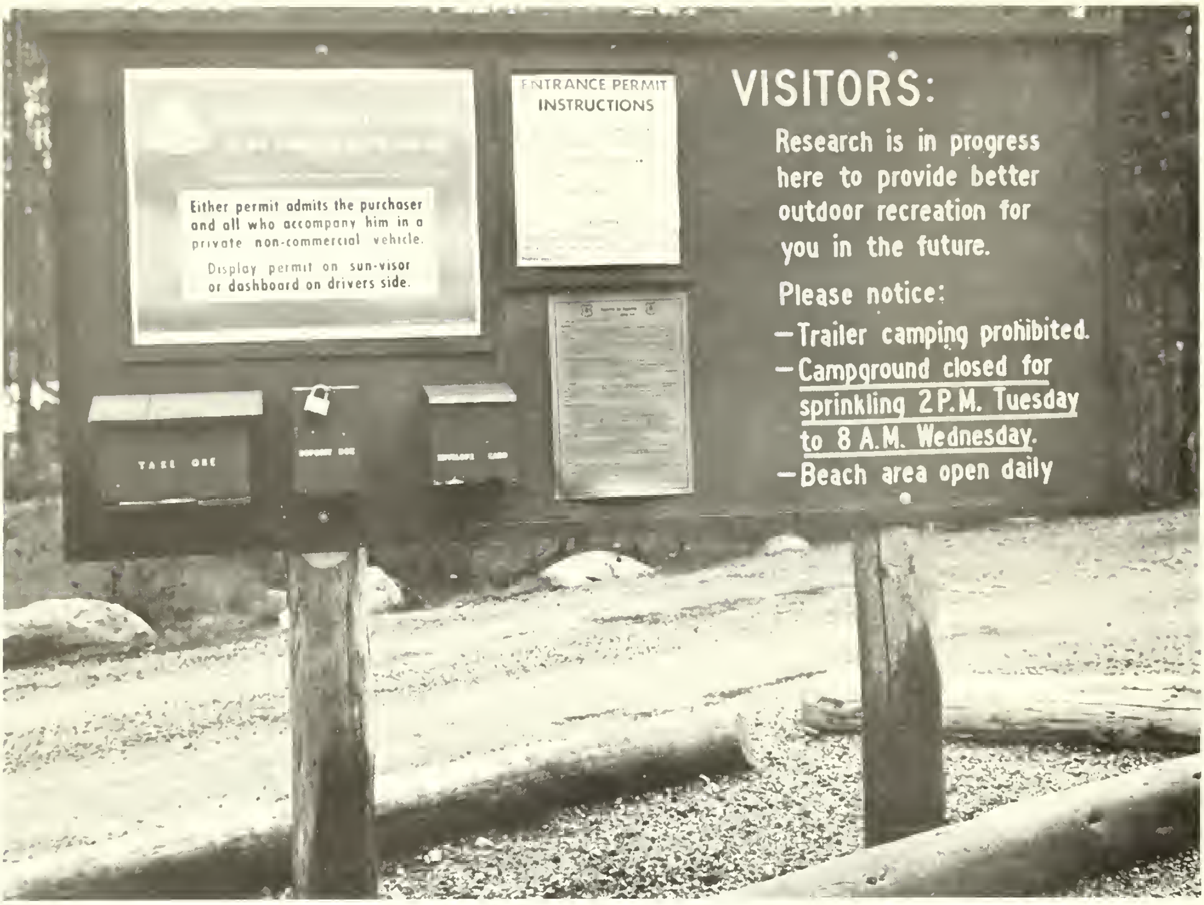

Figure 2.--Entrance sign explains weekly closure of Point Campground for sprinkling.

OPERATION OF THE IRRIGATION SYSTEM

A basic problem at Point Campground was accommodating visitors to an irrigation schedule under which large volumes of water at high pressure were sprayed 1 day each week over each unit. Several possible alternative solutions were considered and will be discussed later. The method selected was to require all visitors to vacate the entire campground on a scheduled basis 1 day each week. This seemingly drastic solution was the most workable and efficient from an administrative standpoint. Eight hours of sprinkling were required to apply a minimum of 1 inch of water, after which a drying-out period was desirable to allow drainage of surface water and to prevent excessive damage from trampling while the vegetation was in a wet, turgid condition.[5]

The campground was closed each Tuesday at 2:00 p.m. and reopened at 8:00 a.m. Wednesday. Watering was done from 2:00 p.m. to 10:00 p.m. These special regulations and the reasons for them were explained to visitors at the entrance by using brochures and a sign (fig. 2). Additional information about the program, explanation of the regulations, and enforcement of them were provided by the campground guard. These

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[5]Previous experimental results indicated excessive levels of damage when vegetation is trampled immediately after watering. See: J. Alan Wagar, Cultural treatment of vegetation on recreation sites. Soc. Amer. Forest. Proc. 1965: 37-39.

special precautions probably explain the surprisingly cooperative visitor reaction, and may provide a model program for use elsewhere. Visitors were often quite interested in the research program; almost no adverse reaction was reported by Sawtooth Valley District personnel. Many visitors who were required to move out on Tuesday afternoon were observed waiting to reenter on Wednesday morning. Their willingness to undertake the inconvenience of moving camping equipment twice attests to the desirability of the site, one factor of which may be the improved condition of vegetation.

DISCUSSION

Installation and operation of such an irrigation system creates many problems of concern to managers. The experience from Point Campground suggests factors that must be considered so that a unique, functional system can be designed within the constraints encountered at other individual campgrounds. These factors can be assigned to three classes: (1) Physical characteristics of the site, (2) design and construction of the campground, and (3) visitors who use it. These are discussed below.

Site characteristics.--Several site factors relevant to a functional irrigation system are important: distance to and volume of the water supply, water absorption, and retention capacity of soils in the campground, slope steepness of areas to be watered, location and size of existing vegetation, and normal precipitation patterns.

Costs of campground irrigation are strongly influenced by the availability of adequate water supplies. At Point Campground, water was available only 2,500 feet from the site in more than sufficient quantity. In areas where water is not available reasonably near the site, hauling water in tank trucks is possible, but at substantially higher cost. With this alternative, water could be hauled and stored until a sufficient quantity was available to water the campground, or several units simultaneously. Alternatively, units could be individually watered directly from the truck as water is delivered to the site. This would eliminate storage tanks and the pipeline delivery system, but substantially increase labor required during watering. Experience with hauling water at a campground in northern Utah indicated the approximate annual cost for irrigating 12 units would be about $1,800, or $150 per unit. On a per-unit basis, this represents more than a 50-percent increase in the costs encountered at Point Campground with the underground irrigation system. Included were wages of one full-time laborer for 3 months, tank truck rental, pumps, hose, and sprinkler head equipment. One-way haul distance was 3 miles. The truck hauled 700 gallons per trip and the water was pumped directly from the truck onto the unit. A total of 1,750 gallons was required to water the 53- by 53-foot test plot at each unit. Although this approach was expensive in terms of labor required, it permitted watering individual units as they became vacant and eliminated the inconvenience of moving suffered by the visitors at Point Campground.

Soils and slopes found at different sites may present additional constraints for irrigation. Impervious or highly erodible surface soils limit the rate at which water may be applied. Similarly, water might run off sloped areas too rapidly to permit satisfactory infiltration to the root level of plants. Mulching and leveling might help alleviate these problems at some sites. In any event, soil and topographic conditions will influence the specifications for output rates of sprinkler heads.

Existing vegetation--particularly trees and taller shrub species--must also be considered in the selection and location of sprinkler heads. Such vegetation can interfere with the designed pattern of water distribution from a particular sprinkler head. Moreover, young thin-barked trees can be seriously injured by the impact of a high pressure stream of water.

Patterns of rainfall will influence decisions regarding irrigation systems. For example, an area may ordinarily receive adequate rainfall for all but a short period of

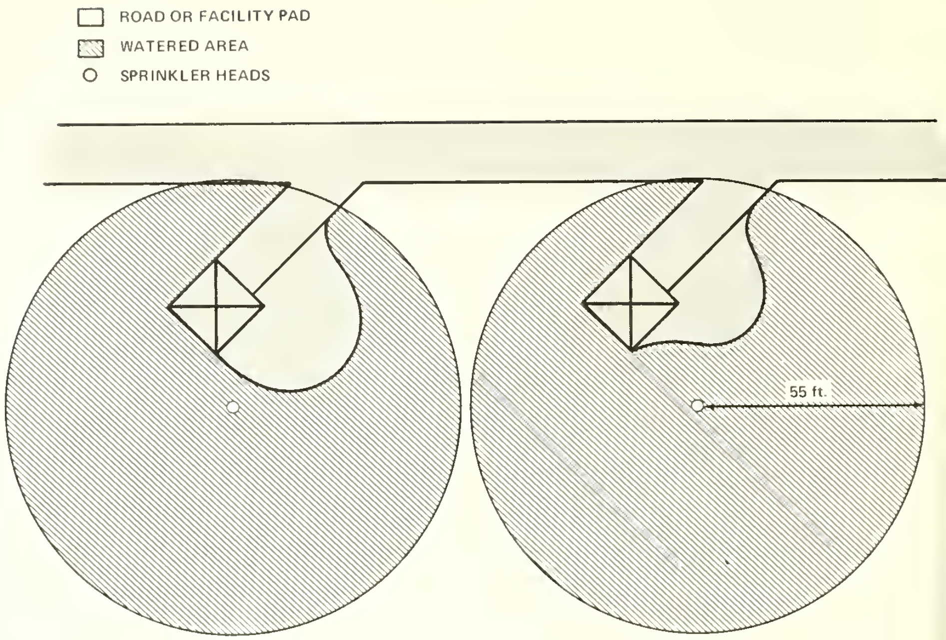

Figure 3.--Present design of camp units at Point Campground. A single sprinkler waters the entire unit but water cannot be excluded from the facility pad area.

the season. In such cases, one or two sprinklings per season may be adequate. This could be accomplished using hoses rather than by installing an expensive underground system. Watering with hoses might also be sufficient when extra moisture is needed only to facilitate germination of newly-planted grass seed.

Campground design and construction.--The shape of the family unit can complicate or simplify irrigation. The area immediately adjacent to the facility pad at each camping unit is the "critical zone" as far as watering is concerned. Because of its location, vegetation within 10 feet of the facility pad is most likely to receive trampling; for this reason, such vegetation needs supplemental watering more than does vegetation growing farther away from the facility pad.

Conventional design of family unit facilities creates problems of incompatibility between visitor occupancy and efficient watering. It is difficult to water the critical zone without getting water on the table, tent pad, and fire grill. At Point Campground, the sprinkler head at each unit sprayed water 55 feet in a complete circle from a point near the facility pad (fig. 3). This pattern provided adequate water for the critical zone. However, the high pressure of the water would quickly penetrate and soak visitors' tents or other equipment at the unit; furthermore, such obstructions to the stream of water prevent uniform watering of the entire unit and create dry spots. For these reasons, visitors could not remain at a unit while it was being watered.

Solutions other than the one used at Point Campground are possible. First, without altering the basic unit design for Point Campground, additional rainbird-type sprinkler heads, each watering only a segment of a circle, could be installed at each unit so that most water could be excluded from the facility pad (fig. 4). This change would eliminate the need to vacate the campground; visitors and their equipment would not be directly sprayed, but wind might carry some water onto the facility pad. However, this alternative is less efficient in the application of water because it fails to reach some areas in the critical zone immediately adjacent to the facility pad. The approximate additional investment for the extra feeder pipes and sprinkler heads at Point Campground would be $100 per unit. This would increase the total annual cost from $95 to $103 per unit.

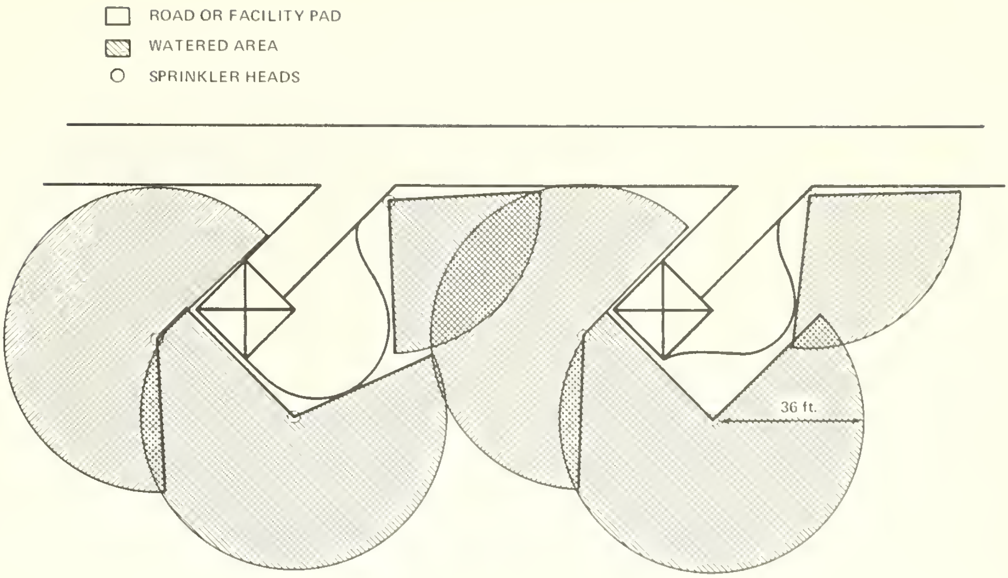

Figure 4.--Water is excluded from the facility pad area if three sprinklers are used. However, parts of the critical zone adjacent to the facility pad may not be adequately watered.

A second alternative would be a redesign of family units to fit a nonwatered sector of a circle as illustrated in figure 5. With such a layout, administrative problems would be reduced, operation of the system would be simplified, and visitors might remain on the facility pad area during sprinkling. The unwatered area adjacent to the facility pad would be minimized. However, this solution is workable only for new construction or major reconstruction.

As a third alternative, each unit could be individually watered as it became vacant. A 7-day camping limit would insure at least weekly watering of each unit.

Sprinkler heads other than the rainbird type may be needed to efficiently water the critical zone. A group of fountain heads, such as those commonly used on residential lawns, could be arranged to water the critical area without getting the table-grill facility area wet. The larger rainbird heads could then be used to water the surrounding areas.

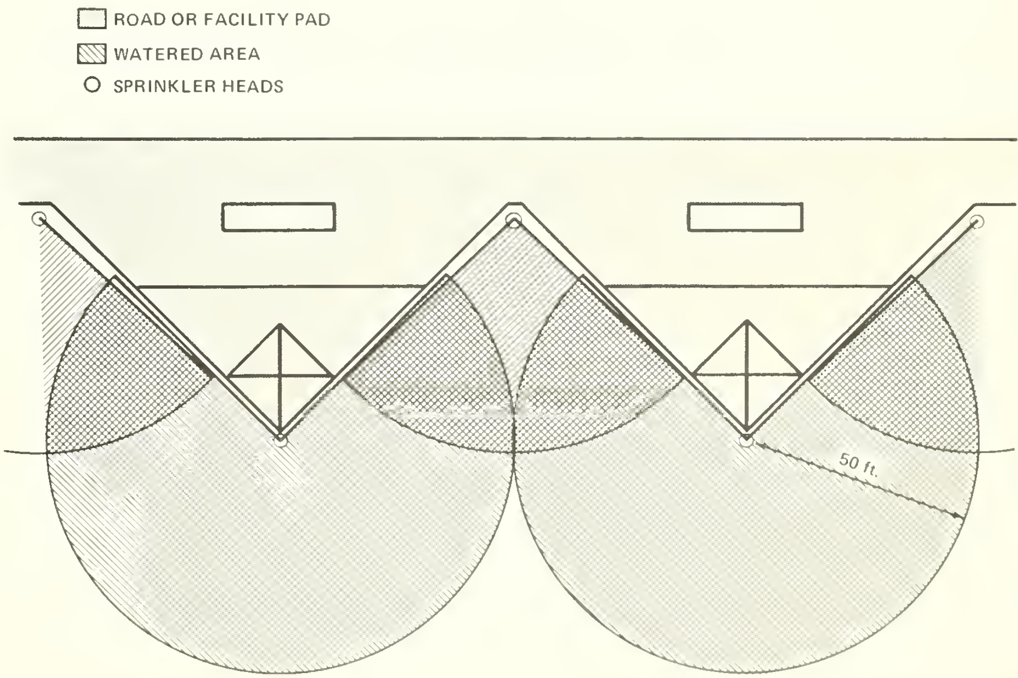

Figure 5.--Redesigned family units could be easily watered while visitors remain on them. Virtually all of the critical area adjacent to the facility pad is adequately watered.

At some point, the sheer size of a campground makes simultaneous watering of all units impossible or impractical. In such cases, available water supply dictates the maximum number of units which can be watered at one time. This fact may influence design criteria for new campgrounds. In the older campgrounds, it might necessitate devising some way of closing portions of the site during watering. Point Campground's road system contained two separate "loops"; this would permit the closure and watering of each half at different times. At other sites, the irrigation system design must be planned to permit watering within the particular restraints encountered.

Visitor-use problems.--All of the alternatives suggested for irrigating camp units have conflicts between visitor-use and watering. If visitors remain at or near units being watered, children might play in the spray and puddles, thus damaging ground-cover vegetation. Or, visitors might shut off or tamper with sprinkler heads, reducing the amount of water applied. On the other hand, extra revenues or benefits from the additional visitor-use might be sufficient to provide a full-time attendant to operate and supervise the system, if the irrigation system can be arranged so that visitors are not forced to vacate.

A system of separate watering days for different sections of the campground may create public relations problems when some visitors must vacate while others remain. Also, it may force some visitors to move more than once in a single week. Where visitors must vacate, additional camping space should be available to them in other nearby campgrounds. At Point Campground, an overflow camping area, normally used only during holiday periods, accommodated the displaced visitors. Watering, of course, was not scheduled during peak-use holidays when the overflow area normally would be filled.

CONCLUSIONS

Irrigation of recreation sites introduces a wide array of problems in several areas (site design, cost, engineering, and public relations) that have not previously concerned campground managers.

One major problem will be to develop a means of sprinkling that will not excessively inconvenience visitors or require them to vacate camp units. This problem can be solved to a large degree through modifications in the design of future campgrounds. New campground construction should not be initiated without carefully considering the possible future need for irrigation and its impact on the shape, size, and spacing of family units.

Irrigation in many existing campgrounds will remain awkward. It is possible to water as vacancies occur in the more lightly-used campgrounds. This technique is less practical for heavily-used sites such as Point Campground where units are seldom vacant. In such situations, the manager will be forced to either (a) periodically close all or part of the campground, and thereby reduce the benefits of public use, (b) restrict irrigation to those parts of the campground where it will not inconvenience visitors, or (c) devise some more costly combination of sprinkler heads that will permit watering without annoyance.

At Point Campground, annual costs for irrigation were $95 per family unit, or about $0.26 per visitor-day of use in 1969. Benefits from irrigation, while not quantifiable, include improved appearance, decreased dust and mud conditions, reduced fire hazard from higher levels of vegetative cover, and a weekly "washing-off" of the facility pad area. At other sites, these and other benefits can be subjectively compared with costs as developed above in irrigation investment decisions.

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ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, ARIZONA, 1969

Theodore S. Setzer[1]

ABSTRACT

The 1969 Arizona roundwood products output decreased to 88,474 MCF since the 1966 estimate of 89,873 MCF. Round pulpwood production increased to 7,622 MCF from 6,647 MCF in 1966. The estimated volume of plant residues (including bark) from the lumber industry was 44,908 MCF. Of this volume, 24,169 MCF were used, mainly for pulpwood and fuel.

The output of roundwood timber products in Arizona in 1969 was 88,474 MCF, somewhat less than the 1966 output of 89,873 MCF. This represents a discontinuance of the gradual upward trend evident since 1952 (fig. 1).

Saw logs as usual were the predominant product, accounting for nearly 75 percent of the volume of all roundwood products (table 1). Saw log output was 66,129 MCF (423,908 MBF),[2] up 6 percent from that of 1966. Pulpwood volume increased to 7,622 MCF, about 15 percent since 1966. The output of all other roundwood products combined decreased about 29 percent since 1966; most of the decrease was accounted for by posts, fuelwood, and miscellaneous farm timbers. A different method for estimating output of mine timbers, posts, and fuelwood was used in 1969; thus, this may account for part of the decrease in the output estimate.

An increase in logging residues from growing stock[3] in 1969 was related to the increase in roundwood products output. The 1969 volume of logging residues was 8,033 MCF, about 524 MCF more than in 1966.

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[1]This paper is based on the 1969 Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at Intermountain Station.

[2]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

[3]The net cubic-foot volume of live sawtimber and poletimber trees cut or killed by logging on commercial forest land and not converted to timber products.

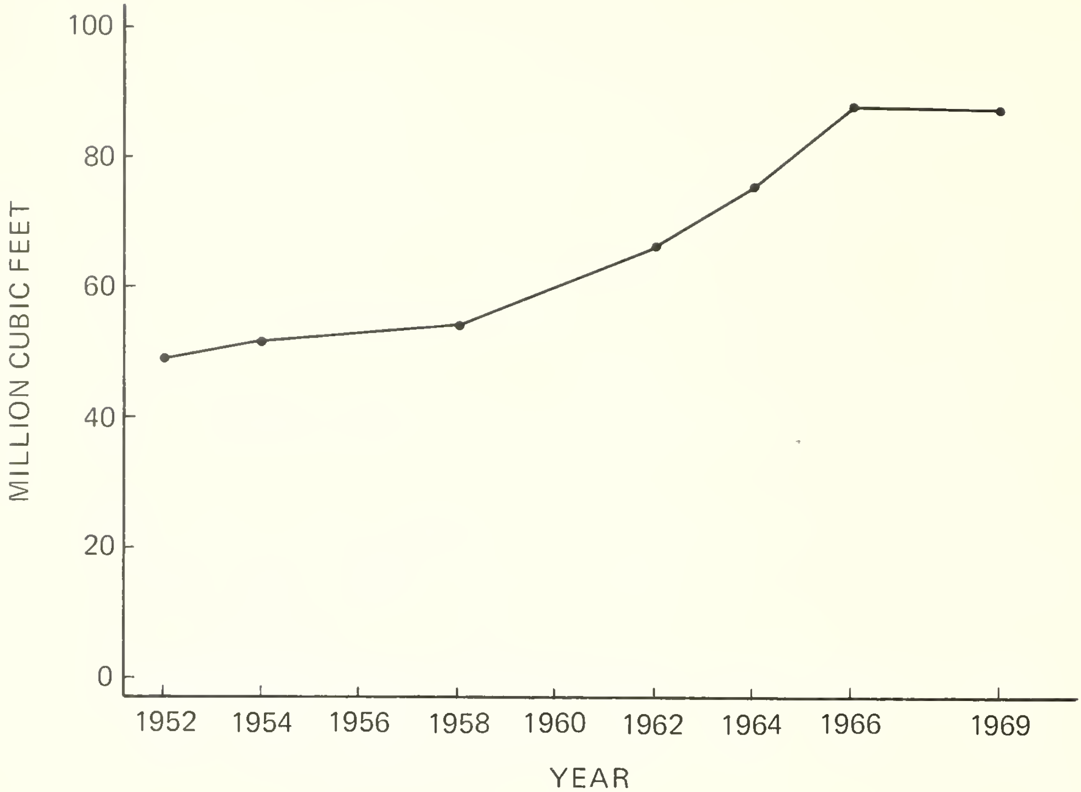

Figure 1.--Arizona roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 25, 1970.)

About 87 percent of the mill receipts of saw logs in 1969 was ponderosa pine (table 2); an additional 7 percent was Douglas-fir. The true firs, Engelmann spruce, limber pine, and aspen accounted for the remaining 6 percent of receipts.

Coconino County again led in saw log output but the 32 percent of the State total it supplied was almost 10 percent less than in 1966. Apache County was second and also supplied about 10 percent less of the State total than in 1966. Third ranking Navajo County, on the other hand, increased its production to 23 percent of the State total as compared to 13 percent in 1966. Greenlee and Graham Counties combined produced over 16 percent of Arizona's saw logs in 1969, up 13 percent from 1966.

Table 2 is based on responses from all known active sawmills in Arizona and the estimates presented are without sampling error.

In 1969, 63 percent of the volume of coarse and fine residues combined was utilized as compared to approximately 59 percent in 1966.

Estimates of plant byproducts and residues included volume of bark for the first time. Table 3 shows that about one-fourth of the bark volume was used for fuel, livestock bedding, and mulch. About 43 percent of the fine residue volume was used, mostly for fuel; and about 85 percent of the coarse residue volume was utilized, principally for pulp chips.

Table 1.--*Output of roundwood products from Arizona timberlands by species, 1969*

Product	Species					All species	
	True firs	Engelmann spruce	Ponderosa pine	Douglas-fir	Other species[1]	Volume	Percent
	Thousand cubic feet						
Saw logs	3,154	782	57,255	4,648	290	66,129	74.8
Pulpwood	23	23	7,576	--	--	7,622	8.6
Mine timbers	--	--	278	--	11	289	.3
Miscellaneous industrial wood[2]	--	--	284	6	163	453	.5
Posts, fuelwood, miscellaneous farm timbers	--	--	279	--	13,702	13,981	15.8
Total	3,177	805	65,672	4,654	14,166	88,474	100.0
Percent of total	3.6	.9	74.2	5.3	16.0	100.0	

[1]Includes juniper; limber, pinyon, and whitebark pines; aspen, cottonwood, and other hardwoods.
[2]Includes excelsior bolts, house logs, and commercial poles.

Table 2.--*Mill receipts of saw logs from Arizona timberlands by species and county of origin, 1969*

County	Species						All species	
	True firs	Engelmann spruce	Ponderosa pine	Limber pine	Douglas-fir	Aspen	Volume	Percent
	Thousand ~~cubic~~ board feet[1]							
Apache	6,127	1,267	84,187	1,391	14,315	112	107,399	25.4
Coconino	5,278	3,250	124,091	--	3,124	--	135,743	32.0
Gila	--	--	14,029	--	--	--	14,029	3.3
Graham	--	--	10,477	--	--	--	10,477	2.5
Greenlee	3,292	499	44,341	337	9,745	--	58,214	13.7
Navajo	5,521	--	89,489	--	2,432	--	97,442	23.0
Pima, Yavapai	--	--	403	22	179	--	604	.1
Total	20,218	5,016	367,017	1,750	29,795	112	423,908	100.0
Percent of total	4.8	1.2	86.6	.4	7.0	([2])	100.0	

[1]International 1/4-inch log rule.
[2]Less than 0.05 percent.

Table 3.--*Estimated volume of used and unused plant residues from the lumber industry in Arizona, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	Thousand cubic feet								
1969	10,578	2,553	8,025	16,475	14,006	2,469	17,855	7,610	10,245

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.

[2]Material such as sawdust and shavings.

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ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, COLORADO, 1969

Theodore S. Setzer[1]

ABSTRACT

The 1969 Colorado roundwood products output was 48,252 MCF, down about 5 percent from the 1966 estimate of 50,879 MCF. Saw log output was 35,502 MCF and veneer log output 4,837 MCF as compared to 1966 estimates of 39,335 MCF and 5,005 MCF, respectively. Round pulpwood output of 672 MCF was more than three times the 1966 estimate of 201 MCF. Estimated volume of plant residues (including bark) from the lumber and veneer and plywood industries was 26,329 MCF. Of this volume, 7,398 MCF (28.1 percent) were used, principally for pulpwood and fuel.

Colorado's 1969 output of roundwood timber products was 48,252 MCF. This volume was down slightly from the record output of 50,879 MCF in 1966 (fig. 1).

Saw log output decreased to 227,574 MBF[2] in 1969 from the 1966 estimate of 252,145 MBF (table 1); this volume was about 73.6 percent of total roundwood output. In 1966 and 1962, respectively, saw logs accounted for about 77.3 and 86.6 percent of total roundwood products output. Veneer log output also decreased (about 3.4 percent) from the 1966 level; 31,825 MBF were reported. Round pulpwood output increased substantially as compared to the 1966 estimate of 201 MCF. Output of all other roundwood products combined was 7,241 MCF; this was an increase of 903 MCF since 1966.

[1]This paper is based on the 1969 Timber Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at the Intermountain Station.

[2]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

Table 3.--*Estimated volume of used and unused plant residues from the lumber industry in Arizona, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	Thousand cubic feet								
1969	10,578	2,553	8,025	16,475	14,006	2,469	17,855	7,610	10,245

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.
[2]Material such as sawdust and shavings.

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
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March 1971

ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, COLORADO, 1969

Theodore S. Setzer[1]

ABSTRACT

The 1969 Colorado roundwood products output was 48,252 MCF, down about 5 percent from the 1966 estimate of 50,879 MCF. Saw log output was 35,502 MCF and veneer log output 4,837 MCF as compared to 1966 estimates of 39,335 MCF and 5,005 MCF, respectively. Round pulpwood output of 672 MCF was more than three times the 1966 estimate of 201 MCF. Estimated volume of plant residues (including bark) from the lumber and veneer and plywood industries was 26,329 MCF. Of this volume, 7,398 MCF (28.1 percent) were used, principally for pulpwood and fuel.

Colorado's 1969 output of roundwood timber products was 48,252 MCF. This volume was down slightly from the record output of 50,879 MCF in 1966 (fig. 1).

Saw log output decreased to 227,574 MBF[2] in 1969 from the 1966 estimate of 252,145 MBF (table 1); this volume was about 73.6 percent of total roundwood output. In 1966 and 1962, respectively, saw logs accounted for about 77.3 and 86.6 percent of total roundwood products output. Veneer log output also decreased (about 3.4 percent) from the 1966 level; 31,825 MBF were reported. Round pulpwood output increased substantially as compared to the 1966 estimate of 201 MCF. Output of all other roundwood products combined was 7,241 MCF; this was an increase of 903 MCF since 1966.

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[1]This paper is based on the 1969 Timber Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at the Intermountain Station.

[2]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

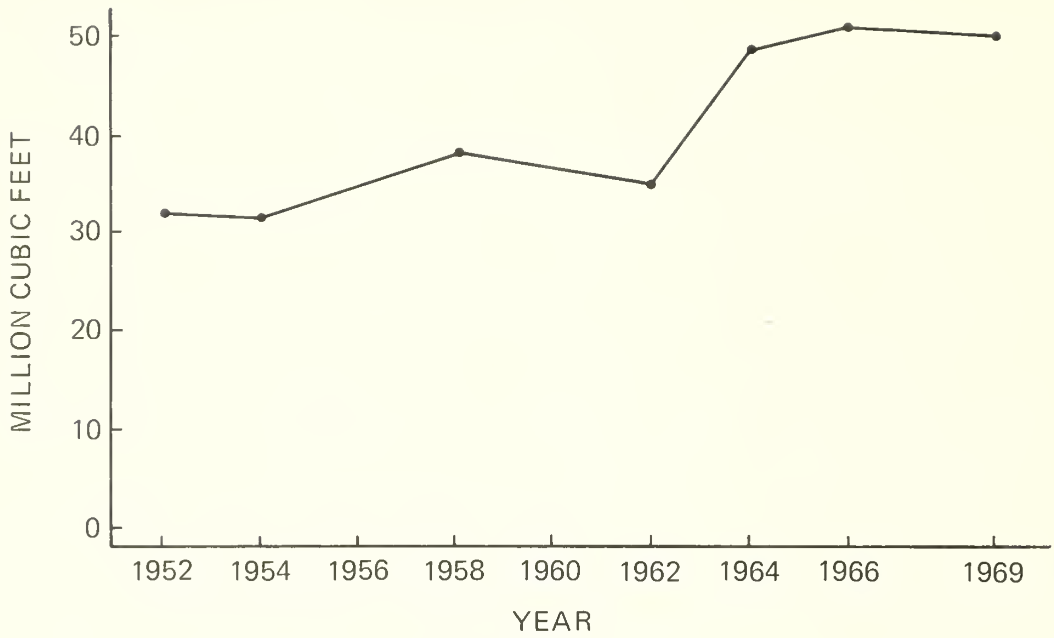

Figure 1.--Colorado roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 29, 1970.)

A decline in logging residues from growing stock[3] in 1969 was related to the decline in roundwood products output. The 1969 logging residues volume was 4,236 MCF, about 110 MCF less than in 1966.

Engelmann spruce, lodgepole pine, and ponderosa pine accounted for 92.5 percent of mill saw log receipts (table 2). Mill receipts also included true firs, Douglas-fir, limber pine, aspen, and cottonwood.

La Plata County led the State in saw log output. Other leading counties were Jackson, Grand, Routt, Saguache, and Gunnison. These six counties provided 50 percent of Colorado's saw logs in 1969.

In 1969, 37 percent of the volume of coarse and fine residues combined was utilized as compared to 11 percent in 1966. Estimates of plant byproducts and residues included volume of bark for the first time (table 3). In 1969 only about 0.5 percent of the bark was utilized, mainly for industrial fuel. About 43 percent of the coarse residues was used, principally for pulpwood; and about 31 percent of the fine residues was used, mostly for fuel and livestock bedding.

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[3]The net cubic-foot volume of live sawtimber and poletimber trees cut or killed by logging on commercial forest land and not converted to timber products.

Table 1.--*Output of roundwood products from Colorado timberlands by species, 1969*

Product	True firs[1]	Engelmann spruce	Ponderosa pine[2]	Douglas-fir	Lodgepole pine	Aspen	Other species[3]	All species: Volume	All species: Percent
	Thousand cubic feet								
Saw logs	1,364	22,639	3,929	851	6,264	150	305	35,502	73.6
Veneer logs	--	2,496	2,341	--	--	--	--	4,837	10.0
Pulpwood	--	--	--	--	672	--	--	672	1.4
Mine timbers	1	300	936	3	750	2	--	1,992	4.1
Miscellaneous industrial wood[4]	--	109	--	13	324	672	--	1,118	2.3
Posts, fuelwood, miscellaneous farm timbers	([5])	53	769	3	1,845	548	913	4,131	8.6
Total	1,365	25,597	7,975	870	9,855	1,372	1,218	48,252	100.0
Percent of total	2.8	53.1	16.5	1.8	20.4	2.9	2.5	100.0	

[1]Includes white, subalpine, and corkbark firs.
[2]Includes 3 MCF of limber pine.
[3]Includes juniper, pinyon pine, and cottonwood.
[4]Includes commercial poles, excelsior bolts, house logs, and match stock.
[5]Less than 0.5 thousand cubic feet.

Table 2.--*Mill receipts of saw logs from Colorado timberlands by species and county of origin, 1969*

County	True firs[1]	Engelmann spruce	Ponderosa pine[2]	Douglas-fir	Lodgepole pine	Aspen	Cottonwood	All species: Volume	All species: Percent
	Thousand board feet[3]								
Archuleta	109	3,098	3,246	135	--	--	--	6,588	2.9
Chaffee, El Paso, Fremont, Lake, Summit	20	145	483	433	119	--	87	1,287	.6
Conejos, Rio Grande	455	2,552	--	406	--	--	--	3,413	1.5
Custer	273	5,147	729	513	--	--	419	7,081	3.1
Delta, Garfield Ouray	4	360	--	620	330	154	41	1,509	.7
Douglas, Jefferson	--	--	2,810	949	--	--	--	3,759	1.7
Eagle	560	5,910	--	--	2,387	--	--	8,857	3.9
Grand	--	9,529	--	--	13,282	--	--	22,811	10.0
Gunnison	1,319	10,157	458	709	918	12	--	13,573	6.0
Hinsdale	1,176	8,059	--	--	--	--	--	9,235	4.1
Huerfano	101	309	2,374	627	--	14	--	3,425	1.5
Jackson	--	6,144	--	--	13,568	--	--	19,712	8.7
La Plata	2,834	24,998	--	165	--	445	--	2 ,442	12.5
Larimer	--	8,567	1,462	16	2,773	--	--	12,818	5.6
Mesa	--	81	2,661	--	--	--	13	2,755	1.2
Mineral	--	8,987	--	--	--	--	--	8,987	3.9
Moffat	343	1,709	1,129	--	543	--	--	3,724	1.6
Montezuma	--	6,087	6,134	--	--	--	--	12,221	5.4
Montrose	136	6,584	2,385	--	--	--	--	9,105	4.0
Park	--	4,269	220	95	1,544	--	--	6,128	2.7
Pitkin	42	4,040	--	--	--	--	--	4,082	1.8
Pueblo	16	--	48	15	--	--	1,394	1,473	.6
Rio Blanco	--	4,321	--	338	360	--	--	5,019	2.2
Routt	854	10,012	--	--	4,225	--	--	15,091	6.6
Saguache	166	13,235	169	314	103	--	--	13,987	6.1
San Miguel	336	821	879	118	--	338	--	2,492	1.1
Total	8,744	145,121	25,187	5,453	40,152	963	1,954	227,574	100.0
Percent of total	3.8	63.8	11.1	2.4	17.6	.4	.9	100.0	

[1]Includes white, subalpine, and corkbark firs.
[2]Includes 21 MBF of limber pine.
[3]International 1/4-inch log rule.

Table 3.--*Estimated volume of used and unused plant residues from the lumber and veneer and plywood industries in Colorado, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	Thousand cubic feet								
1969	6,431	30	6,401	10,503	4,491	6,012	9,395	2,877	6,518

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.
[2]Material such as sawdust and shavings.

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ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, IDAHO, 1969

Theodore S. Setzer[1]

ABSTRACT

The 1969 Idaho roundwood products output increased to 340,096 MCF since the 1966 estimate of 316,188 MCF. Round pulpwood production increased to 13,510 MCF from 9,172 MCF in 1966. The estimated volume of plant residues (including bark) from the lumber, and veneer and plywood industries was 209,345 MCF. Of this volume, 131,294 MCF (62.7 percent) were used, principally for pulpwood and fuel.

Idaho roundwood timber products output in 1969 was 340,096 MCF. This continues the general upward trend since 1952, and also the sharper upward trend since 1962 (fig. 1). The 1969 output exceeded the 1966 output of 316,188 MCF by more than 7 percent.

The volume of saw log output in 1969 was 281,169 MCF (1,802,369 MBF)[2] accounting for about 83 percent of the total 1969 roundwood products output (table 1); this compares with about 82 percent in 1966. Veneer log output was down in 1969. The volume of 36,748 MCF was more than 6 percent less than the 1966 volume of 39,236 MCF. The volume of round pulpwood produced, 13,510 MCF, continued a strong upward trend since 1962 and was up 47 percent since 1966. The output of all other roundwood products combined was about 8,669 MCF and accounted for less than 3 percent of total roundwood products output.

Logging residues from growing stock[3] increased to 38,793 MCF in 1969. This increase was related to the increase in roundwood products output for the same year. The volume of logging residues in 1966 was 36,034 MCF.

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[1]This paper is based on the 1969 Timber Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at Intermountain Station.

[2]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

[3]The net cubic-foot volume of live sawtimber and poletimber trees cut or killed by logging on commercial forest land and not converted to timber products.

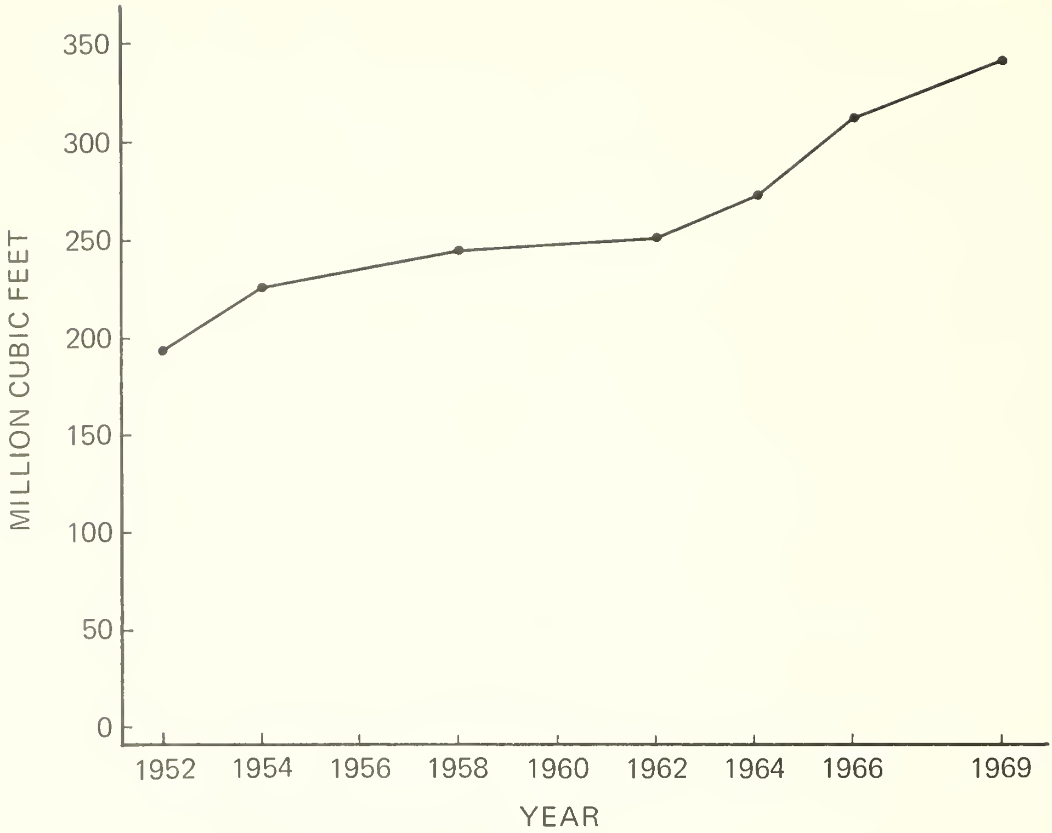

Figure 1.--Idaho roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 9, 1970.)

More than 23 percent of the mill receipts of saw logs in 1969 were true firs (table 2). Other important species were Douglas-fir, accounting for 19.5 percent of mill receipts; western white pine, 17.6 percent; and ponderosa pine, 17.4 percent. Douglas-fir volume decreased slightly since 1966 while the volume of the other three species increased. Mill receipts also included smaller volumes of western redcedar, western larch, Engelmann spruce, lodgepole pine, western hemlock, aspen, and cottonwood.

Clearwater County led the State in saw log output, supplying nearly 560 MMBF (31.1 percent). This is an increase of about 66 MMBF as compared to 1966 output. Two other leading counties were Shoshone, 219 MMBF; and Idaho, 180 MMBF. The output volume of both of these counties was down in comparison with 1966.

In 1969, 70 percent of the volume of coarse and fine residues combined was utilized as compared to approximately 62 percent in 1966.

Estimates of plant byproducts and residues included volume of bark for the first time in 1969 (table 3). In 1969 about 39 percent of the bark was being utilized for fuel and miscellaneous uses such as mulching and composting. About 76 percent of the coarse residues was used, principally for pulpwood. Of the total volume of fine residues produced, about 64 percent was used, mostly for fuel and pulp.

Table 1.--*Output of roundwood products [illegible]*

Product	True firs[1]	Western larch	Engelmann spruce	Lodgepole pine	Western white pine	Ponderosa pine	Douglas-fir	Western redcedar	Western hemlock	Other species	All species: Volume	All species: Percent
	Thousand cubic feet											
Saw logs	65,332	17,917	13,584	10,471	49,309	48,836	54,862	18,916	1,899	43	281,169	82.7
Veneer logs	10,698	2,524	3,042	693	13,912	356	5,357	68	98	--	36,748	10.8
Pulpwood	5,054	582	508	275	2,847	239	759	--	3,246	--	13,510	4.0
Poles, piling	--	4	--	228	--	--	14	2,953	--	--	3,199	.9
Mine timbers	--	38	--	49	--	--	95	--	--	--	182	.1
Miscellaneous industrial wood[3]	--	--	--	29	--	--	--	3,184	--	--	3,213	[illegible]
Posts, fuelwood, miscellaneous farm timbers	14	442	--	813	--	--	152	423	--	231	2,[illegible]	[illegible]
Total	81,098	21,507	17,134	12,558	66,068	49,431	61,239	25,544	5,243	274	340,096	100.0
Percent of total	23.9	6.3	5.0	3.7	19.4	14.5	18.0	7.5	1.6	.1	100.0	

[1]Includes grand, white, and subalpine firs.
[2]Includes juniper; aspen, cottonwood, and other hardwoods.
[3]Includes house logs, shingle bolts, and miscellaneous cedar products.

Table 2.--*Mill receipts of saw logs from Idaho timberlands by species and county of origin, 1968*

County	True firs[1]	Western larch	Engelmann spruce	Lodgepole pine	Western white pine	Ponderosa pine	Douglas-fir	Western redcedar	Western hemlock	Other species	All species: Volume	All species: Percent
	Thousand board feet[3]											
Adams	16,782	4,886	3,324	936	--	47,454	34,578	--	--	--	107,900	6.0
Bannock, Bear Lake, Bonneville, Caribou, Franklin, Madison	193	--	213	1,431	--	--	685	--	--	245	2,767	.1
Benewah	29,633	13,356	54	653	6,594	7,403	19,365	4,287	--	--	81,345	4.5
Blaine, Camas, Cassia, Gooding, Oneida, Twin Falls	326	--	--	342	--	--	925	--	--	32	1,625	.1
Boise	2,529	--	344	226	--	78,728	31,453	--	--	--	113,280	[illegible]
Bonner	19,462	13,659	1,651	1,762	8,370	4,948	14,966	2,651	4,729	--	72,198	4.0
Boundary	7,717	2,543	452	146	2,778	402	2,288	3,079	1,104	--	20,509	1.1
Clark	29	--	--	74	--	--	10,271	--	--	--	10,374	.6
Clearwater	165,030	29,818	15,843	526	194,155	9,652	64,132	78,577	2,152	--	559,885	31.1
Custer, Lemhi	--	--	--	--	--	--	399	--	--	--	399	(4)
Elmore	283	--	123	322	--	53,265	16,565	--	--	--	70,55[illegible]	3.9
Fremont	51	--	--	40,104	--	--	8,226	--	--	--	48,381	2.7
Gem	7,269	4	603	252	--	4,483	1,909	--	--	--	14,520	.8
Idaho	58,225	5,600	34,669	1,061	10,651	21,677	33,991	14,417	--	--	180,291	10.0
Kootenai	17,334	9,852	--	733	7,810	6,837	11,485	672	--	--	54,723	3.0
Latah	18,866	8,245	--	--	3,710	11,372	17,345	6,244	--	--	65,782	3.7
Lewis, Nez Perce	2,533	25	--	--	--	3,456	2,671	--	--	--	8,68[illegible]	.5
Shoshone	45,585	22,796	11,454	12	82,018	6,224	35,205	11,332	4,187	--	218,813	12.1
Teton	--	--	--	14,542	--	--	766	--	--	--	15,308	.9
Valley	26,946	4,065	18,347	4,000	--	57,153	44,455		--	--	154,966	8.6
Total	418,793	114,849	87,077	67,122	316,086	313,054	351,680	121,259	12,172	277	1,802,369	100.0
Percent of total	23.2	6.4	4.8	3.7	17.6	17.4	19.5	6.7	.7	( )	100.0	

[1]Includes grand, white, and subalpine firs.
[2]Includes aspen and cottonwood.
[3]International 1/4-inch log rule.
[4]Less than 0.05 percent.

Table 3.--*Estimated volume of used and unused plant residues from the lumber and veneer and plywood industries in Idaho, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	- - - - - - - - - - - - - - *Thousand cubic feet* - - - - - - - - - - - - -								
1969	49,851	19,584	30,267	84,499	63,889	20,610	74,995	47,821	27,174

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.

[2]Material such as sawdust and shavings.

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UNITED STATES DEPARTMENT OF AGRICULTURE
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ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, MONTANA, 1969

Theodore S. Setzer[1]

ABSTRACT

This report shows that the 1969 Montana roundwood products output increased to 245,948 MCF since the 1966 estimate of 238,231 MCF. Saw log output increased to 211,174 MCF and veneer log output to 28,574 MCF, as compared to the 1966 estimates of 195,603 MCF and 27,884 MCF, respectively. The round pulpwood production of 1,682 MCF was down from 3,753 MCF in 1966. Estimated volume of plant residues (including bark) from the lumber, and veneer and plywood industries was 156,230 MCF. Of this volume, 97,779 MCF (62.6 percent) were used, principally for pulpwood and fuel.

The 1969 Montana roundwood timber products output of 245,948 MCF was up about 3 percent since 1966. This reverses the downward dip evident between 1964 and 1966 as shown in figure 1.

Saw log output climbed to 211,174 MCF (1,353,682 MBF)[2] to account for about 86 percent of the total 1969 roundwood products output (table 1). The veneer log output of 28,574 MCF was up about 2.5 percent as compared to the 1966 estimate. Round pulpwood output of 1,682 MCF, on the other hand, decreased 123 percent from the 1966 estimate of 3,753 MCF. Output of all other roundwood products combined was 4,518 MCF and accounted for less than 2 percent of total roundwood products output.

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[1]This paper is based on the 1969 Timber Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at Intermountain Station.

[2]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

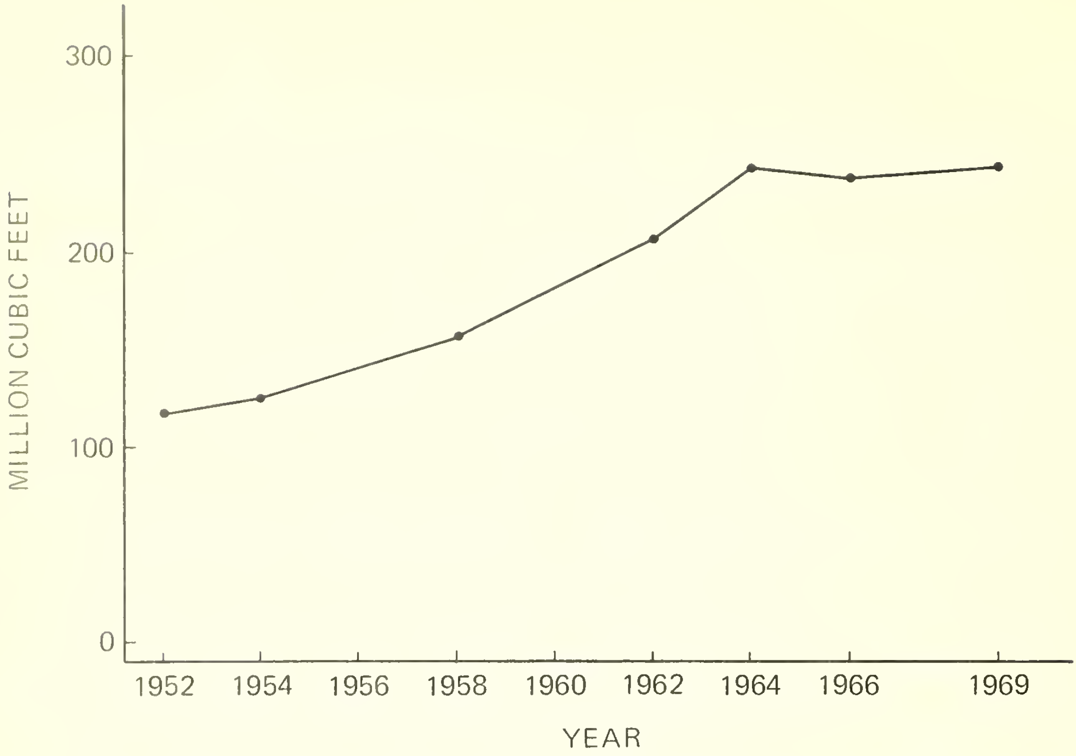

Figure 1.--Montana roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 13, 1970.)

An increase in logging residues from growing stock[3] in 1969 was related to an increase in roundwood products output for the same year. The 1969 logging residues volume was 38,722 MCF, about 1.9 MCF more than in 1966.

About 25 percent of the mill receipts of saw logs in 1969 was Douglas-fir (table 2). Other important species were ponderosa pine, 20 percent of mill receipts; western larch, 17 percent; Engelmann spruce, 15 percent; and lodgepole pine,13 percent. The remaining 10 percent of mill receipts included the following species: true firs, western white pine, western redcedar, western hemlock, limber pine, and cottonwood.

Lincoln County led the State in saw log output, supplying 38.7 percent or 524 MMBF in 1969. This volume represents better than a 70 percent increase over the 1966 estimate of 308 MMBF. Flathead was another leading county, supplying 17.2 percent or 232 MMBF; this volume was higher than that of 1966 by about 39 percent. Ranking third in saw log output was Missoula County, supplying 9 percent or 122 MMBF; this volume was down 27 MMBF from 1966.

In 1969, 74 percent of the volume of coarse and fine residues combined was utilized as compared to approximately 66 percent in 1966.

Estimates of plant byproducts and residues included volume of bark for the first time in 1969 (table 3). Also, in 1969 about 28 percent of the bark was utilized, mainly for fuel. More than 86 percent of the coarse residues was used, principally for pulpwood; and about 60 percent of the fine residues was used, mostly for fuel.

[3]The net cubic-foot volume of live sawtimber and poletimber trees cut or killed by logging on commercial forest land and not converted to timber products.

Table 1.--*Output of roundwood products from Montana timberlands by species, 1969*

Product	Species										All species	
	True firs[1]	Western larch	Engelmann spruce	Lodgepole pine	Western white pine[2]	Ponderosa pine	Douglas-fir	Western redcedar	Western hemlock	Cottonwood	Volume	Percent
	Thousand cubic feet											
Saw logs	9,594	36,455	32,371	26,479	5,836	41,739	53,519	3,348	1,825	8	211,174	85.9
Veneer logs	546	12,365	4,489	421	220	1,045	9,472	--	--	16	28,574	11.6
Pulpwood	184	2	269	880	4	41	2	--	300	--	1,682	.7
Poles	--	172	--	474	--	--	--	73	--	--	719	.3
Mine timbers	10	798	--	5	--	2	807	--	--	--	1,622	.6
Miscellaneous industrial wood[3]	--	--	--	85	--	61	4	268	--	--	418	.2
Posts, fuelwood, miscellaneous farm timbers	2	51	5	1,503	--	6	138	54	--	--	1,759	.[illegible]
Total	10,336	49,843	37,134	29,847	6,060	42,894	63,942	3,743	2,125	24	245,948	100.0
Percent of total	4.2	20.3	15.1	12.1	2.5	17.4	26.0	1.5	.9	([4])	100.0	

[1]Includes grand, white, and subalpine firs.
[2]Includes 251 MCF of limber pine.
[3]Includes converter poles, house logs, and cedar specialties.
[4]Less than 0.05 percent.

Table 2.--*Mill receipts of saw logs from Montana timberlands by species and county of origin, 1969*

County	Species										All species	
	True firs[1]	Western larch	Engelmann spruce	Lodgepole pine	Western white pine[2]	Ponderosa pine	Douglas-fir	Western redcedar	Western hemlock	Cottonwood	Volume	Percent
	Thousand board feet[3]											
Beaverhead	1,314	--	10,883	20,458	275	--	9,488	--	--	--	42,418	3.1
Broadwater, Cascade, Chouteau, Lewis and Clark, Meagher	--	--	242	530	--	4,600	2,959	--	--	--	8,331	.6
Carbon, Powder River, Rosebud	--	--	--	210	--	3,470	4,627	--	--	--	8,307	.6
Deer Lodge, Jefferson, Madison, Silver Bow	--	--	210	4,638	--	--	1,629	--	--	--	6,477	.5
Fergus, Judith Basin, Musselshell	--	--	--	--	--	4,995	389	--	--	--	5,384	.4
Flathead	8,074	31,835	100,952	15,337	7,782	25,500	40,347	2,484	--	--	232,311	17.2
Gallatin	2,104	--	2,944	27,843	--	--	837	--	--	--	33,728	2.5
Granite	1,677	--	9,487	24,033	680	265	22,371	--	--	--	58,513	4.3
Lake	5,134	19,602	15,980	3,072	2,439	14,417	17,767	1,211	--	41	79,663	5.9
Lincoln	32,164	150,055	45,073	45,008	24,366	93,615	114,028	8,386	11,644	--	524,339	38.7
Mineral	--	7,252	4,692	526	--	31,244	11,137	--	--	--	54,851	4.0
Missoula	2,221	21,859	3,621	12,979	14	42,373	29,967	8,923	--	12	121,969	9.0
Park, Sweet Grass	--	--	1,258	1,108	--	235	4,966	--	--	--	7,567	.6
Powell	729	832	3,571	4,628	1,258	1,801	10,980	--	--	--	23,799	1.8
Ravalli	7,150	--	8,118	7,361	148	11,293	44,467	210	--	--	78,747	5.8
Sanders	933	2,253	473	2,004	450	33,749	27,111	252	53	--	67,278	5.0
Total	61,500	233,688	207,504	169,735	37,412	267,557	343,070	21,466	11,697	53	1,353,682	100.0
Percent of total	4.5	17.3	15.3	12.5	2.8	19.8	25.3	1.6	.9	([4])	100.0	

[1]Includes grand, white, and subalpine firs.
[2]Includes 1,585 MBF of limber pine.
[3]International 1/4-inch log rule.
[4]Less than 0.05 percent.

Table 3.--*Estimated volume of used and unused plant residues from the lumber and veneer and plywood industries in Montana, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	Thousand cubic feet								
1969	37,913	10,552	27,361	61,302	53,075	8,227	57,015	34,152	22,863

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.
[2]Material such as sawdust and shavings.

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
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March 1971

ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, NEW MEXICO, 1969

Theodore S. Setzer[1]

ABSTRACT

The 1969 New Mexico roundwood products output was 47,209 MCF, down about 7 percent from the 1966 estimate of 50,986 MCF. Saw log output was 39,212 MCF as compared to 42,352 MCF in 1966. Estimated volume of plant residues (including bark) from the lumber industry was 26,309 MCF. Of this volume, 6,053 MCF (23 percent) were used, principally for pulpwood.

New Mexico's 1969 output of roundwood timber products was 47,209 MCF. This volume was down from the record output of 50,986 MCF in 1966 (fig. 1).

Saw logs continued to be the dominant timber product in New Mexico (table 1). However, saw log output decreased to 251,361 MBF[2] in 1969 from the 1966 estimate of 271,485 MBF. Output of all other roundwood products combined was 7,997 MCF, down 637 MCF from the 1966 estimate of 8,634 MCF.

A decline in logging residues from growing stock[3] in 1969 was related to the decline in roundwood products output. The 1969 volume of logging residues was 4,701 MCF, about 421 MCF less than in 1966.

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[1]This paper is based on the 1969 Timber Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at the Intermountain Station.

[2]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

[3]The net cubic-foot volume of live sawtimber and poletimber trees cut or killed by logging on commercial forest land and not converted to timber products.

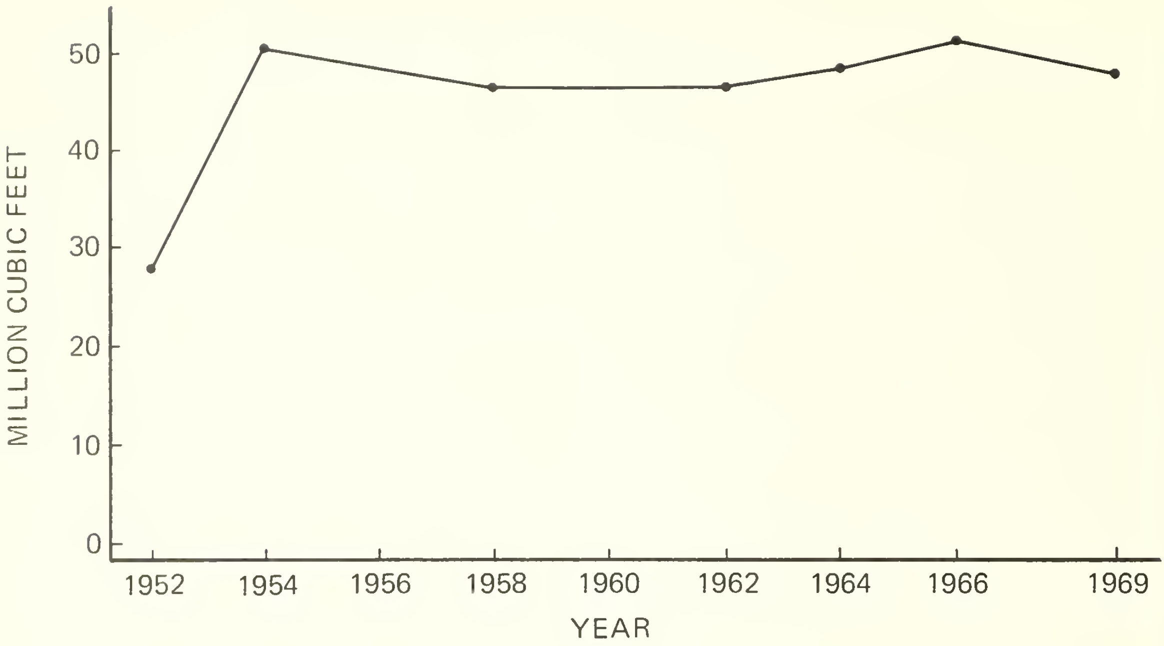

Figure 1.--New Mexico roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 35, 1970.)

Ponderosa pine, Douglas-fir, and Engelmann spruce accounted for more than 90 percent of sawmill log receipts (table 2). In addition to these three species, mill receipts also included white fir, aspen, pinyon pine, and small volumes of unidentified pines (probably Mexican white pine) and limber pine.

Leading the State in saw log output was Sandoval County, providing about one-fourth of the volume. An additional one-half of the total saw log output came from the following Counties: Rio Arriba, Otero, Catron, and Grant.

In 1969, 30 percent of the volume of coarse and fine residues combined was utilized as compared to approximately 28 percent in 1966. Estimates of plant byproducts and residues included volume of bark for the first time (table 3). In 1969 about 1 percent of the bark was utilized, mainly for fuel. About 61 percent of the coarse residues was used, principally for pulpwood. Less than one-half percent of the fine residues was used.

Table 1.--*Output of roundwood products from New Mexico timberlands by species, 1969*

Product	Species								All species	
	White fir	Engelmann spruce	Ponderosa pine	Douglas-fir	Pinyon pine	Juniper	Aspen	Other species[1]	Volume	Percent
	Thousand cubic feet									
Saw logs	3,160	5,309	19,371	10,699	230	--	412	31	39,212	83.1
Mine timbers	([2])	--	245	--	1	--	78	--	324	.7
Posts, fuelwood, miscellaneous farm timbers	--	--	616	--	3,338	3,413	--	306	7,673	16.2
Total	3,160	5,309	20,232	10,699	3,569	3,413	490	337	47,209	100.0
Percent of total	6.7	11.2	42.9	22.7	7.6	7.2	1.0	.7	100.0	

[1]Includes unidentified pines (probably Mexican white pine), limber pine, oak, and other hardwoods.

[2]Less than 0.5 thousand cubic feet.

Table 2.--*Mill receipts of saw logs from New Mexico timberlands by species and county of origin, 1969*

County	Species							All species	
	White fir	Engelmann spruce	Ponderosa pine	Douglas-fir	Aspen	Pinyon pine	Other species[1]	Volume	Percent
	Thousand board feet[2]								
Catron, Grant	973	232	37,702	5,776	--	--	174	44,857	17.8
Colfax	2,443	2,270	3,311	5,759	681	--	--	14,464	5.8
Lincoln	--	--	5,390	284	--	--	--	5,674	2.3
McKinley	--	--	3,815	34	--	--	--	3,849	1.5
Mora	309	--	684	598	--	--	--	1,591	.6
Otero	3,085	--	19,000	13,451	--	--	4	35,540	14.1
Rio Arriba	4,778	13,061	17,152	7,686	1,959	--	--	44,636	17.8
Sandoval	4,855	14,596	18,745	22,405	--	--	3	60,604	24.1
San Miguel, Santa Fe	1,406	2,102	2,655	3,777	--	--	--	9,940	4.0
Socorro	--	--	944	69	--	1,418	17	2,448	1.0
Taos	1,702	1,089	1,414	5,855	--	--	--	10,060	4.0
Valencia	704	685	13,364	2,887	--	58	--	17,698	7.0
Total	20,255	34,035	124,176	68,581	2,640	1,476	198	251,361	100.0
Percent of total	8.1	13.5	49.4	27.3	1.0	.6	.1	100.0	

[1]Includes unidentified pines (probably Mexican white pine) and limber pine.

[2]International 1/4-inch log rule.

Table 3.--*Estimated volume of used and unused plant residues from the lumber industry in New Mexico, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	Thousand cubic feet								
1969	6,173	80	6,093	9,681	5,931	3,750	10,455	42	10,413

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.

[2]Material such as sawdust and shavings.

Research Note

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ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, UTAH AND NEVADA, 1969

Theodore S. Setzer[1]

ABSTRACT

The 1969 Utah roundwood products output was 12,806 MCF, down about 9 percent from the 1966 estimate of 14,030 MCF. Saw log output was 11,439 MCF as compared to 12,129 MCF in 1966. Nevada's total output was 612 MCF, about three times the 1966 estimate of 223 MCF. Estimated volume of plant residues (including bark) from the lumber industry of Utah and Nevada combined was 7,623 MCF. Of this volume, about 2,329 MCF were used, principally for livestock bedding and pulpwood.

UTAH

Utah's 1969 output of roundwood timber products was 12,806 MCF. This volume was 1,224 MCF less than the 1966 output (fig. 1). Saw logs continued to be the dominant timber product in Utah (table 1). Log receipts at sawmills in 1969 totaled 73,328 MBF,[2] about 4,400 MBF less than the 1966 estimate. The output of all other roundwood products combined was 1,367 MCF, down 534 MCF from the 1966 estimate of 1,901 MCF.

The 1969 volume of logging residues from growing stock[3] was 851 MCF, about 635 MCF less than in 1966. A recently completed study in Utah has made possible the development of new logging residue factors. The use of these new factors may have contributed to the lower residue volume estimate, as did the reduced product output.

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[1]This paper is based on the 1969 Timber Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at the Intermountain Station.

[2]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

[3]The net cubic-foot volume of live sawtimber and poletimber trees cut or killed by logging on commercial forest land and not converted to timber products.

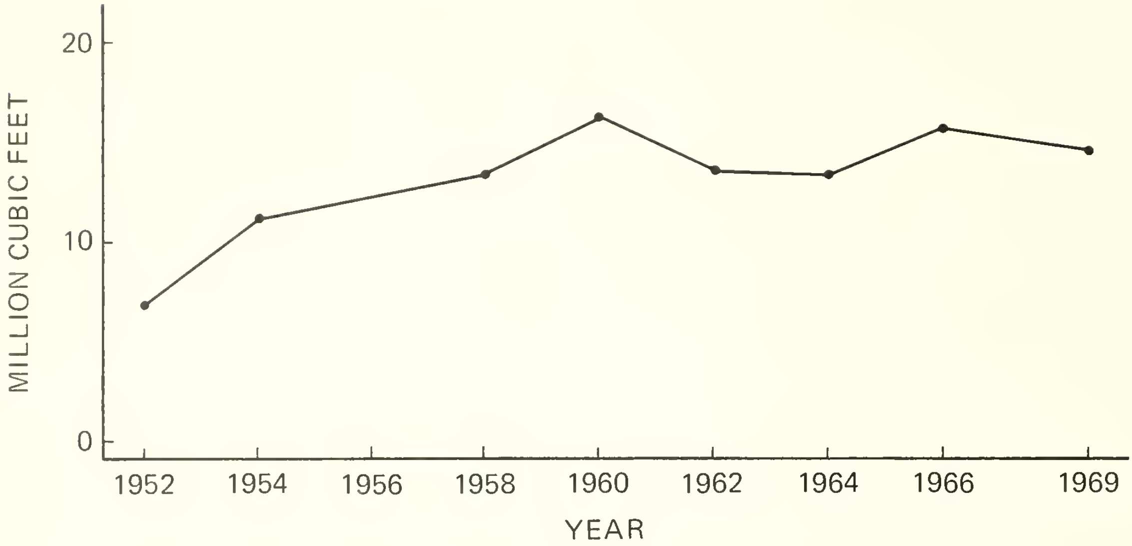

Figure 1.--Utah roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 40, 1970.)

Ninety-two percent of Utah's saw log receipts for 1969 were ponderosa pine, lodgepole pine, Engelmann spruce, and Douglas-fir (table 2). Other species included true firs, limber pine, aspen, and cottonwood.

Sixty percent of the State's saw log output came from Garfield, San Juan, and Summit Counties. An additional 18 percent came from Kane and Duchesne Counties. The outputs of Garfield, San Juan, and Duchesne Counties showed decreases in comparison to 1966 outputs; Summit and Kane Counties showed increases.

Twenty-five percent of the volume of coarse and fine residues combined was utilized in 1969 as compared to 8 percent in 1966. Estimates of plant byproducts and residues included volume of bark for the first time (table 3). Thirteen percent of the bark was utilized in 1969, 19 percent of the coarse residues, and 31 percent of the fine residues

Table 1.--*Output of roundwood products from Utah timberlands by species, 1969*

Product	Species						All species	
	True firs[1]	Engelmann spruce	Lodgepole pine	Ponderosa pine	Douglas-fir	Other species[2]	Volume	Percent
	Thousand cubic feet							
Saw logs	848	1,702	1,918	5,563	1,350	58	11,439	89.4
Mine timbers	1	32	303	4	9	--	349	2.7
Miscellaneous industrial wood[3]	--	--	20	--	--	431	451	3.5
Posts, fuelwood, miscellaneous farm timbers	--	--	39	--	([4])	528	567	4.4
Total	849	1,734	2,280	5,567	1,359	1,017	12,806	100.0
Percent of total	6.6	13.5	17.8	43.5	10.6	8.0	100.0	

[1]Includes white, subalpine, and corkbark firs.
[2]Includes juniper, limber pine, aspen, and cottonwood.
[3]Includes commercial poles and excelsior bolts.
[4]Less than 0.5 thousand cubic feet.

Table 2.--*Mill receipts of saw logs from Utah timberlands by species and county of origin, 1969*

County	Species						All species	
	True firs[1]	Engelmann spruce	Lodgepole pine	Ponderosa pine	Douglas-fir	Other species[2]	Volume	Percent
	Thousand board feet[3]							
Cache, Rich	1,151	34	23	--	3,450	11	4,669	6.4
Daggett	--	--	374	2,432	575	--	3,381	4.6
Duchesne	345	888	2,409	1,655	115	115	5,527	7.5
Garfield	598	5,656	--	15,469	2,091	126	23,940	32.7
Grand	--	--	--	287	--	--	287	.3
Iron, Millard	--	29	--	288	16	--	333	.5
Kane	2,380	11	--	3,628	1,356	115	7,490	10.2
San Juan	--	--	--	10,068	--	--	10,068	13.7
Sanpete	486	161	--	--	--	--	647	.9
Sevier	--	20	--	255	21	--	296	.4
Summit	395	1,927	6,961	15	502	--	9,800	13.4
Uintah	--	473	2,474	--	--	--	2,947	4.0
Utah	78	--	--	--	484	--	562	.8
Wasatch	--	1,664	57	--	--	--	1,721	2.3
Wayne	--	51	--	1,564	45	--	1,660	2.3
Total	5,433	10,914	12,298	35,661	8,655	367	73,328	100.0
Percent of total	7.4	14.9	16.8	48.6	11.8	.5	100.0	

[1]Includes white, subalpine, and corkbark firs.
[2]Includes limber pine, aspen, and cottonwood.
[3]International 1/4-inch log rule.

Table 1.--Estimated volume of used and unused plant residues from the lumber industry in Utah, 1969

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	Thousand cubic feet								
1969	1,099	139	960	2,784	533	2,251	3,000	917	2,083

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.

[2]Material such as sawdust and shavings.

NEVADA

Nevada's 1969 output of roundwood timber products was 612 MCF, considerably higher than the 223 MCF produced in 1966 (fig. 2). Over the years the State's output has been very erratic, though recently there has been less variation in the estimates due to smaller output volumes. Variable output will undoubtedly continue at the lower levels evident since 1962.

Fuelwood was the dominant product in 1969. The estimated production was about 6,000 cords. Saw log output was 487 MBF, and 18 MCF of posts were produced.

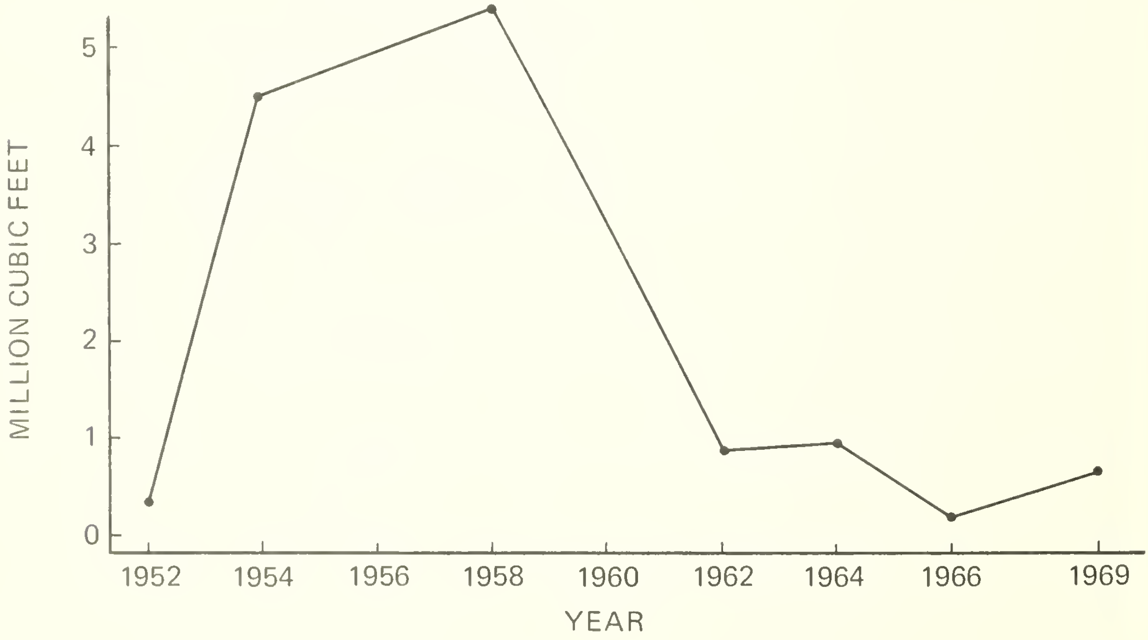

Figure 2.--Nevada roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 33, 1970.)

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ESTIMATES OF TIMBER PRODUCTS OUTPUT AND PLANT RESIDUES, WYOMING AND WESTERN SOUTH DAKOTA,[1] 1969

Theodore S. Setzer[2]

ABSTRACT

The 1969 Wyoming roundwood products output was 30,048 MCF. South Dakota's output for 1969 was 15,030 MCF. Output for both States was down in comparison to 1966 estimates of 33,523 MCF and 15,859 MCF, respectively. Saw log output for both States, however, was up. Wyoming's 1969 saw log output was 29,287 MCF as compared to the 1966 estimate of 27,065 MCF; South Dakota's output was 7,352 MCF as compared to 6,912 MCF in 1966. Estimated volume of plant residues (including bark) from Wyoming's lumber industry was 19,915 MCF of which 6,534 MCF were utilized. The estimated volume for South Dakota was 4,995 MCF of which 1,736 MCF were used.

WYOMING

Wyoming's 1969 output of roundwood timber products was 30,048 MCF, down about 10 percent from the 1966 estimate of 33,523 MCF (fig. 1).

Saw log output increased to 187,736 MBF[3] in 1969 from the 1966 estimate of 173,491 MBF (table 1). The volume of saw logs increased by 2,222 MCF to account for 97.5 percent of total roundwood products output in 1969; the comparable percentage for 1966 was 80.7. No roundwood pulpwood output was reported in 1969. Output of all other roundwood products combined was 761 MCF, down substantially from the 1966 estimate of

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[1]West of the 103d meridian. Western South Dakota may be referred to as South Dakota in this report.

[2]This paper is based on the 1969 Timber Products Survey conducted by the Forest Survey Research Unit of the Intermountain Forest and Range Experiment Station during 1970. The author is in charge of the products and timber removals phase of the Forest Survey at the Intermountain Station.

[3]International 1/4-inch log rule is used throughout this report for board-foot volumes of roundwood.

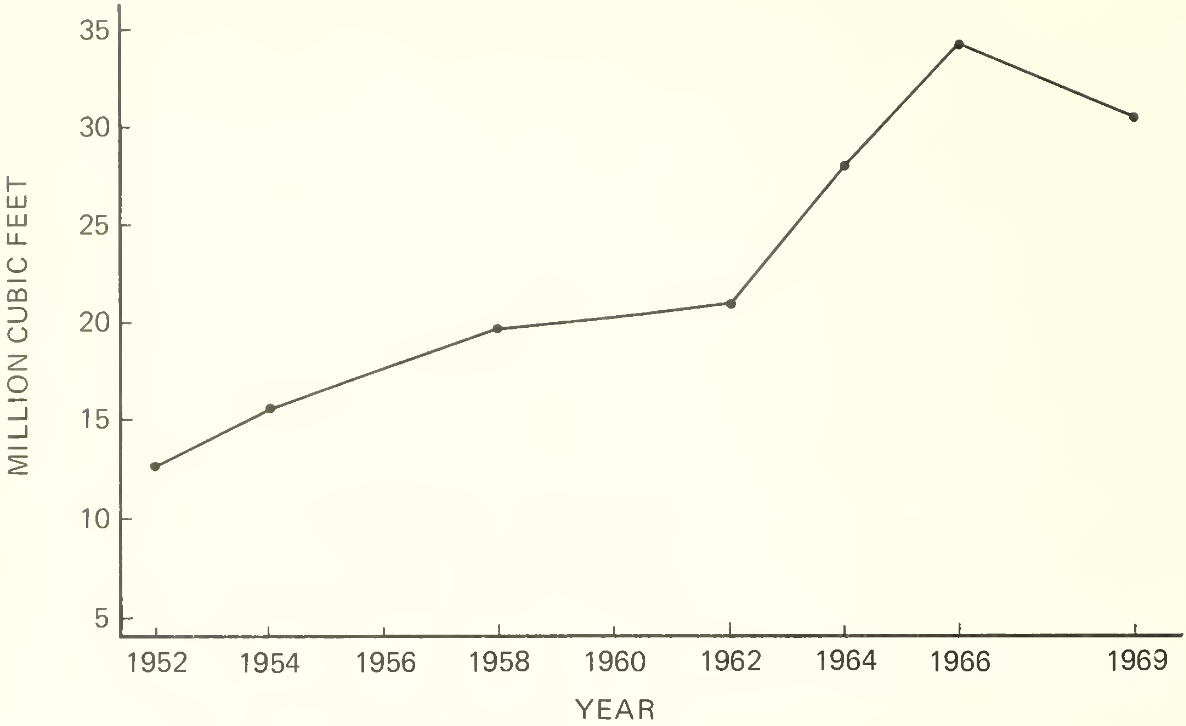

Figure 1.--Wyoming roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 21, 1970.)

6,317 MCF. Some recent changes in compilation methods for estimating output of these products in Wyoming and South Dakota may account for part of the decrease in the output figures between 1966 and 1969.

The 1969 volume of logging residues from growing stock[4] was 2,202 MCF, about 513 MCF less than in 1966. Recently completed studies in Wyoming and South Dakota have made possible the development of new logging residue factors. The use of these new factors, together with lower product output, may have contributed to the lower estimate of residues volume.

Lodgepole pine, ponderosa pine, and Engelmann spruce accounted for 96 percent of the sawmill log receipts (table 2). Other species included subalpine fir, Douglas-fir, and limber pine.

More than half of Wyoming's saw log output came from Fremont, Carbon, and Lincoln Counties. Other counties contributing substantially (adding 36 percent) were Crook, Sheridan, Sublette, Albany, and Johnson.

In 1969, 43 percent of the volume of coarse and fine residues combined was utilized as compared to 22 percent in 1966. Estimates of plant byproducts and residues included volume of bark for the first time (table 3). In 1969, bark essentially was not utilized. About 58 percent of the coarse residues was used, mainly for pulpwood, and about 29 percent of the fine residues was used, principally for fuel.

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[4]The net cubic-foot volume of live saw timber and pole timber trees cut or killed by logging on commercial forest land and not converted to timber products.

Table 1.--*Output of roundwood products from Wyoming timberlands by species, 1969*

Product	Species						All species	
	Subalpine fir	Engelmann spruce	Lodgepole pine	Ponderosa pine	Douglas-fir	Other species[1]	Volume	Percent
	Thousand cubic feet							
Saw logs	369	3,399	21,300	3,383	833	3	29,287	97.5
Miscellaneous industrial wood[2]	([3])	233	43	1	--	--	277	.9
Posts, fuelwood, miscellaneous farm timbers	--	5	376	97	--	6	484	1.6
Total	369	3,637	21,719	3,481	833	9	30,048	100.0
Percent of total	1.2	12.1	72.3	11.6	2.8	([4])	100.0	

[1]Includes limber pine and juniper.
[2]Includes commercial poles, piling, and mine timbers.
[3]Less than 0.5 thousand cubic feet.
[4]Less than 0.05 percent.

Table 2.--*Mill receipts of saw logs from Wyoming timberlands by species and county of origin, 1969*

County	Species					All species	
	Subalpine fir	Engelmann spruce	Lodgepole pine	Ponderosa pine[1]	Douglas-fir	Volume	Percent
	Thousand board feet[2]						
Albany	--	2,776	8,097	1,921	--	12,794	6.8
Big Horn	--	240	1,348	--	244	1,832	1.0
Carbon	--	9,005	13,838	--	--	22,843	12.2
Converse, Platte	--	--	--	723	--	723	.4
Crook	--	--	--	14,980	--	14,980	8.0
Fremont	--	327	55,834	63	252	56,476	30.1
Hot Springs	--	828	1,904	--	137	2,869	1.5
Johnson	--	125	10,546	131	1,346	12,148	6.5
Lincoln	1,318	3,789	11,977	18	2,685	19,787	10.5
Park	207	3,245	832	--	126	4,410	2.3
Sheridan	--	23	13,583	--	56	13,662	7.3
Sublette	843	1,180	10,510	--	368	12,901	6.9
Teton	--	--	2,350	--	123	2,473	1.3
Uinta	--	252	5,721	--	--	5,973	3.2
Weston	--	--	--	3,865	--	3,865	2.0
Total	2,368	21,790	136,540	21,701	5,337	187,736	100.0
Percent of total	1.3	11.6	72.7	11.6	2.8	100.0	

[1]Includes 18 MBF of limber pine.
[2]International 1/4-inch log rule.

Table 3.--*Estimated volume of used and unused plant residues from the lumber industry in Wyoming, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	Thousand cubic feet								
1969	4,686	3	4,683	7,322	4,262	3,060	7,907	2,269	5,638

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.

[2]Material such as sawdust and shavings.

WESTERN SOUTH DAKOTA

The 1969 South Dakota roundwood products output was 15,030 MCF, down about 5 percent from the 1966 estimate of 15,859 MCF (fig. 2).

Saw log output increased to 47,128 MBF in 1969 and accounted for about one-half of the total roundwood products output (table 4). Saw log output in 1966 was 44,308 MBF. The 1969 round pulpwood output was 5,313 MCF; this was more than 14 percent higher than the 1966 estimate of 4,645 MCF and continued the upward trend since 1958. The 1969 output of all other roundwood products combined was 2,365 MCF as compared to 4,302 MCF in 1966.

The 1969 volume of logging residues was 577 MCF, about 190 MCF less than in 1966. Because a large proportion of South Dakota's output of roundwood products is pulpwood, studies were initiated, and recently completed, leading to development of factors for estimating logging residues from pulpwood harvesting. Use of these and other new residue factors may have contributed, along with reduced roundwood output, to the lower logging residues volume estimate in 1969.

Table 5 is based on responses from all known active sawmills in South Dakota and the statistics presented are without sampling error. All of South Dakota's saw log output came from four counties. Ponderosa pine and a small volume of white spruce accounted for all sawmill log receipts in 1969.

Forty-five percent of the volume of coarse and fine residues combined was utilized in 1969 as compared to 41 percent in 1966 (table 6). About 24 percent of the fine residues and less than 1 percent of the bark was used. More than 68 percent of the coarse residues was used, however, principally for pulpwood.

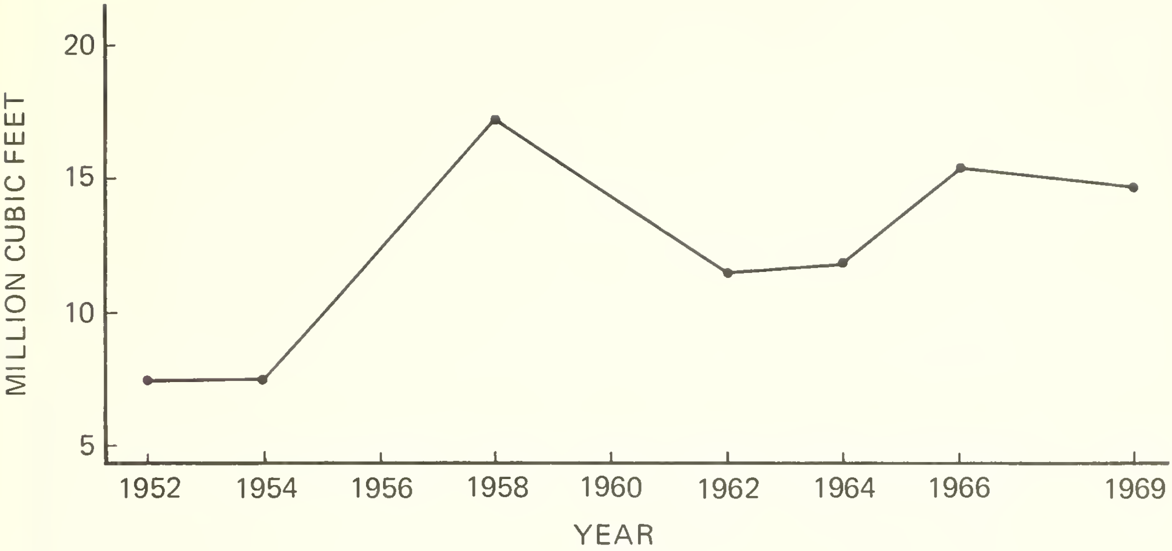

Figure 2.--South Dakota roundwood products output, 1952-1969. (Plotted volumes through 1966 are taken from USDA Forest Service Resource Bull. INT-9, p. 18, 1970.)

Table 4.--*Output of roundwood products from western South Dakota timberlands by species, 1969*

Product	Species		All species	
	White spruce	Ponderosa pine	Volume	Percent
	- - - - - *Thousand cubic feet* - - - -			
Saw logs	2	7,350	7,352	48.9
Pulpwood	51	5,262	5,313	35.4
Commercial poles, piling, posts, fuelwood, miscellaneous farm timbers	--	2,365	2,365	15.7
Total	53	14,977	15,030	100.0
Percent of total	.4	99.6	100.0	

Table 5.--*Mill receipts of saw logs from western South Dakota timberlands by species and county of origin, 1969*

Product	Species		All species	
	White spruce	Ponderosa pine	Volume	Percent
	- - - - *Thousand board feet*[1] - - - -			
Custer	--	18,593	18,593	39.5
Lawrence	11	11,036	11,047	23.4
Meade	--	2,419	2,419	5.1
Pennington	--	15,069	15,069	32.0
Total	11	47,117	47,128	100.0
Percent of total	([2])	100.0	100.0	

[1]International 1/4-inch log rule.
[2]Less than 0.05 percent.

Table 6.--*Estimated volume of used and unused plant residues from the lumber industry in western South Dakota, 1969*

Year	Bark			Coarse[1]			Fine[2]		
	Total	Used	Unused	Total	Used	Unused	Total	Used	Unused
	- - - - *Thousand cubic feet* - - - -								
1969	1,176	8	1,168	1,835	1,254	581	1,984	474	1,510

[1]Material suitable for chipping, such as slabs, edgings, and trimmings.
[2]Material such as sawdust and shavings.

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
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A PUMP-MANOMETER FOR GROUND WATER STUDIES

Bland Z. Richardson and Edward R. Burroughs, Jr.[1]

ABSTRACT

The pump-manometer provides a way to quickly and accurately measure hydraulic conductivity in the field by means of either the auger-hole method or the piezometer method. The device can be operated easily by a two-man crew, but with practice one man could perform the entire operation. The particular advantage of the manometer is that measurement of the rate of rise of water can begin as soon as the well is pumped dry without removing one instrument from the well and inserting another.

Hydrologists and engineers are often concerned with measuring the hydraulic conductivity of the soil. Many methods have been developed for the field measurement of hydraulic conductivity in saturated soils (Luthin 1957). Two of the most popular techniques are the auger-hole method and the piezometer method.

The mathematical expression of hydraulic conductivity for each of these techniques includes the rate of rise of water in a well pumped dry and also a term to indicate the depth of the water in the well below the static water level (Boersma 1965).

The accuracy of each of these methods depends largely upon careful measurements of the rate of rise of the water and the depth to the water level at any instant. One of the difficulties in using these techniques is the lag in time that occurs between pumping a well dry and starting to measure the rise of water in the well. This paper describes a combination pump and manometer which will allow the operator to pump a well dry, then, without interruption, to observe and time the rise of water in the well.

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Figure 1.--Measuring hydraulic conductivity on the Elk Meadows research site, Idaho.

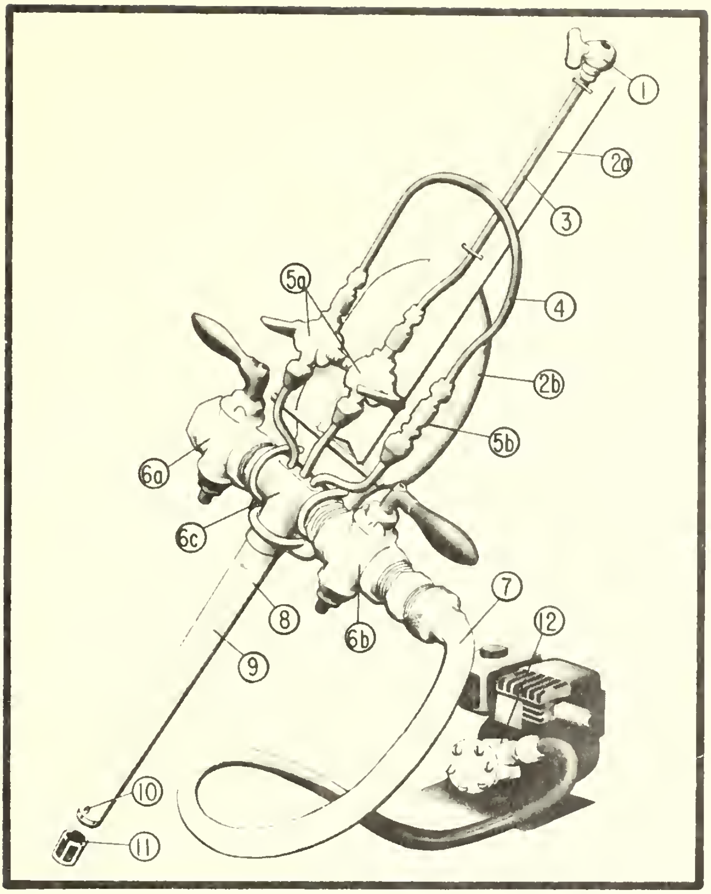
The pump-manometer consists of an air-liquid manometer built into the suction tube of a pump. After the pump has drained the well, a valve can disconnect the pump and the manometer can immediately function to measure rate of rise in the well. The level of the rising water is indicated by an extension of the manometer fastened to a scale. Burroughs (1967) and Richardson (1966) have reported that the pump-manometer has been used successfully in wells drilled in rocky soils and cased with 3/4-inch pipe on a study site in Idaho (fig. 1).

MANOMETER CONSTRUCTION SPECIFICATIONS

Major components of the pump-manometer are indicated by numbers in figure 2. The manometer scale (2a)[2] is 3/4- by 3/4- by 1/8-inch aluminum angle. The support is an 1/8-inch aluminum channel that clamps to a backplate (2b) of 1/4-inch aluminum slotted to allow vertical adjustment of the manometer scale (fig. 3).

The body of the manometer is composed of a copper 3/4-inch tee (6c) that has a slot (1 inch long and 3/8 inch wide) cut in the top. A 1/2-inch steel suction tube (8) is fitted into the bottom of the copper tee by means of an adapter machined for snug fit and these pieces are silver soldered. A 5/16-inch hole is drilled 1 inch above the bottom of the suction tube to form the manometer inlet (10). A piece of 1/4-inch copper tubing, 1 foot longer than the suction tube, is inserted in the bottom of the suction tube and out the slot in the top of the tee. The lower end of the copper tube is bent in such a way that (as it is pulled into the suction tube) it will press against the sides of the tube and will drop into the 5/16-inch hole (fig. 4). The copper tube is pulled into the 5/16-inch hole, silver soldered, and filed flush with the outside of the suction tube. Two pieces of 1/4-inch copper tubing are cut 1 foot longer than the suction tube and one end of each piece is bent as sharply as possible without causing the tubing to collapse. The two pieces are laid side by side with the bends overlapping A cut is made through both pieces so that when the cut ends are joined, there will be approximately 1/8 inch between the two lengths of copper tubing (fig. 4). The joint is silver soldered and slipped into the bottom of the suction tube. Then, the upper ends of the copper tubing are pulled through the slot in the top of the tee.

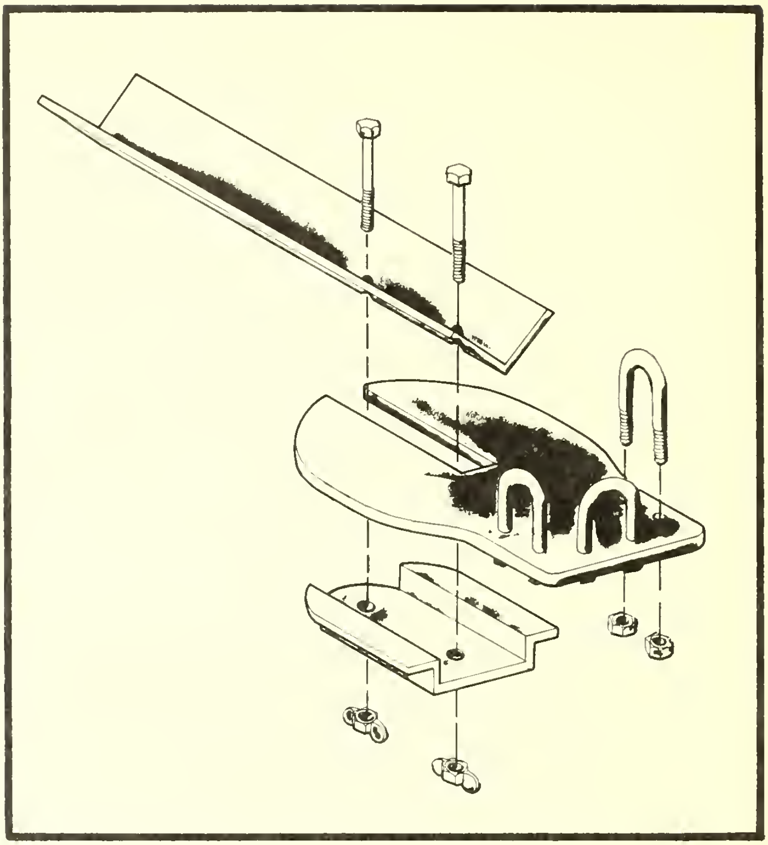
[2]Numbers in parentheses refer to appropriate figure.



PARTS LIST			
KEY	DESCRIPTION	KEY	DESCRIPTION
1	Manometer vent valve	6b	Pump valve
2a	Manometer scale	6c	Copper tee 3/4X3/4X3/4
2b	Manometer back plate	7	Pump hose 3/4"
3	Plastic manometer tube	8	Suction tube
4	Plastic loop	9	Suction tube scale
5a	Manometer valves	10	Manometer inlet
5b	Union connector	11	Strainer
6a	Bleed valve	12	Self-priming pump unit

Figure 2.--Manometer parts.

Figure 3.--Manometer scale, backplate, and support.



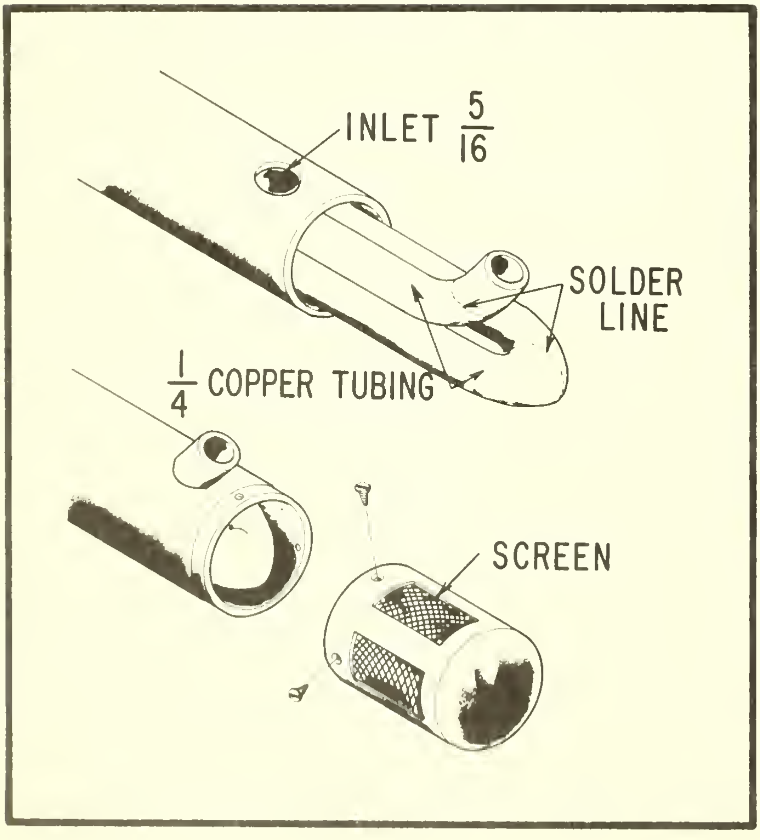


Figure 4.--Lower suction tube assembly details.

The copper tube from the manometer inlet is positioned on the left side of the slot and cut off about 3-1/2 inches above the tee. A nut is placed on the tube and the tubing flared (fig. 2). One of the ends of the joined tubes is placed in the center of the slot and the tube cut off about 2 inches above the tee. A nut is placed over the end and the tubing flared for later attachment to the plastic manometer tube (3). The remaining copper tube is cut, a nut installed, and the tube flared to match the manometer inlet tube on the left side of the slot.

Two brass, 1/4-inch shutoff cock valves (5a) are installed on the manometer inlet tube and the center tube. A piece of 1/8-inch brass welding rod is silver soldered to all three copper tubes to act as a brace. The slot in the tee, from which the three tubes exit, is closed with silver solder. The aluminum backplate is fastened to the copper tee with U-bolts (fig. 3).

A copper 3/4- by 3/4-inch adapter is inserted in each end of the copper tee and silver soldered in place. A brass, 3/4-inch stop-and-drain cock (6a and 6b) is threaded onto each adapter. A garden hose adapter is screwed onto the pump valve (6b). A full union (5b) is fastened on the right-hand tube. The upper end of each fitting is equipped with a compression fitting for plastic tubing. A piece of 1/4-inch plastic tubing (4), about 14 inches long, connects the manometer inlet tube with the right-hand tube. A piece of 1/4-inch plastic tubing (3), 2 inches longer than the manometer scale, is connected to the center tube. A small, brass manometer vent valve (1) is installed on the upper end of the plastic manometer. The manometer scale (2a) and its support are bolted to the backplate (2b), and the plastic manometer (3) fastened to the scale (2a) with metal clips.

PUMP SPECIFICATIONS

A Jabsco bronze self-priming gasoline motor pump unit[3] is attached to the instrument by a length of 3/4-inch garden hose (fig. 5). This pump unit weighs 32 pounds and is powered by a Briggs and Stratton 3-1/2 horsepower, 4-cycle, 2,000-rpm, "shock-free" gasoline engine with a windup starter and carrying handle. A parts breakdown of the pump is shown in figure 6.

The impeller (4) is made of a heat-resistant Neoprene compound that has excellent sealing qualities. The wear plate (6) may have to be replaced periodically if water contains sand. The pump body (9) is internally fitted for 1-inch diameter pipe. This pump is capable of pumping 35 gallons per minute to a 10-foot head or 24 gallons per minute to an 80-foot head.

The strainer (11) used in the pump-manometer is made from 60-mesh brass screen (fig. 2). It is cylinder-shaped, 1 inch long, and fitted on the lower part of the suction tube where it is held in place by screws.

CALIBRATION

The manometer fluid is ethyl alcohol. Enough dye is added to provide a good color contrast with the manometer scale. The manometer is primed by injecting the alcohol-dye mixture into the upper end of the plastic manometer with a syringe. The system is primed when the fluid level rises to the zero level on the manometer scale. It is important to keep the manometer vent valve and the two manometer valves closed when the instrument is idle to prevent evaporation or spillage.

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[3]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

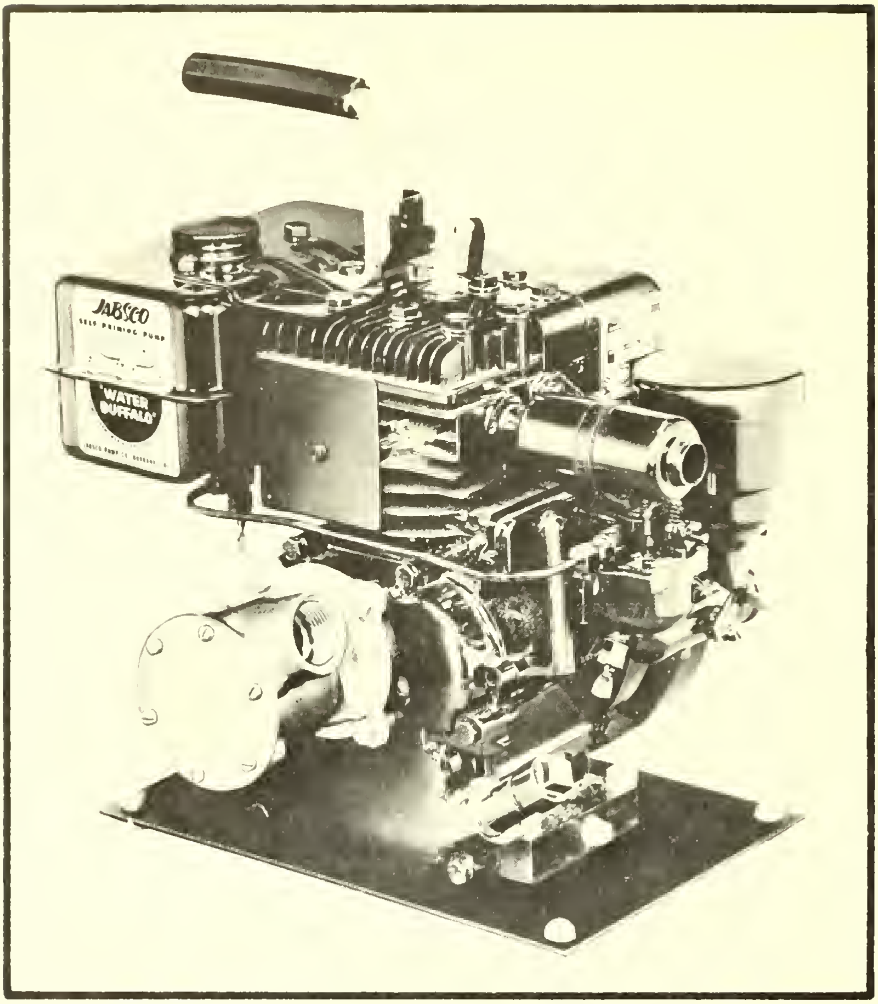
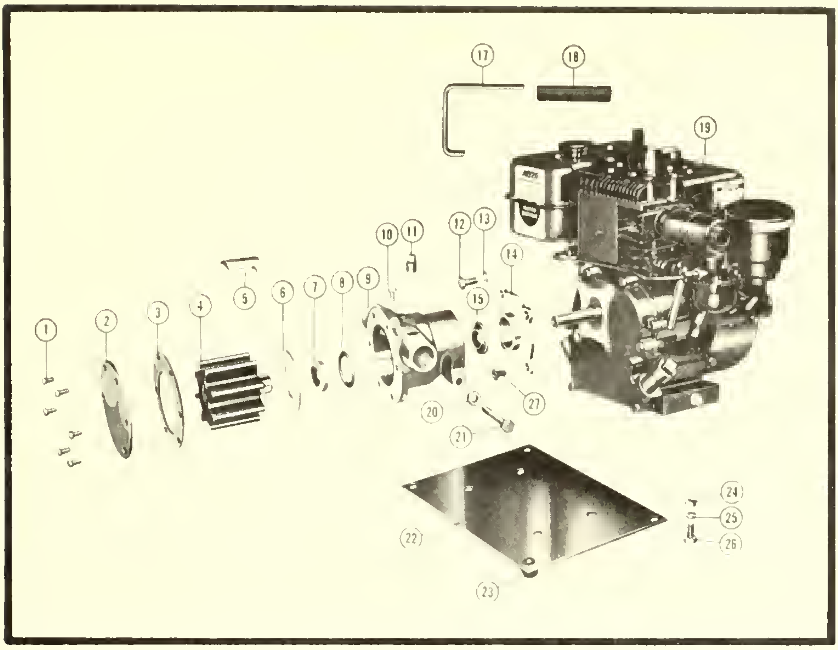


Figure 5.--Self-priming gasoline motor pump unit.

It is necessary to calibrate the instrument so that a unit length of rise of water can be accurately measured by the air-liquid manometer. There are two reasons for calibrating the manometer: first, compression of the air by the rising water results in a shortened manometer scale; and second, the thermal characteristics of the manometer fluid are different from water. Consequently, the calibration process should be carried out in water of the same temperature as that of the ground water. The calibration process integrates the compression effect of the trapped air and the thermal characteristics of the manometer fluid at a given temperature. Water used to calibrate this manometer had a temperature of 40° to 45° F.

The manometer is calibrated in a tank or tube, at least as deep as the wells that are to be measured. The blank scale is inserted behind the manometer tube and the water level in the tank is raised until the manometer inlet is covered. The zero point is carefully scribed on the scale opposite the meniscus of the fluid. The water level is raised 1 inch and a new mark is scribed on the scale. Alternate scales may be made by transforming the original scale into tenths of feet or centimeters. The suction tube is scored at 1-inch intervals beginning at the upper side of the inlet hole (part 9, fig. 2). The appropriate number is stamped on each scored ring so the distance above the inlet tube can be easily read.



PARTS LIST					
KEY	DESCRIPTION	QTY REQ	KEY	DESCRIPTION	QTY REQ
1	Screws, end cover	6	14	Adaptor	1
2	End cover	1	15	Slinger	1
3	Gasket	1	17	Handle	1
4	Impeller assembly	1	18	Handle grip	1
5	Cam	1	19	Engine	1
6	Wearplate	1	20	Nut	1
7	Seal shaft	1	21	Bolt	1
8	O-ring	1	22	Base	1
9	Body	1	23	Rubber bumper	4
10	Screw, cam	1	24	Nut	4
11	Plug	1	25	Washer	4
12	Bolt	2	26	Bolt	4
13	Washer	2	27	Flat head screw	2

Figure 6.--Breakdown of self-priming pump parts.

The theoretical depth from which water can be pumped depends on a number of factors, such as barometric pressure, water temperature, type of pump, etc. For practical application, the best method that can be used to determine the maximum depth of a well with this manometer is described below. Place a 25-foot suction hose on the type of pump to be used. Insert the suction hose in a well of desired depth. Start pump and remove water until maximum depth is reached (at sea level this is about 20 feet). The suction tube on the manometer cannot exceed this length, but the manometer handles best at a depth of less than 12 feet.

OPERATION

Certain dimensions of the well must be determined before field measurements of hydraulic conductivity can begin. These dimensions define the initial depth of the well and the initial (or static) depth of water in the well. Refer to figure 7 which illustrates the following dimensions:

D - Depth of the well below the datum, which is the soil surface for the auger-hole method and the top of the well casing for the piezometer method;

E - Depth of the static water level below the datum;

d - Depth of the water in the well for both the auger-hole method and piezometer method, $d = D - E$;

L - Depth from the datum to the water surface in the well;

h - Average depth of water from the bottom of the well;

R - Radius of the well; and

s - Distance from the bottom of the well to the restricting layer.

E is determined by slowly lowering the suction tube into the well until the fluid in the manometer begins to move from its zero position; the scale on the outside of the suction tube at the datum level indicates the depth to water below the datum. D is determined by lowering the suction tube into the well until it rests on the bottom, and by reading the scale on the outside of the suction tube at the datum level and adding the 2 inches that the suction tube screen extends below the manometer inlet. The instrument is allowed to remain immersed for 2 minutes to allow the fluid in the suction tube portion of the manometer to come to thermal equilibrium with the well water. At equilibrium conditions, the manometer fluid may have increased or decreased its volume depending on its initial temperature. The instrument, which is withdrawn from the well until the manometer inlet is above the water, then is lowered until the fluid begins to move from its zero position. Note that the manometer screen extends 2 inches below the manometer inlet; therefore, the manometer scale is adjusted vertically until the 2-inch mark on the scale corresponds to the fluid level visible in the plastic manometer.

With the preliminary measurements completed, the instrument can be lowered to the bottom of the well and the pump can be started. The bleed valve (part 6a, fig. 2) should be closed and the pump valve (6b) opened. The manometer will indicate the falling water level. When the well is empty, the air moving past the manometer inlet (10) and up the suction tube (8) will cause the manometer to indicate a negative water level. At this point, the pump valve (6b) is closed and the bleed valve (6a) is opened. Laboratory tests show that only 30 ml. of water is retained in the suction tube after the well is pumped dry. When the pump valve is closed, this water drops back but causes only a negligible amount of water rise in the well. Ground water will immediately begin to rise in the well and the fluid in the manometer tube will begin to move as soon as water covers the manometer inlet.

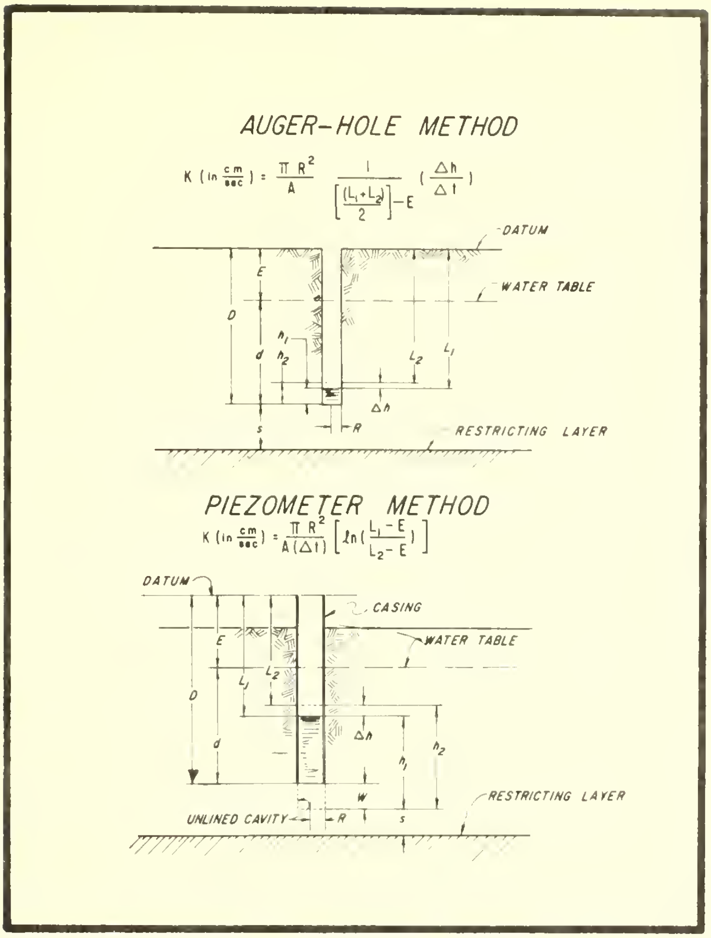


Figure 7.--Dimensions used in both the auger-hole and piezometer methods to determine hydraulic conductivity in the field. (Adapted from Boersma 1965).

In sandy and gravelly soils, the rise of water in the first inch is usually so rapid that the operator may not be able to begin timing until the manometer fluid reaches the first inch above zero. The operator should be poised to time the rise of the fluid between convenient intervals on the manometer scale. A skilled operator can time alternate 1-inch intervals on the manometer scale. For accurate calculation of hydraulic conductivity with the auger-hole method, all measurements should be completed before the water in the well has reached a depth of 0.2d. For the piezometer method, measurements may continue until the water in the well has risen to within 20 cm. of its static level (Boersma 1965). Measurements should not be repeated until the water in the well has returned to its original static level. During operation, it is important to turn the instrument so that the plastic manometer tube is not exposed to direct sunlight for extended periods of time; error can be introduced by heating and expansion of the manometer fluid.

CALCULATIONS

The equations for calculating the hydraulic conductivity, K in cm./sec., are given in figure 7. "A" is a geometric factor in units of length, which relates the flow rate of water into the well to d, R, and s. "A" can be determined for both the auger-hole and piezometer methods by means of the procedure outlined in Boersma (1965). Because the pump-manometer measures h instead of L, the computation of the hydraulic conductivity in terms of h will be given for the two methods.

For the auger-hole method the term

$$\left[\frac{(L_1 + L_2)}{2}\right] - E$$

is equivalent to

$$\frac{(L_1 - E) + (L_2 - E)}{2} \qquad \text{Eq. 1.}$$

Since

$$L_1 - E = d - h_1$$

and

$$L_2 - E = d - h_2,$$

Equation 1 may be rewritten as

$$\frac{(d - h_1) + (d - h_2)}{2},$$

which can be reduced to

$$d - \left[\frac{(h_1 + h_2)}{2}\right].$$

The computational formula for K can be converted to:

$$K = \frac{\pi R^2}{A} \quad \frac{1}{d - \left[\frac{(h_1 + h_2)}{2}\right]} \quad \frac{\Delta h}{\Delta t}.$$

For the piezometer method, the quantity

$$L_1 - E$$

is equivalent to

$$d - h_1.$$

The equation for hydraulic conductivity for the piezometer method is

$$K = \frac{\pi R^2}{A(\Delta t)} \quad \ln \left[\frac{d - h_1}{d - h_2}\right].$$

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APPENDIX

Suggested computation sheets are given below.

Height of water in well (cm)	Rise increment (cm)	Time increment (sec)	Ratio $\frac{\Delta h}{\Delta t}$	$\frac{h_1 + h_2}{2}$	$d - \left[\frac{h_1 + h_2}{2}\right]$	$\frac{1}{d - \left[\frac{h_1 + h_2}{2}\right]}$	$\frac{\pi R^2}{A}$	$K \frac{cm}{sec} = \frac{\pi R^2}{A} \frac{1}{d - \left[\frac{h_1 + h_2}{2}\right]} \frac{\Delta h}{\Delta t}$
1	2	3	4	5	6	7	8	9
h_1 = h_2 =								

*Figure 8.--Sheet for hydraulic conductivity by the auger-hole method**

Height of water in well (cm)	d - h (cm)	$\frac{d - h_1}{d - h_2}$	$\ln \left[\frac{d - h_1}{d - h_2}\right]$	Time increment (sec)	$\frac{\pi R^2}{A}$	$K \frac{cm}{sec} = \frac{\pi R^2}{A(\Delta t)} \ln \left[\frac{d - h_1}{d - h_2}\right]$
1	2	3	4	5	6	7
h_1 = h_2 =	$d - h_1$ = $d - h_2$ =		Δt =			

*Figure 9.--Sheet for hydraulic conductivity by the piezometer method**

* Adapted from Boersma 1965.

Research Note

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RETARDANT SALT CONCENTRATION MEASURED IN THE FIELD

Charles W. George[1]

ABSTRACT

The effectiveness of long-term fire retardants is related to the concentration of the active fire-inhibiting salt. Quality control at each retardant base is necessary to assure that maximum effectiveness is obtained. This note describes simple field methods for determining the salt content of retardant solutions now in use.

Previous studies have indicated that the effectiveness of long-term fire retardants is related to the amount and type of active chemical salt present in a given fuel and fire situation. To assure that the desired salt concentration and effectiveness is obtained, retardant base personnel must have the capability of monitoring the salt content.

Previous methods of monitoring retardant quality have included viscosity and density measurements.[2] [3] Although viscosity is important because of its relation to aerial drop characteristics, it is not necessarily related to salt content. Viscosity has an important effect, however, on the amount of salt retained by aerial fuels. The viscosity of a retardant depends on the type and amount of thickening agent, water hardness, temperature, and method of mixing (shear, etc.). The density and specific

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[1]Research Forester, stationed at the Northern Forest Fire Laboratory, Missoula, Montana.

[2]Charles W. George and Charles E. Hardy. Revised Marsh funnel table for measuring viscosity of fire retardants. USDA Forest Serv. Res. Note INT-91, 2 p., 1969.

[3]National Fire Protection Association. Chemicals for forest fire fighting. Ed. 2, p. 75-87. Boston: National Fire Protection Association, 1967.

gravity[4] are related to the concentration of salt and other ingredients in solution. The retardant salt is the primary ingredient in fire retardants and its concentration can be correlated to the specific gravity if the manufacturer's formulation remains constant. Past salt analyses show the manufacturer's formulation to remain acceptably constant if the samples are of an adequate size.

AVAILABLE MEASURING METHODS

Methods for measuring the density and specific gravity of retardants have included use of the Baroid mud balance[5] and the hydrometer. The mud balance consists of a graduated arm that has a constant volume cup attached to one end and an adjustable counterweight on the other end. The arm is scaled for both specific gravity and density. The hydrometer is a simple floating instrument which measures gravimetrically the buoyancy exerted on a glass-enclosed body of definite volume immersed in the liquid. The instrument is graduated in units of specific gravity.

Direct measurements of the specific gravity and density of retardants with the hydrometer and mud balance are complicated by the presence of thickening agents. These agents decrease the accuracy of such measurements for several reasons:

1. Viscous materials restrict free movement of the hydrometer and provide a poor meniscus. (The meniscus is the curved liquid surface in contact with the hydrometer.)

2. The volume of some types of thickening agents (especially clays) is dependent on the amount of hydration and mixing. Thus, a change in the volume and density may be due to changes in physical properties of the solution rather than a change in its salt content.

3. Air bubbles are common in freshly agitated retardant samples and cause errors in weight-volume measurements taken with the mud balance; also, bubbles affect the buoyancy exerted on a hydrometer.

FIELD PROCEDURES

The above problems can be solved by breaking down the thickening agent before measuring the specific gravity and estimating the salt content of presently used fire retardants. Retardants[6] presently being used and their major physical-chemical properties are given in table 1. The viscosity of highly viscous gum-thickened retardants such as Phos-Chek® 202 and 202XA can be reduced prior to determining the specific gravity by addition of a chemical known to break polymeric chains. A procedure to remove the clay from clay-thickened products, such as Fire-Trol 100, must be used because clay interferes with free hydrometer movement. Because of the nature of

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[4]The density is the weight per unit volume. The specific gravity of a liquid is the ratio of its density to that of water at 4° C. and for practical purposes is equivalent to its density in grams per cubic centimeter.

[5]The Baroid mud balance is manufactured by the Baroid Division, National Lead Co., P.O. Box 1675, Houston, Tex. The use of firm names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.

[6]The retardants presently being used and mentioned in this paper were formally submitted and evaluated under USDA Forest Service Interim Specification 5100-00301, Specification for Retardant, Forest Fire, Dry Chemical and Fixed-Wing Aircraft Application; or USDA Forest Service Interim Specification 5100-00302, Specification for Retardant, Forest Fire, Liquid Chemical, Unthickened for Aircraft or Ground Application.

Table 1.--*Physical-chemical characteristics of presently used fire retardants*

Retardant[1]	Recommended use level lbs./gal. of water or dilution rate[2]	Viscosity[3]	Density of slurry	Percent DAP $(NH_4)_2HPO_4$ or DAP equivalent	Percent ammonium sulfate $(NH_4)_2SO_4$	Percent[4] P_2O_5 equivalent	Specific gravity of slurry or filtrate (using analyses procedures)
		Centipoise	*Lbs./gal.*				
Phos-Chek 202	1.14	800-1500	8.9	10.6		5.7	1.072
Phos-Chek 202XA	1.14	1500-2000	8.9	10.6		5.7	1.072
Phos-Chek 259	1.60	50-100	9.1	15.0		8.1	1.095
Fire-Trol 930	4:1	5-60	9.1	16.2		8.7	1.096
Fire-Trol 931	4:1	30-120	9.2	15.4		8.3	1.092
Fire-Trol 934	4:1	5-60	9.1	15.8		8.5	1.094
Fire-Trol 100	2.78	1500-2500	9.4		15.6		1.101
Pyro (11-37-0)	5:1	50-100	9.0	14.9		8.0	1.078

[1]Phos-Chek is a product of Monsanto, St. Louis, Missouri. Fire-Trol is a product of Arizona Agrochemical Co., Phoenix, Arizona. Fire-Trol 930 is composed of Allied Chemical Co.'s Arcadian Poly-N 10-34-0 and a corrosion inhibitor. Fire-Trol 931 is composed of Allied Chemical Co.'s Arcadian Poly-N 10-34-0, clay, coloring, and corro- sion inhibitor. Fire-Trol 934 is composed of Allied Chemical Co.'s Arcadian Poly-N 10-34-0, wetting agent, and corrosion inhibitor. Pyro (11-37-0) is manufactured by Tennessee Valley Authority, Muscle Shoals, Alabama, and con- tains 1.5 percent $Na_2Cr_2O_7$ corrosion inhibitor.

[2]The dilution rate is by volume; a dilution rate of 4:1 means 4 gallons of water are added to 1 gallon of liquid concentrate to provide approximately 5 gallons of retardant solution.

[3]Viscosities by Brookfield viscometer Model LVF, at 60 r.p.m., spindle number 2 or 4.

[4]The P_2O_5 equivalent is determined from the percent by weight DAP using the formula: Percent P_2O_5 = percent DAP ÷ 1.86. The equivalent P_2O_5 content is not necessarily the same as the *active* salt content (because of other retardant ingredients) although the P_2O_5 equivalent can be used for quality control.

clay, it can be removed more readily by filtration than by use of flocculation agents. The specific gravity of products that have no thickening agent (Pyro, Fire-Trol 930 and 934) or gum-thickened products with only slight viscosity (Phos-Chek 259) can be determined without any special preparatory procedures.

Thus, because of the types of thickening agents, three different procedures are necessary for determining the salt content of present fire retardants. These procedures were developed by trial and error after excluding the possibility of devising a simple field method based on chemical analyses and are given in the three following sections.

1. Procedure for unthickened or thin, gum-thickened retardants--Pyro (TVA 11-37-0) Fire-Trol 930 and 934, and Phos-Chek 259.

2. Procedure for thick, gum-thickened retardants--Phos-Chek 202 and 202XA.

3. Procedure for clay-thickened retardants--Fire-Trol 100 and 931. Fire-Trol 931 is a clay-thickened, liquid concentrate which when diluted falls in the unthickened retardant category.

Following development of satisfactory field procedures, the specific gravity and the retardant salt content were correlated. For calibration purposes, a minimum of 10 samples of each retardant was prepared, varying only the mixing ratio or use level. This provided 10 different salt contents and specific gravities. The specific gravity was read while temperature of the solution was at 80±2° F. Using a computer method for linear regression, an equation was determined that fitted these points best in the least squares sense. The equation for salt content as a function of specific gravity was then evaluated and a table compiled. A correction factor was then calculated for retardant salt contents which deviated from the recommended salt content. *This use-level correction factor per 100 gallons of retardant solution will enable field personnel to adjust an improper salt content. (See the table for each product: tables 2, 3, 4, 5, 6, and 7).* Selection of a method for correction of an improper salt content will depend on the type of retardant, the mixing equipment, and the existing plumbing.

Under field conditions the specific gravity of a retardant solution or slurry may be measured at a temperature other than 80±2° F.; therefore, it was necessary to determine the effect of temperature on specific gravity. Samples of each retardant with the recommended salt content were prepared and the specific gravity measured at 10° intervals between 40° and 110° F. The effect of temperature on the specific gravity was found to be the same for all retardants, for all practical purposes. The average change in specific gravity was found to be approximately 0.002 specific gravity units per 10° F. Thus, if the specific gravity of the retardant solution cannot be measured near 80° F., the following rule of thumb should be applied: *For every 10° F. the retardant solution is below 80° F., subtract 0.002 from the hydrometer reading; or for every 10° F. the retardant solution is above 80° F., add 0.002 to the hydrometer reading*

PROCEDURES FOR SPECIFIC PRODUCTS[7]

PROCEDURE FOR UNTHICKENED OR THIN, GUM-THICKENED RETARDANTS

Pyro (TVA 11-37-0), Fire-Trol 930 and 934, and Phos-Chek 259

The retardants are either unthickened, or thickened only slightly, and regular hydrometer readings can be taken.

1. Take a freshly agitated quart sample of the solution or slurry to be analyzed for salt content. (This sample will also be suitable for viscosity measurement, using the Brookfield viscometer or the Marsh funnel.) Allow the sample to reach room temperature (approximately 80° F.).

2. After all entrapped air bubbles are allowed to escape, measure the specific gravity of the solution using a high precision hydrometer (Sargent-Welch S-41885G for specific gravity 1.060 - 1.130 by 0.001 divisions). Be sure to let the hydrometer settle in the solution for 3 to 5 minutes before reading.

3. Record the specific gravity to the nearest 0.001 and extrapolate from tables 2, 3, and 4 the percent by weight, P_2O_5 equivalent, or DAP $[(NH_4)_2HPO_4]$ equivalent. (If the active chemical used in the retardant formulation was DAP, the percent DAP rather than P_2O_5 equivalent will appear in the first column following the specific gravity.)

[7]The equipment recommended for use in these field procedures is given on page 14 following the procedures.

Table 2.--*Pyro 11-37-0 salt content as related to specific gravity*[1]

Measured specific gravity of retardant solution	Percent P_2O_5 equivalent (by weight)	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Correction[2] required per 100 gallons of retardant solution: Concentrate	Water
			- - - - *Gals.*	- - - -
1.045	4.9	9.1	8.1	
1.050	5.4	10.0	6.8	
1.055	5.8	10.8	5.8	
1.060	6.3	11.7	4.5	
1.065	6.8	12.6	3.2	
[3] 1.070	7.3	13.6	1.9	
1.075	7.7	14.3	.8	
1.078	8.0	14.9	0	0
1.080	8.2	15.3		3
1.085	8.7	16.2		10
1.090	9.2	17.1		16
1.095	9.6	17.9		22
1.100	10.1	18.8		29
1.105	10.6	19.7		36
1.110	11.1	20.6		43
1.115	11.5	21.4		49
1.120	12.0	22.3		56
1.125	12.4	23.1		62
1.130	13.0	24.2		71
1.135	13.4	24.9		77
Expanded Scale				
1.150	14.9	27.7		99
1.175	17.2	32.0		135
1.200	19.6	36.5		174
1.225	22.0	40.9		214
1.250	24.3	45.2		255

[1]The recommended use level for Pyro 11-37-0 is 5 parts water to 1 part concentrate by volume. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent P_2O_5 equivalent = 95.05 specific gravity - 94.44.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

Table 3.--*Fire-Trol 930 and 934 salt content as related to specific gravity*[1]

Measured specific gravity of filtrate	Percent P_2O_5 equivalent (by weight)	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Correction[2] required per 100 gallons of retardant solution: Concentrate	Water
			- - - - *Gals.* - - - -	
1.060	5.6	10.4	10.2	
1.065	6.0	11.2	9.3	
1.070	6.5	12.1	6.5	
1.075	6.9	12.8	5.3	
1.080	7.3	13.6	4.1	
[3] 1.085	7.7	14.3	2.8	
1.090	8.2	15.3	1.3	
1.095	8.6	16.0	0	0
1.100	9.0	16.7		5
1.105	9.5	17.7		12
1.110	9.9	18.4		17
1.115	10.3	19.2		23
1.200	10.8	20.1		29
1.125	11.2	20.8		34
1.130	11.6	21.6		39
1.135	12.0	22.3		45
1.140	12.5	23.3		52
1.145	12.9	24.0		57
1.150	13.3	24.7		63
1.155	13.8	25.7		70
Expanded Scale				
1.175	15.5	28.8		94
1.200	17.6	32.7		126
1.225	19.8	36.8		160
1.250	21.9	40.7		193

[1]The recommended use level for Fire-Trol 930 and Fire-Trol 934 is 4 parts water to 1 part concentrate by volume. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent P_2O_5 equivalent = 85.92 specific gravity - 82.09.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

Table 4.--*Phos-Chek 259 salt content as related to specific gravity*[1]

Measured specific gravity of retardant solution	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Percent P_2O_5 equivalent (by weight)	Correction[2] required per 100 gallons of retardant solution: Retardant	Correction[2] required per 100 gallons of retardant solution: Water
			Lbs.	*Gals.*
1.050	8.2	4.4	76	
1.055	9.0	4.8	68	
1.060	9.7	5.2	60	
1.065	10.5	5.6	51	
1.070	11.2	6.0	43	
1.075	12.0	6.4	34	
1.080	12.7	6.8	27	
1.085	13.5	7.3	17	
[3] 1.090	14.2	7.7	9	
1.095	15.0	8.1	0	0
1.100	15.7	8.4		6
1.105	16.5	8.9		11
1.110	17.3	9.3		17
1.115	18.0	9.7		22
1.120	18.8	10.1		28
1.125	19.5	10.5		34
1.130	20.3	10.9		40
1.135	21.0	11.3		45
1.140	21.8	11.7		52
1.145	22.5	12.1		57
1.150	23.3	12.5		64

[1]The recommended use level for Phos-Chek 259 is 1.60 lbs./gal. of water. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent DAP = 150.72 specific gravity - 150.05.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

PROCEDURE FOR THICK, GUM-THICKENED RETARDANTS

Phos-Chek 202 and 202XA[8]

1. Take a freshly agitated sample of the Phos-Chek® slurry to be analyzed for salt content (this sample will also be suitable for viscosity measurement, using either the Brookfield viscometer or the Marsh funnel). Allow the sample to reach room temperature (approximately 80° F.).

2. Using this sample, fill a quart jar one-half full. Then, using a teaspoon measure, *add two level teaspoon measures* (5 grams) of Phos-Chek® Breaker[9] to the sample. *NOTE: It is important that exactly the correct amount of Phos-Chek® Breaker be added.*

3. Shake vigorously for at least 30 seconds and loosen the lid to relieve air pressure and allow entrapped air bubbles to escape.

4. Allow the material to sit for 10 minutes.

5. Pour the material into a hydrometer cylinder and allow it to reach room temperature (approximately 80° F.). A 32 by 200 mm. test tube will suffice.

6. After allowing the material to sit for an additional 10 minutes (20 minutes from the time the enzyme was added), measure the specific gravity of the solution using a high precision hydrometer (Sargent-Welch S-41885G for specific gravity 1.060 - 1.130 by 0.001 divisions). Allow the hydrometer to settle in the solution for at least 1 minute before reading. *Do not allow any solution containing Phos-Chek® Breaker to be returned to the storage tank since a small amount can cause gradual reduction in viscosity of the entire tank.*

7. After recording the specific gravity to the nearest 0.001, extrapolate from table 5 the percent by weight DAP $[(NH_4)_2HPO_4]$ or P_2O_5 equivalent.

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[8]The procedure used for Phos-Chek 202 and 202XA is a modification of a method proposed by H. L. Vandersall and G. F. Snow, Monsanto Co., 1971.

[9]Phos-Chek® Breaker is a cellulase enzyme supplied by the Monsanto Co. Phos-Chek® Breaker packaged for fire retardant salt analysis can be obtained from the Northern Forest Fire Laboratory, Drawer G, Missoula, Montana 59801; or Monsanto Co., 810 East Main St., Ontario, California 91761.

Table 5.--*Phos-Chek 202 and 202XA salt content as related to specific gravity*[1]

Measured specific gravity of retardant solution	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Percent P_2O_5 equivalent (by weight)	Correction[2] required per 100 gallons of retardant solution	
			Retardant	Water
			Lbs.	*Gals.*
1.030	4.0	2.2	72	
1.035	4.7	2.5	65	
1.040	5.5	3.0	56	
1.045	6.2	3.3	49	
1.050	7.0	3.8	40	
1.055	7.8	4.2	31	
1.060	8.5	4.6	24	
[3]				
1.065	9.3	5.0	15	
1.070	10.0	5.4	7	
1.074	10.6	5.7	0	0
1.075	10.8	5.8		2
1.080	11.5	6.2		9
1.085	12.3	6.6		17
1.090	13.0	7.0		24
1.095	13.8	7.4		33
1.100	14.6	7.8		41
1.105	15.4	8.3		50
1.110	16.1	8.7		57
1.115	16.9	9.1		66
1.120	17.6	9.5		73

[1]The recommended use level for Phos-Chek 202 and 202XA is 1.14 lbs./gal. of water. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent DAP = 151.83 specific gravity - 152.42.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

PROCEDURE FOR CLAY-THICKENED RETARDANTS

Fire-Trol 100 and 931

1. Take a freshly agitated 1- to $1\frac{1}{2}$-quart sample of the Fire-Trol slurry to be analyzed for salt content. (This sample will also be suitable for viscosity measurement using the Brookfield viscometer or the Marsh funnel.)

2. Place the sample in an 8-inch funnel containing a rapid and fairly retentive filter paper (Sargent-Welch S-32915L general purpose filter paper). Collect 80 to 100 ml. of the filtrate. Fire-Trol 100 samples will require about 30 minutes depending partially on the viscosity. Fire-Trol 931 samples will require about 10 minutes.

3. Place the filtrate in a hydrometer cylinder and allow it to reach room temperature (approximately 80° F.). A 32 by 200 mm. test tube will suffice.

4. Measure the specific gravity of the solution using a high precision hydrometer (Sargent-Welch S-41885G for specific gravity 1.060 - 1.130 by 0.001 divisions). Allow the hydrometer to settle in the solution for 1/2 to 1 minute before reading.

5. Record the specific gravity to the nearest 0.001 and extrapolate from tables 6 and 7 the percent by weight ammonium sulfate [$(NH_4)_2SO_4$], P_2O_5 equivalent, or DAP [$(NH_4)_2HPO_4$] equivalent, depending on type of retardant.

Table 6.--*Fire-Trol 100 salt content as related to specific gravity*[1]

Measured specific gravity of filtrate	Percent $(NH_4)_2SO_4$ by weight	Correction[2] required per 100 gallons of retardant solution: Retardant	Correction[2] required per 100 gallons of retardant solution: Water
		Lbs.	*Gals.*
1.045	7.3	154	
1.050	8.1	140	
1.055	8.8	127	
1.060	9.6	114	
1.065	10.3	100	
1.070	11.0	86	
1.075	11.8	73	
1.080	12.5	59	
1.085	13.3	45	
1.090	14.0	31	
[3] 1.095	14.8	16	
1.100	15.5	2	
1.101	15.6	0	0
1.105	16.2		4
1.110	17.0		10
1.115	17.7		15
1.120	18.5		21
1.125	19.2		26
1.130	20.0		32
1.135	20.7		37
1.140	21.4		43
1.145	22.2		48
1.150	22.9		54
1.155	23.7		60
1.160	24.4		65

[1]The recommended use level for Fire-Trol 100 is 2.78 lbs./gal. of water. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent AS = 148.40 specific gravity - 147.74.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

Table 7.--*Fire-Trol 931 salt content as related to specific gravity*[1]

Measured specific gravity of filtrate	Percent P_2O_5 equivalent (by weight)	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Correction[2] required per 100 gallons of retardant solution: Concentrate	Correction[2] required per 100 gallons of retardant solution: Water
			- - - - *Gals.*	- - - -
1.060	5.7	10.6	8.4	
1.065	6.1	11.4	7.1	
1.070	6.5	12.1	5.8	
1.075	6.9	12.9	4.4	
1.080	7.3	13.6	3.1	
[3] 1.085	7.8	14.4	1.8	
1.090	8.2	15.2	.4	
1.092	8.3	15.4	0	0
1.095	8.6	16.0		4
1.100	9.0	16.7		9
1.105	9.4	17.5		15
1.110	9.8	18.3		20
1.115	10.2	19.1		26
1.120	10.6	19.8		32
1.125	11.1	20.6		38
1.130	11.5	21.4		43
1.135	11.9	22.1		49
1.140	12.3	22.9		55
1.145	12.7	23.7		61
1.150	13.1	24.4		67
		Expanded Scale		
1.175	15.2	28.3		98
1.200	17.3	32.1		130
1.225	19.4	36.0		163
1.250	21.4	39.8		198

[1]The recommended use level for Fire-Trol 931 is 4 parts water to 1 part concentrate (by volume). An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent P_2O_5 equivalent = 82.80 specific gravity - 82.09.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

EQUIPMENT

THE FOLLOWING EQUIPMENT RECOMMENDED FOR USE IN FIELD PROCEDURES[10]

1. *Procedure for unthickened or thin, gum-thickened retardants*

Pyro (TVA 11-37-0), Fire-Trol 930 and 934, and Phos-Chek 259

A. Quart jar or plastic bottle (S-8416, 32-ounce; 50 cents each).

B. Hydrometer[11] (S-41885G 1.060 to 1.130 by 0.001 divisions; $3.75 each).

2. *Procedure for viscous, gum-thickened retardants*

Phos-Chek 202 and 202XA

A. Quart jar or plastic bottle (S-8416, 32-ounce; 50 cents each).

B. Measuring teaspoon (obtained from hardware store).

C. Hydrometer[11] (S-41885G 1.060 to 1.130 by 0.001 divisions; $3.75 each).

D. Phos-Chek® Breaker, a cellulase compound, can be obtained at no cost from the Northern Forest Fire Laboratory, Drawer G, Missoula, Montana 59801; or the Monsanto Company, 810 East Main Street, Ontario, California 91761.

3. *Procedure for clay-thickened products*

Fire-Trol 100 and 931

A. Funnel (S-35433F, 8-inch diameter, short stem; $2.75 each).

B. Filter paper (S-32915L No. 500, 40-cm. diameter; $3.62 per package of 100).

C. Test tube (S-79540W 32 by 200 mm.; 48 cents each).

D. Hydrometer[11] (S-41855G 1.060 to 1.130 by 0.001 divisions; $3.75 each).

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[10]The equipment used to prepare the tables was obtained from Sargent-Welch, 4040 Dahlia, Denver, Colorado 80207, telephone 303-399-8220. The numbers refer to Sargent Catalog 115 numbers. Field use of similar equipment would help insure reliable results.

[11]For specific gravity measurements outside the normal range 1.060 to 1.130, an appropriate hydrometer may be obtained ($3.75 each):

S-41885F 1.000 to 1.070 by 0.001 divisions
S-41885H 1.120 to 1.190 by 0.001 divisions
S-418851 1.180 to 1.250 by 0.001 divisions

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
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THE PYROLYTIC EFFECT OF TREATING COTTONWOOD WITH PLANT ASH[1]

Charles W. Philpot[2]

ABSTRACT

Cottonwood and cottonwood cellulose were treated with plant ash produced by ignition. The treatments caused changes in thermal behavior and pyrolysis products. However, the effect was not as pronounced as that resulting from naturally contained levels of minerals. This may mean that isolation of minerals by ignition produces changes which render the treatment less effective.

Recent research on the pyrolysis of cellulose contaminated with inorganic compounds has led to speculation that the flammability of plant materials could be influenced by their inorganic constituents.[3] [4] Further evidence supporting this possibility was reported by King and Vines who found the burning characteristics of dry, extractive-free leaves to be directly related to their mineral content.[5] The thermal properties of several plant materials determined by differential thermal analysis (DTA) and thermogravimetric analysis (TGA) were found to be correlated with their silica-free mineral content.[6] This suggests a variable to be altered or considered when developing fire resistant plants, rating natural fuels, and assessing the seasonal changes in flammability.

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[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

[2]Research Forester, stationed at Northern Forest Fire Laboratory, Missoula, Montana.

[3]A. Broido and M. Nelson. Ash content: its effects on combustion of corn plants. Sci. 146: 3644, 3652-3653. 1964.

[4]Y. Waisel and J. Friedman. The use of tamarisk trees for the restriction of fires. La-Yaaran 15(3): 77-82 (Hebrew); 84-88 (English). 1965.

[5]N. King and R. Vines. Variation in the flammability of the leaves of some Australian forest species. Div. Appl. Chem., CSIRO, Australia, 14 p. 1969.

[6]C. Philpot. Influence of mineral content on the pyrolysis of plant materials. Forest Sci. 16(4): 461-471, illus. 1970.

Since the majority of past work has dealt with natural fuels of varying mineral contents, we tried the inverse experiment by using artificially applied minerals. The resulting report presents some preliminary results from the pyrolysis of cottonwood *(Populus trichocarpa)* and cottonwood cellulose. Cottonwood samples were treated with 5 percent by weight of cottonwood ash and also with 5 percent by weight ponderosa pine *(Pinus ponderosa)* ash. Cottonwood cellulose samples were also given these two treatments. This initial work was done in conjunction with a larger study previously reported.[7] A complete description of the equipment, techniques, and methods was presented at that time.

EXPERIMENTAL PROCEDURES

Samples of cottonwood and cellulose isolated from cottonwood were given the two treatments of 5 percent cottonwood ash (CWA) and 5 percent ponderosa pine ash (PPA) by weight. The ash was obtained from cottonwood wood and ponderosa pine needles, using standard ignition methods at 600° C.[8] The ponderosa pine needle ash was used for convenience. A partial elemental analysis of both ashes and the amount of each element added by a 5 percent treatment is shown in table 1. The treated samples were analyzed by thermal analysis and pyrolysis gas chromatography. The untreated cottonwood cellulose contained <0.1 percent mineral content.

Differential thermal analysis (DTA) was performed by using 10 mg. of sample on a DuPont Model 700-750 thermal analyzer. The heating rate was 15°/minute and the atmosphere was nitrogen flushing at 100 cc./minute. Thermogravimetric analysis (TGA) was run on 10 mg. of sample at the same heating rate and atmospheric conditions. The pyrolysis temperature for gas analysis was 600° C. A Hewlett-Packard FM Model 5750 chromatograph was used with dual 14-foot stainless steel columns packed with 10 percent carbowax M on Fluropak 80. Standard identification procedures of each product were performed as previously reported.[9] The char is the residue remaining after 20 minutes in the pyrolysis chamber that is connected to the chromatograph.

Table 1.--*Partial elemental analysis of plant ash*

Ash type	SiO_2	Element				
		P	K	Ca	Fe	Na
		Percent				
Cottonwood	0.00	3.30	17.57	15.94	0.20	0.16
5 percent cottonwood ash	.00	.16	.88	.79	.01	.00
Ponderosa pine	59.95	1.80	5.68	12.92	.52	.00
5 percent ponderosa pine ash	3.00	.09	.28	.65	.03	.00

[7]C. W. Philpot. The pyrolysis products and thermal characteristics of western cottonwood and its components. USDA Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah (Manuscript in preparation.)

[8]American Society for Testing and Materials. Method of test of ash in wood. D1102-56, Philadelphia, Pa. 1956.

[9]See footnote 7.

RESULTS

Preliminary results show a definite effect of the two kinds of ashes on the pyrolytic behavior of cottonwood and cottonwood cellulose. Figure 1 shows the DTA of cellulose resulting from the two ash treatments. Although both ashes lowered the initiation temperature of the cellulose and decreased the intensity of the endotherm, the most effective ash seems to be cottonwood. The initiation temperature is the temperature where pyrolysis begins. Figure 2 shows the TGA of cellulose with both treatments. The pyrolysis rate was decreased and the char increased by both treatments with cottonwood ash being the most effective.

Some of the pyrolysis products from cottonwood and its treatments are shown in table 2. Generally there was a slight increase in water and CO_2 products from the treated samples and the char also increased. There was also an increase in fixed gases; a decrease in acrolein, acetic acid, and acetaldehyde was apparent.

Some of the products from cottonwood cellulose and its treatments are listed in table 3. Fixed gases, CO_2, H_2O, char, 1-hydroxy-2-propanone, acetic acid, and 2-furaldehyde all increased. There was a decrease in furan and 2,3-butanedione.

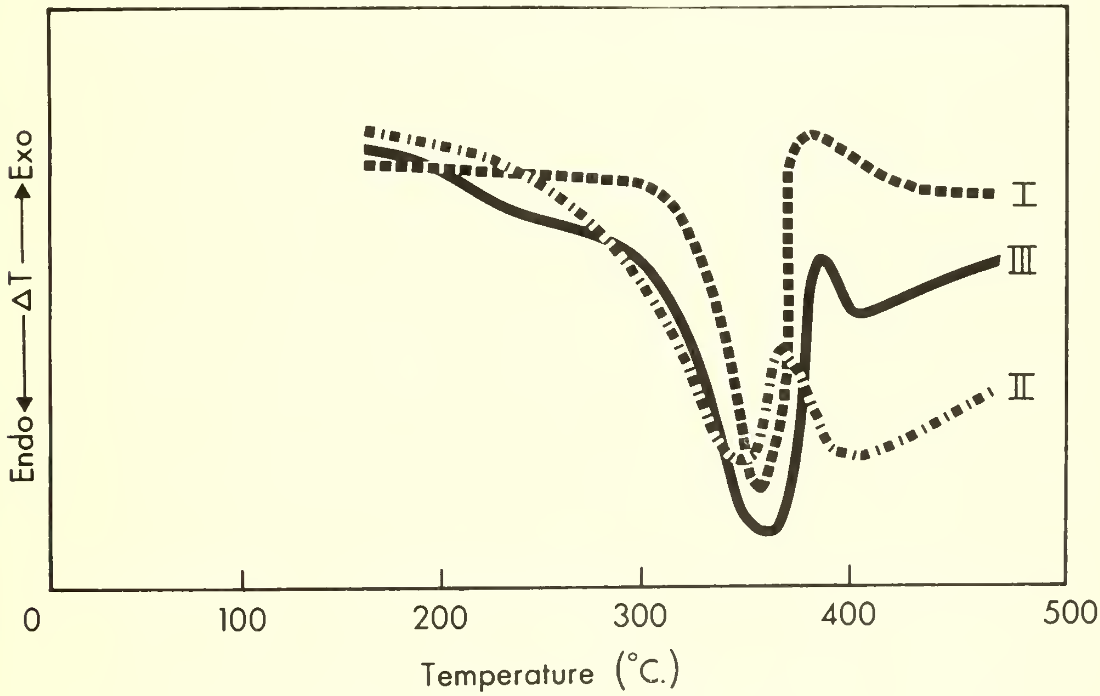

Figure 1.--Differential thermal analysis of cottonwood cellulose (I); cottonwood cellulose plus 5 percent cottonwood ash (II); and cottonwood cellulose plus 5 percent ponderosa pine ash (III).

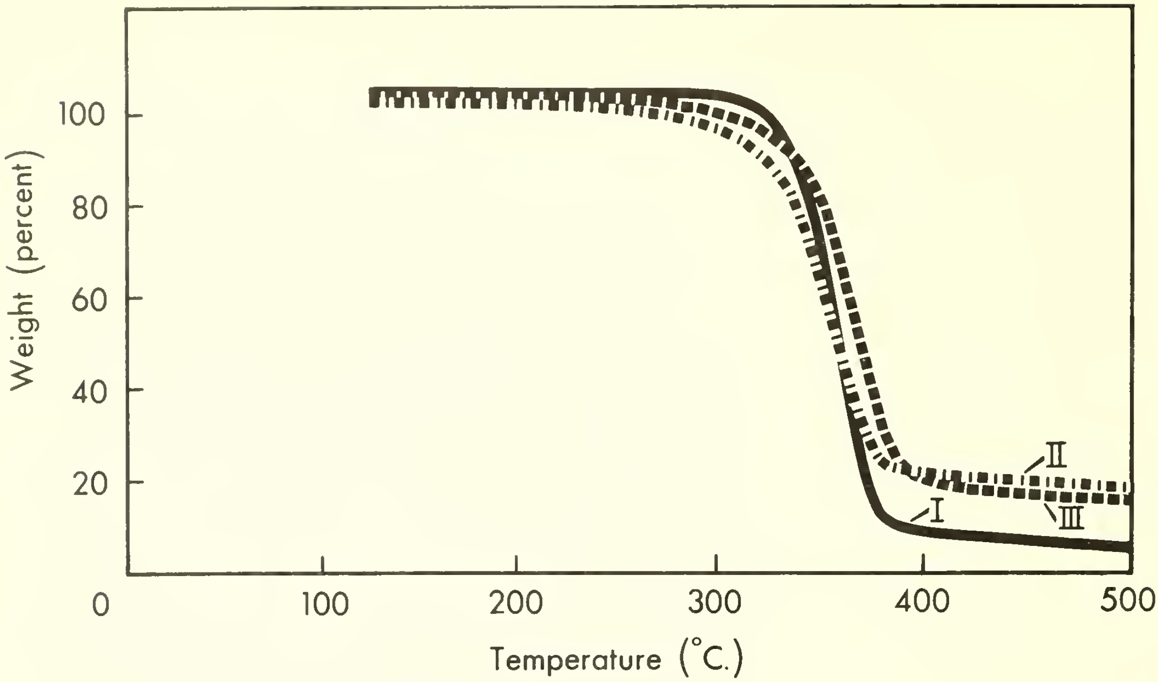

Figure 2.--Thermogravimetric analysis of cottonwood cellulose (I); cottonwood cellulose plus 5 percent cottonwood ash (II); and cottonwood cellulose plus 5 percent ponderosa pine ash (III).

Table 2.--*Some pyrolysis products from untreated cottonwood and cottonwood treated with 5 percent ponderosa pine ash (PPA) and 5 percent cottonwood ash (CWA)*

Product	Cottonwood		
	Untreated	PPA	CWA
	Counts/mg.		
Fixed gases	21,900	23,400	23,500
	Percent (dry weight)		
Acetaldehyde	2.3	1.6	1.7
Furan	1.6	1.0	1.7
Acrolein	3.2	1.4	1.1
2,3-Butanedione	2.0	1.3	1.2
1-hydroxy-2-propanone	2.1	2.7	2.3
Glyoxal	2.2	2.1	2.9
Acetic acid	6.7	5.2	4.6
2-Furaldehyde	1.1	1.8	1.1
CO_2	12.0	13.0	14.0
H_2O	18.0	19.0	19.0
Char	15.0	19.0	19.0

Table 3.--*The volatile products and char from untreated cottonwood cellulose and cottonwood cellulose treated with 5 percent ponderosa pine ash (PPA) and 5 percent cottonwood ash (CWA)*

Product	Cellulose		
	Untreated	PPA	CWA
	Counts/mg.		
Fixed gases	12,900	17,000	18,600
	Percent (dry weight)		
Acetaldehyde	1.3	1.1	1.5
Furan	1.4	.7	.6
Acrolein	1.5	1.4	1.0
2,3-Butanedione	1.4	.6	.6
1-Hydroxy-2-propanone	1.9	2.7	3.2
Glyoxal	2.0	2.0	3.1
Acetic acid	.8	2.0	2.8
2-Duraldehyde	.9	1.7	2.0
CO_2	6.0	9.0	11.0
H_2O	11.0	15.0	15.0
Char	5.0	13.0	13.0

CONCLUSIONS

Ash from cottonwood and ponderosa pine needles changed the pyrolysis characteristics of cottonwood and also changed the products obtained from cottonwood and cottonwood cellulose. The thermal analysis of treated cellulose showed typical changes due to contamination; cottonwood ash was most effective. The effects of treatments were not as pronounced as was observed for equal levels of naturally-held plant inorganics.[10] Although the treatments produced changes in pyrolysis products, they are generally not too pronounced. It is also interesting that such changes did not seem to correspond to those previously produced by acid or alkali model contaminants.[11]

The major problem of this study was probably the method of isolating the inorganics. Drastic changes may have occurred that rendered the treatment less effective than natural contaminants. Before this work is continued, the forms in which minerals exist in plant tissue must be considered. This will enable the treatments to more closely represent natural plant inorganics.

[10] See footnote 6.

[11] See footnote 7.

Research Note

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BARK RESIDUES IN WESTERN MONTANA

David P. Lowery, John P. Krier, and John R. Host[1]

The manufacturing industries of western Montana[2] are based primarily on natural resources; the forest industry is the area's largest employer. Although the utilization practices of the wood industries have steadily improved, one portion of the tree remains for which no economically satisfactory use has been developed, the bark.

At the present time, most of the residues from primary manufacture, such as slabs, edgings, trim ends, veneer log roundup, and clipper trim material, are chipped and used in the manufacture of pulp and paper. Sawdust, planer shavings, and bark are usually burned, often as boiler fuel. Bark is the single component of the residue fuel portion that is economically unsuitable for any other large-scale use.

One of the factors confounding the development of a profitable bark-utilization process is the area's mixture of timber species. Ponderosa pine, Douglas-fir, and western larch are the principal species used; however, Engelmann spruce, white fir, hemlock, lodgepole pine, western white pine, and western redcedar are also harvested in lesser quantities. The mixture of bark from these species precludes the development of a bark-utilization process based on a single species, as is done in some other parts of the country.

Essentially, the bark-utilization problem of western Montana is the need for a method or process whereby the vast quantities of bark generated can be used economically or further processed locally. Ideally, the process should utilize bark from all species indiscriminately and the final product should have a value sufficient to repay manufacturing and transportation costs at least. A prerequisite to bark utilization is a reasonably accurate estimate of the material available and its location. The objective of this paper is to provide this information.

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[2]As used in this paper, western Montana denotes that portion of the State west of the Continental Divide.

AVAILABLE BARK RESIDUE

Within the last 15 years the timber processing industry of western Montana has become more diversified and complex. In earlier years, lumber, millwork items, poles, mine timbers, and railroad ties were the only items produced. Today, the area has a pulp and paper mill, a particle-board and six plywood plants, in addition to two large-, 11 medium-, and 21 small-sized sawmills.[3]

The 1969 estimate of processed production in western Montana includes: 300 thousand tons of pulp and paper; 457 million square feet of plywood (3/8-inch basis); and 1,206 million board feet of lumber.[4]

The pulp and paper mill west of Missoula is dependent upon chips and sawdust produced by other segments of the industry. This mill also utilizes hogged (ground up) waste containing 30 to 35 percent bark for boiler fuel. A particle-board plant has recently been constructed near Missoula. This plant will have an initial production of 300 tons per day and will use sawdust and planer shavings generated within a 100-mile radius. Therefore, the principal sources of bark and the bark disposal problems are and will continue to be centered at the plywood and sawmilling operations.

Bark yield per log varies considerably depending on its position in the tree, growth rate, log size, and species. For this reason, estimates of bark yield based on data derived from logs in other areas of the country may not be appropriate to western Montana. Krier and River[5] have developed a procedure for estimating bark yield at Missoula sawmills. Using this procedure, they estimated total annual bark production in the Missoula vicinity to be about 97,154 tons (based on a sawmill production of 268 million board feet), or 725 pounds of ovendry bark per 1,000 board feet log scale.

Assuming that this value can be applied throughout western Montana, the total annual ovendry bark tonnage produced by sawmills from 1965 through 1969 has varied from about 345,535 to 460,194 tons. Approximately 400 board feet of logs are required to produce 1,000 square feet of plywood (3/8-inch basis). With the inclusion of the bark produced at plywood operations, the annual bark tonnage produced over the same period varied from 426,127 to 550,594 tons. Calculated another way, using a conversion factor of 22 cubic feet of bark per thousand board feet log scale, the volume generated varied annually from about 24,750,000 to 31,906,600 cubic feet of bark. A recent survey of sawmills in western Montana indicates that in 1969 about 30 percent of the available bark supply was used for fuel and the residual 70 percent was disposed of as waste. The volume of bark material available for use (even after discounting the total volume by 30 percent) is still quite sizable.

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[3]For purposes of this report, sawmills are classified individually by production, regardless of ownership. Large mills have an annual production in excess of 100 million board feet; medium-sized mills, from 30 to 100 million board feet; and small mills, from 5 to 30 million board feet.

[4]Source, the trade journals, *Pulp and Paper* and *Timber Industries*. Bureau of Census figures are not available.

[5]John P. Krier and Bryan H. River. Bark residues: a model study for quantitative determination. Proc. 22nd Annual Northwest Wood Products Clinic. Spokane, Washington. 1967.

[6]Obtained from primary wood products and plant residue survey data of 1970, collected by the Forest Survey research work unit, Ogden, Utah. These data are being compiled for future publication.

DISTRIBUTION OF BARK RESIDUE

Because of the relatively high cost of transporting bark long distances, the western Montana region has been divided into four areas, each of which has a 50-mile radius (fig. 1). Although the areas of this figure overlap somewhat, the transportation systems of the region hinder the movement of bark residue between circles. If a suitable bark-utilization method were developed, the bark obtained from the smaller mills might be processed at a centrally located plant.

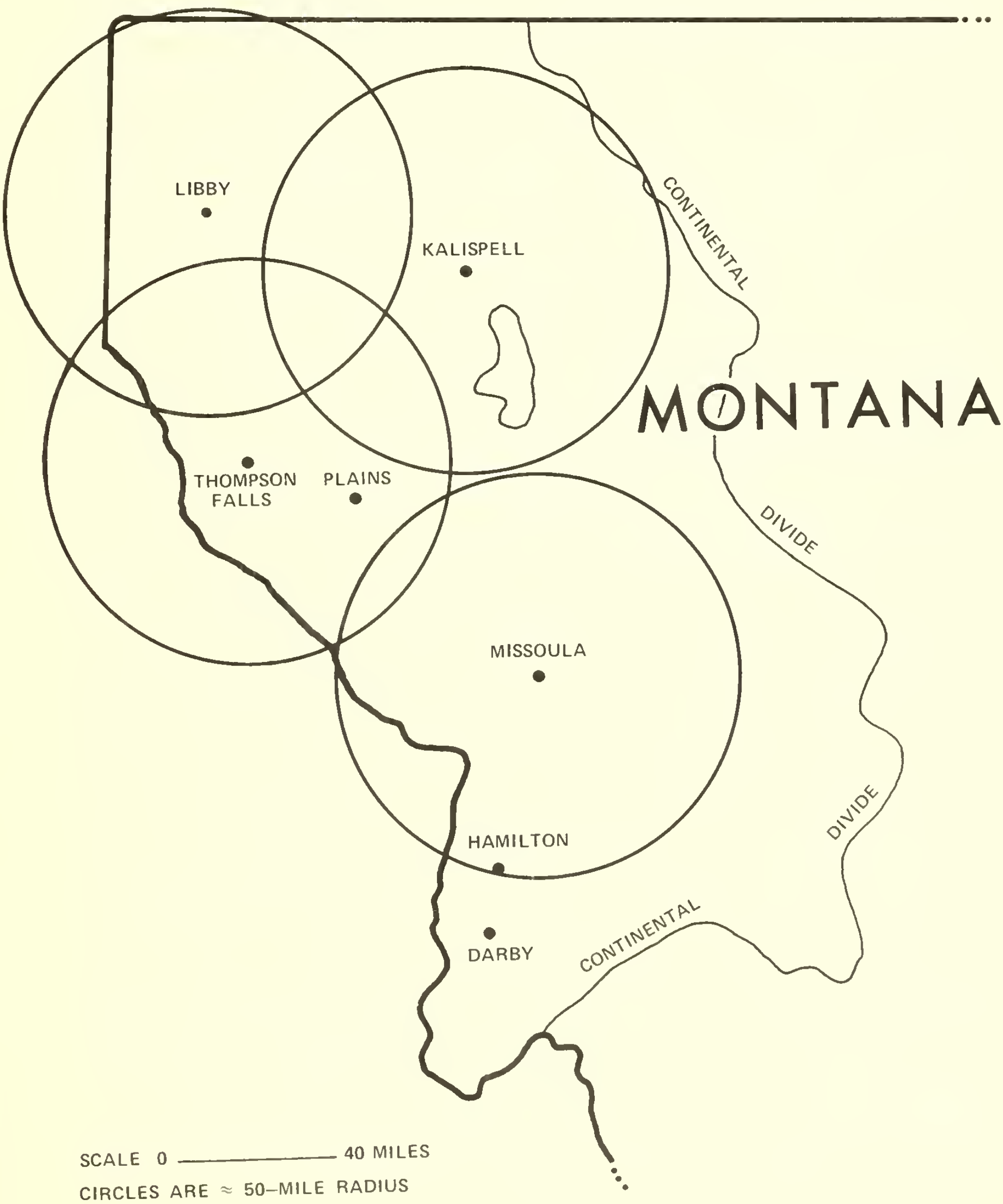

Figure 1.--Bark production circles with a 50-mile radius in western Montana.

The first area is centered at Missoula and contains one plywood plant and 15 sawmills, which together produce approximately 200,000 tons of bark per year. The second area, centered at Thompson Falls, produces about 40,000 tons per year. The third and fourth areas are centered at Kalispell and Libby, respectively. The Kalispell area contains four plywood plants and 14 sawmills and the annual bark production has exceede 170,000 tons. The Libby area produces about 90,000 tons of bark annually. Estimates of the bark production for each area for the past 5 years are shown in table 1.

Table 1.--*Estimates*[1] *of the ovendry bark produced at plywood and sawmill operations in each of four circular areas for the years 1965 through 1969*

Circle	Number of plywood plants	Number of sawmills[2]	Estimate of tons of bark produced				
			1965	1966	1967	1968	1969
Missoula	1	15	187,702	193,792	188,355	210,902	202,311
Thompson Falls	0	4	34,256	39,114	38,389	41,107	42,521
Kalispell	4	14	142,028	167,693	171,934	180,271	173,306
Libby	1	2	48,974	81,055	87,580	93,453	85,296
Total	6	35	412,960	481,654	486,258	525,733	503,434

[1]Estimates are based on the factor of 725 pounds of bark per thousand board feet of lumber.

[2]Sawmills producing more than 5 million board feet annually.

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
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A QUICK REFERENCE FOR COMPARING RAIL FREIGHT COSTS OF SOFTWOOD LUMBER ITEMS

John R. Host[1]

ABSTRACT

Summarizes freight costs for a typical softwood lumber item (2 by 4 dimension) between 12 principal lumber production areas and 8 major markets. The purpose is to demonstrate a method for making a general comparison of freight costs of such lumber items without going through the tedious task of computing freight costs. The method can be used by those who may need to develop more detailed freight costs on specific items.

Transportation costs comprise a substantial portion of the delivered price for lumber products and can account for as much as 45 percent of the total price for some grades. As a result, freight charges can play an important role in the marketing program of individual producers, in that they can influence the type of products that can be produced and where such products can be sold profitably.

This study converts freight per hundredweight to costs per thousand board feet (MBF) and compares such costs between 8 major market areas and 12 western, southwestern, and southern production areas (fig. 1). The steps used in estimating freight costs per MBF of lumber are as follows:

1. *Determine freight rates for each combination of production area market points being considered.* Rates are established by railroads, approved by the Interstate Commerce Commission, and published in various tariff books by freight bureaus.

The rates for the production area/market points used in our study are shown in table 1. Note that all western shipping points have the same rate to Detroit. This rate applies to all points in the northeastern United States called the "Blanket Territory"--for western lumber shippers.

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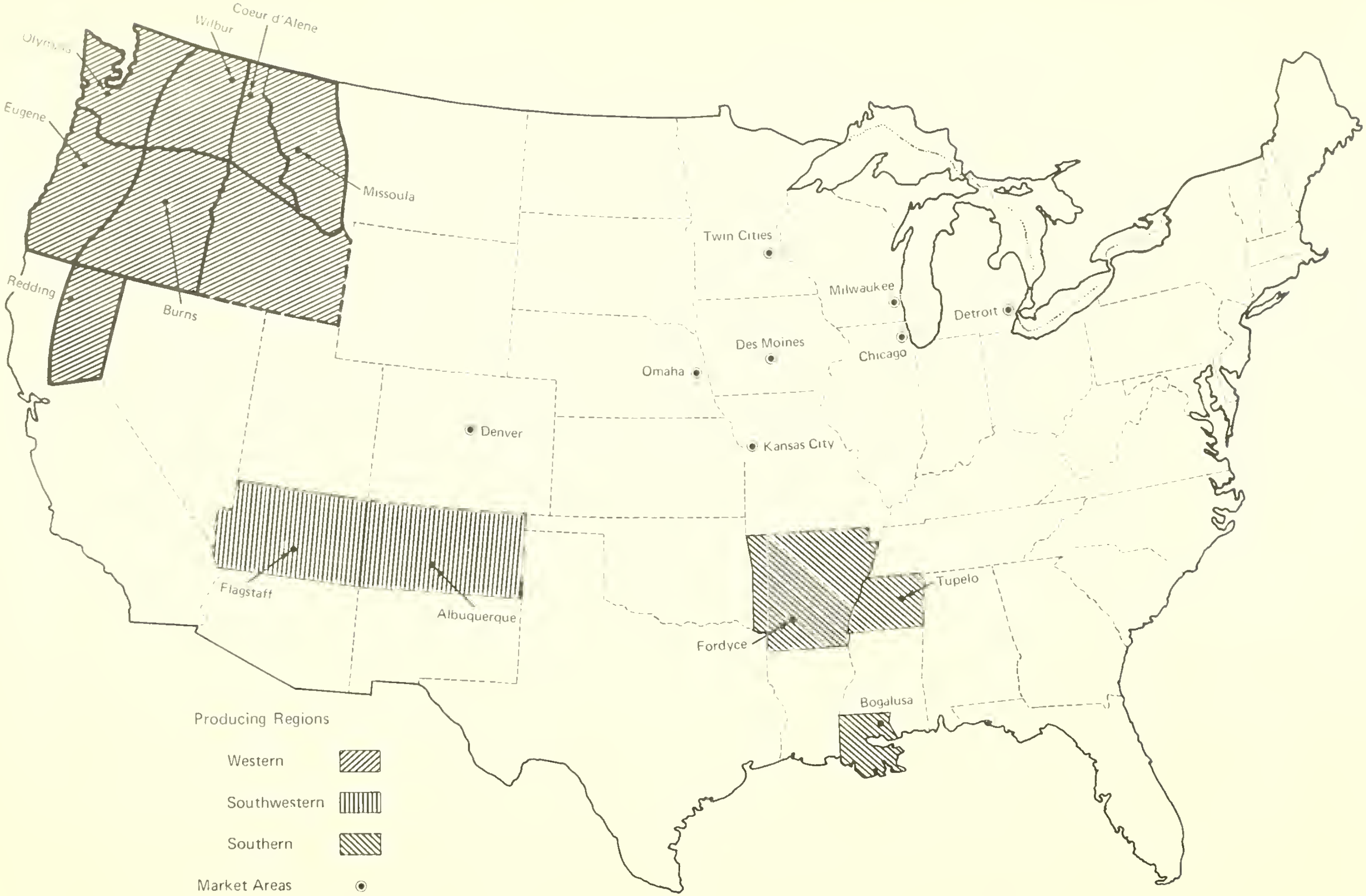

Figure 1.--Principal lumber production areas and shipping destination cities for major markets used in this study.

Table 1.--*Railroad tariff rates between shipping points in 12 production areas and 8 major market areas, January 1, 1971* [1] [2]

Shipping points	Chicago, Illinois	Denver, Colorado	Des Moines, Iowa	Detroit, Michigan	Kansas City, Missouri	Milwaukee, Wisconsin	Minneapolis-St. Paul, Minnesota	Omaha, Nebraska
	Cents per hundredweight							
WESTERN AREAS								
Olympia, Washington	172	133	166	180	152	172	152	152
Wilbur, Washington	169	120	161	180	149	169	149	149
Eugene, Oregon	172	133	166	180	152	172	152	152
Burns, Oregon	168	119	160	180	146	168	146	146
Coeur d'Alene, Idaho	168	119	160	180	146	168	146	146
Missoula, Montana	164	113	156	180	143	164	143	143
Redding, California	169	133	161	180	149	169	149	149
SOUTHERN AND SOUTHWESTERN AREAS								
Albuquerque, N. Mexico	113	91	112	142	92	141	116	101
Flagstaff, Arizona	124	114	120	154	110	154	126	117
Fordyce, Arkansas[3]	69	94	75	82	63	75	89	74
Bogalusa, Louisiana[3]	80	117	89	93	77	86	105	92
Tupelo, Mississippi[3]	63	101	70	74	64	68	85	75

[1]Rates can vary by 1 or 2 cents from these because of routing differencess.
[2]Rates shown are incentive rates; this means that railcars are loaded to full capacity or some minimum weight.
[3]Rates are based upon 60,000 pounds net weight per car.

Table 2.--*Estimated rail shipping weights per MBF for selected lumber items*[1]

Items	Thickness	Nominal width (Inches) 4, 6	8	10, 12
	Inches			
DIMENSION:				
Douglas-fir, hemlock, and Douglas-fir/larch (kiln dry)	1-5/8	2,200	2,250	2,300
	1-1/2	2,000	2,050	2,100
Douglas-fir (green)	1-5/8	2,800	2,850	2,900
White fir, spruce, and ponderosa pine (kiln dry)	1-5/8	2,000	2,000	2,000
	1-1/2	1,600	1,600	1,600
Southern pine (kiln dry)	1-1/2	2,300	2,300	2,300
BOARD (common, select & shop):			All widths	
Ponderosa pine, Idaho white pine	4/4 (1 inch)		1,900	
Sugar pine, spruce (kiln dry)	5/4 and 6/4		2,200	
Western redcedar	4/4		1,600	
	5/4 and 6/4		2,000	

[1]Except for $1\frac{1}{2}$-inch dimension these are based on Western Wood Products Association and Southern Pine Association weights.

2. *Determine the weight per MBF of the lumber item being considered.* Wood producer associations publish the estimated shipping weights per MBF for lumber according to sizes, species, and finish pattern. The estimated weights for selected lumber items are shown in table 2. Note that weights per MBF vary considerably by thickness and width.

3. *Convert freight rates per hundredweight to estimated costs per MBF.* To do this, multiply the appropriate rates and weights for the production area/market points and lumber item being considered. Freight costs for nominal 2 by 4 inch dimension, $1\frac{1}{2}$-inch bases are summarized in table 3. Two typical species for each production area are shown, except for production areas in the South.

A graphic comparison of some typical freight costs extracted in table 3 is shown in figure 2. This shows, for example, that west coast Douglas-fir from Olympia or Eugene has only a slightly higher freight cost than Douglas-fir/larch from Missoula ($3 to $4 difference to all points except Denver and Detroit). But spruce from Missoula has a substantially lower freight cost because of its lighter weight. Similarly, Tupelo enjoys the lowest rates per hundredweight to Midwest markets (refer to table 1), but Albuquerque has competitive freight costs per MBF to several points because of weight differences between southern pine and ponderosa pine or Engelmann spruce.

This method provides a quick reference for making general comparisons of freight costs for typical lumber items and principal production area/market points. The method shown can also be used to derive other freight costs from table 1 (freight rates) and table 2 (shipping weights).

The reader should bear in mind the following:

1. Freight rates change periodically (there have been seven increases in the past 4 years) and these changes may alter relationships to some extent. Our data is based on January 1, 1971, rates.

2. Rates shown are incentive rates, which means the railcars are loaded to full visible capacity or some minimum weight. Railcars not so loaded have somewhat higher rates.

3. This report deals only with rail freight costs because most western lumber is moved by rail. Truck rates are generally higher except for hauls under 200 miles. However, comparison with truck rates may be desirable in some cases--some customers might not have rail sidings at the mill or yard; customers might demand truck shipments because of lower unloading costs; customers might order smaller shipments than a railcar would carry economically; or delivery time might be shorter for truck shipments.

4. Weights per MBF and resulting freight costs used in this method are based on what various wood producing associations estimate as typical or average weights. Overweights or underweights (variations from estimated weights) might occur because of variations in moisture content, wood density, or other factors. These overweights or underweights should be taken into account in any precise analysis of freight costs.

5. Milling in transit rates might vary from those shown here. Railroads offer "in transit" rates; these permit a shipper to ship material from point A to point B for processing, and then send it on to point C (the market). When this is done, the freight costs incurred are lower than they would be for two shipments--from points A to B, and from points B to C.

6. The comparison presented here is based on only a small number of possible production area/market point combinations; for other combinations, freight rates that apply to specific situations must be determined. For example, figure 3 shows only some of the several hundred freight rates that apply for shipments from western Montana to markets throughout the United States.

Table 3.--*Freight costs for 2 by 4 dimension lumber (1 -inch basis) selected species*

Shipping points	Species	Chicago, Illinois	Denver, Colorado	Des Moines, Iowa	Detroit Michigan	Kansas City Missouri	Milwaukee, Wisconsin	Minneapolis-St. Paul, Minnesota	Omaha, Nebraska
		-Dollars per MBF-							
Olympia	Douglas-fir	34.40	26.60	33.20	36.00	30.40	34.40	30.40	30.40
	Hemlock	34.40	26.60	33.20	36.00	30.40	34.40	30.40	30.40
Wilbur	Douglas-fir/ larch	33.80	24.00	32.20	26.00	29.80	33.80	29.80	29.80
	Ponderosa pine	27.04	19.20	25.76	28.80	23.84	27.04	23.84	23.84
Eugene	Douglas-fir	34.40	26.60	33.20	36.00	30.40	34.40	30.40	30.40
	White fir	27.52	21.28	26.56	28.80	24.32	27.52	24.32	24.32
Burns	Douglas-fir	33.60	23.80	32.00	36.00	29.20	33.60	29.20	29.20
	Ponderosa pine	26.88	19.04	25.60	28.80	23.36	26.88	23.36	23.36
Coeur d'Alene	Douglas-fir/ larch	33.60	23.80	32.00	36.00	29.30	33.60	29.20	29.20
	White fir	26.88	19.04	25.60	28.80	23.36	26.88	23.36	23.36
Missoula	Douglas-fir/ larch	32.86	22.60	31.20	36.00	28.60	32.80	28.60	28.60
	Engelmann spruce	26.24	18.08	24.96	28.80	22.88	26.24	22.88	22.88
Redding	Douglas-fir	33.80	26.60	32.20	36.00	29.80	33.80	29.80	29.80
	Ponderosa pine	27.04	21.28	25.76	28.80	23.84	27.04	23.84	23.84
Albuquerque	Ponderosa pine	18.08	14.56	17.92	22.72	14.72	22.56	18.56	16.16
	Engelmann spruce	18.08	14.56	17.92	22.72	14.72	22.56	18.56	16.16
Flagstaff	Douglas-fir	24.80	22.80	24.00	30.80	22.00	30.80	25.20	23.40
	Ponderosa pine	19.84	18.24	19.20	24.64	17.60	24.64	20.16	18.72
Fordyce	Southern yellow pine	15.87	21.62	17.25	18.86	14.49	17.25	20.47	17.02
Bogalusa	Southern yellow pine	18.40	26.91	20.47	21.39	17.71	19.78	24.15	21.16
Tupelo	Southern yellow pine	14.49	23.23	16.10	17.02	11.72	15.64	19.55	17.25

Figure 2.--Comparison of freight costs per MBF for 2 by 4 lumber for various selected species and production points.

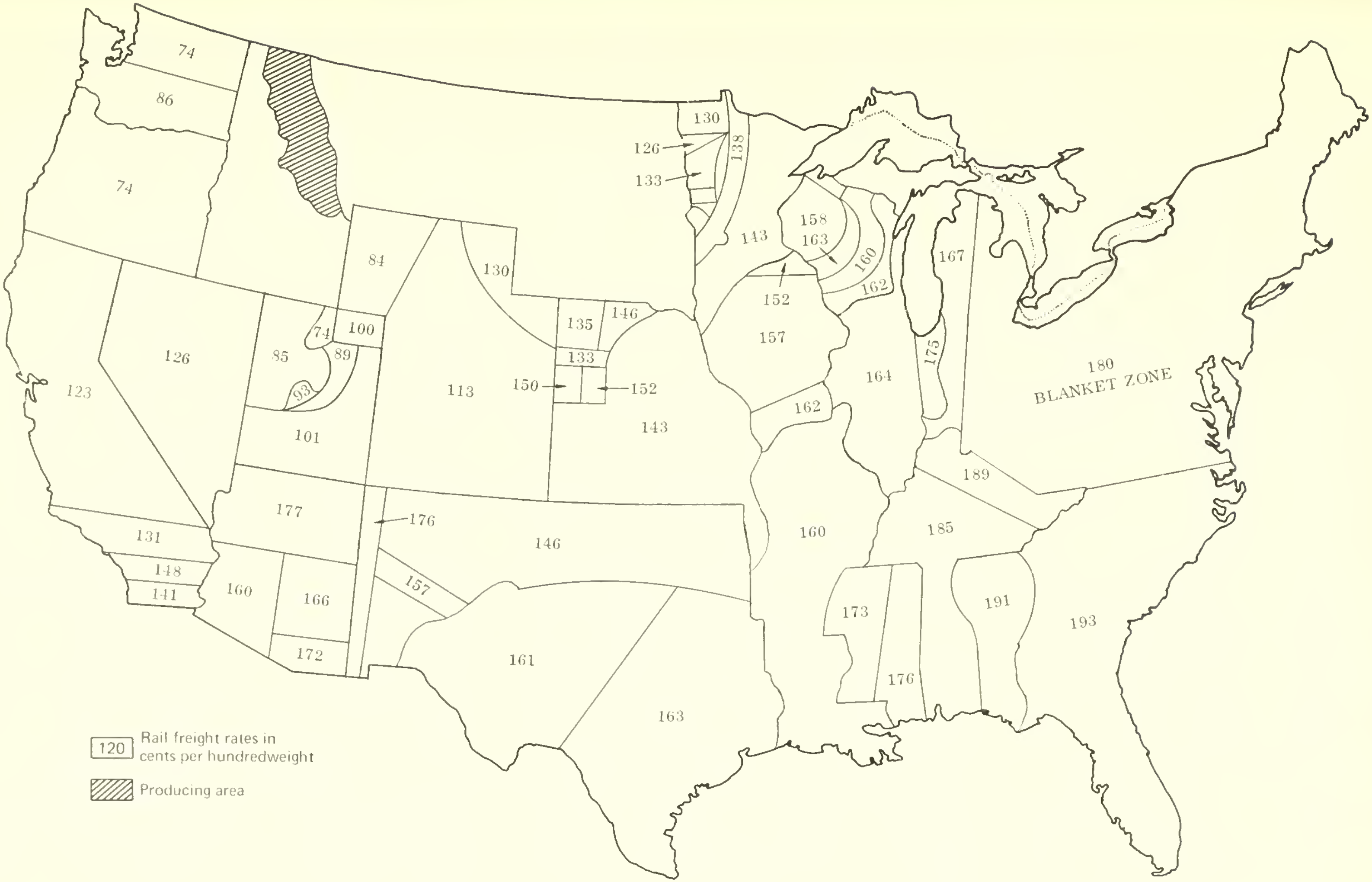

Figure 3.--Freight rates from lumber production areas in western Montana to markets throughout the United States.

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CONSTRUCTION AND OPERATION OF A COMPACT FINE-WIRE PSYCHROMETER

Ray W. Brown and Marie Lynn H. Caldwell[1]

ABSTRACT

The construction and use of a fine-wire, unaspirated thermocouple-psychrometer capable of sensing rapid fluctuations in air temperature and relative humidity within plant canopies is discussed. Maximum depression of the wet sensor is achieved at windspeeds greater than 36 cm. sec.$^{-1}$ (0.8 m.p.h.). Under still-air conditions (0 cm. sec.$^{-1}$), estimates of relative humidity exceeded true values by 1 to 4 percent relative humidity. The use of a radiation shield was found necessary to reduce errors due to radiative heating of the sensors. A convenient means of periodically cleaning the wet-sensor wick is discussed.

Precise determinations of atmospheric humidity in the immediate microenvironment of a plant may be complicated and ill-defined by the instrument used. Standard humidity-sensing instruments, such as the hair-hygrometer or the somewhat more compact aspirated mercury-in-glass thermometer- and thermistor-psychrometers, have large sensors and bulky dimensions that grossly influence the microenvironment. These instruments only sample the average humidity in several air layers and have rather slow response times to fluctuating humidity conditions. Also, the artificially aspirated psychrometers seriously disturb the air layer in which the desired measurements are being made.

The instrument discussed in this paper was originally designed and built as part of a larger study of the physiological responses of plants to changes in the immediate microenvironment. This instrument is a small, compact, unaspirated thermocouple psychrometer capable of sensing rapid fluctuations of humidity within the canopy of growing plants. Originally, this instrument was designed to measure the humidity in the air layers near plant surfaces to facilitate estimates of the vapor pressure gradient between the plant and the surrounding air mass.

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A large number of unaspirated thermoelectric-psychrometers have been developed to measure atmospheric humidity with a minimum of disturbance to the microenvironment (Bellaire and Anderson 1951, Swinbank 1951, Raschke 1954, Berger-Landefeldt 1955, McIlroy 1955, Long 1957, and Caldwell and Caldwell 1970). Typically, these instruments basically consist of two small thermocouple or thermistor elements; one of these is dry and senses the air temperature, the other is kept moist with water and senses the "wet bulb" temperature. In most cases, these instruments can provide continuous measurements of humidity that can either be read instantaneously or recorded at some distance from the sensors.

The principal difficulty encountered in using unaspirated psychrometric instruments is the need for providing an optimum quantity of water to the wet element while allowing for maximum evaporative cooling of the sensor. In addition, the evaporation process and the resultant cooling of the air immediately adjacent to the wet element must not influence the response of the dry element. During measurements, it is assumed: that a steady state of relative humidity exists, that the heat required to vaporize water from the wet element is supplied by the air flowing over the sensor, and that the rate of evaporation is a function of the vapor pressure gradient between the sensor and the air. Therefore, for an unaspirated wet sensor to achieve maximum cooling for any given vapor pressure deficit, convective heat transfer must be sufficient to maintain the vapor pressure gradient, hence, maximum evaporation. These criteria can be met by using sufficiently small sensing elements wherein convective heat loss increases with a decrease in element size. A second advantage of very small elements is that the error due to absorption of shortwave radiation decreases with a reduction in size. The theoretical aspects of sensor size and convective transfer of heat, together with design criteria, are discussed in greater detail by Platt and Griffiths (1964) and Powell (1936)

METHODS

The compact thermocouple-psychrometer consists of two copper-constantan thermocouple sensing elements, which are attached directly to a water reservoir constructed of stainless steel tubing (fig. 1). The dry sensor (1) is mounted about 1 cm. above the wet sensor (2). Both sensors are constructed of 0.0076-cm. (0.003-inch) diameter copper-constantan wire. The junctions of both sensors were made by twisting the two thermocouple wires, soldering them together by using a high-grade silver solder, then trimming them to a junction length of 0.5 mm. The copper and constantan wires of the two thermocouples were trimmed to a length of 1 cm. Then, each junction was silver-soldered to the ends of 24-gage insulated thermocouple lead wires (3), which extend through a rubber stopper (4) in the end of the stainless steel tube (1 cm. diameter and 20 cm. long) water reservoir (5).

The wet junction is kept moist by means of a three-strand cotton thread wick (6) that extends from the water reservoir, through the rubber stopper, along the fine copper wire, over the junction, and to about 1 cm. beyond the junction. These design criteria, first discussed by Powell (1936), may be used to minimize the conduction of heat to the sensor along highly conductive copper wire. The individual strands of the wick can be separated so that the copper wire and junction can be inserted among them. Then the strands can be twisted together again. Construction of the wick assembly and provision of an optimum rate of water flow are the most critical and difficult aspects to consider in constructing a psychrometer. Trial-and-error adjustments are required to achieve the optimum rate of water flow, particularly as this is influenced by wick length and evaporating conditions of the environment.

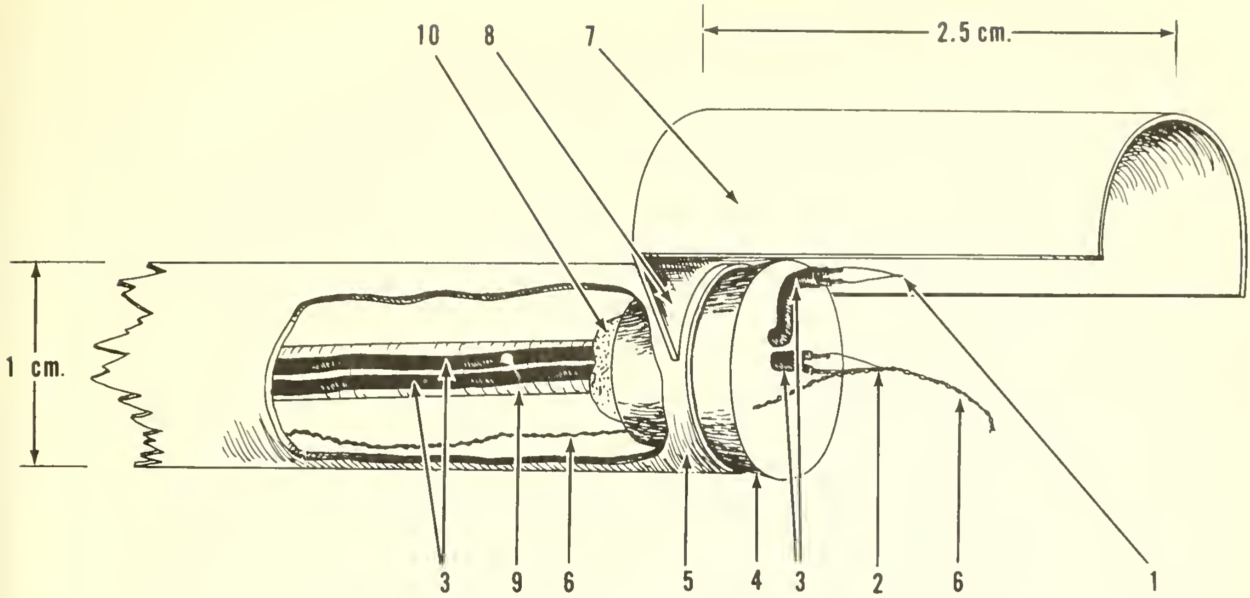

Figure 1.--Schematic of the fine-wire psychrometer showing: (1) dry sensor, (2) wet sensor, (3) insulated 24-gage thermocouple lead wires, (4) rubber stopper, (5) water reservoir, (6) cotton thread wick, (7) radiation shield, (8) radiation shield bracket, (9) plastic tube, (10) epoxy cement.

A radiation shield (7) is used to reduce sensor errors caused by direct incident solar radiation. The shield is constructed of polished, lightweight stainless steel (2.5 $cm.^2$) bent to form an arc with a 2 cm. diameter. The shield is soldered to a bracket 0.5 cm. high (8), which is also soldered to the stainless steel tube. It is advisable to place the sensing junctions below the level of curvature of the shield to avoid interference with natural convection.

The insulated thermocouple lead wires (3) extend through the rubber stopper (4), back into the water reservoir tube, and out the other end. Behind the rubber stopper and within the water reservoir, these lead wires are enclosed in a plastic tube (9) to prevent deterioration and corrosion. The plastic tube is cemented to the rubber stopper with epoxy cement (10). At the opposite end of the water reservoir tube, the lead wires and the plastic tubing extend through the rubber stopper used to seal the end of the reservoir. Water can be added to the reservoir periodically by removing the stopper and injecting water through a hypodermic syringe. The lead wires should extend at least 1 m. beyond the reservoir to prevent disturbances to the environment when measurements are made.

When the psychrometer is not being used or is being moved, the sensor end of the psychrometer is enclosed within a plastic vial to prevent sensor damage and to maintain a clean wick. A No. 6 rubber stopper, that has a hole 1 cm. in diameter through its center, is slipped over the water reservoir tube up to the radiation shield. The vial can then be slipped onto the stopper.

RESULTS AND DISCUSSION

The influence of windspeed on the temperature depression of the wet sensor below that of the dry sensor and the effect of shortwave solar radiation on sensor output were of primary concern. The influence of windspeed on the psychrometer performance was tested under carefully controlled conditions in a growth chamber. A small wind tunnel containing a rheostat-controlled fan was used and airflow rate was measured by a hot wire anemometer (Hastings RB - 1[2] omnidirectional probe). The thermocouple-psychrometer outputs were measured with a temperature potentiometer (Leeds and Northrup Co., No. 8692), and compared with values taken from an Assmann aspirated psychrometer (Wilk Lambrecht Co., Type 761).

The effect of windspeed on the response of the wet sensor under different relative humidities is summarized in table 1. These data show that for the range of environmental conditions studied maximum depression of the wet sensor response is reached at windspeeds greater than 36 cm. sec.$^{-1}$ (0.8 m.p.h.). The only significant errors in depression of the wet sensor response were recorded in still air, a phenomenon rarely observed under field conditions. At a windspeed of 23 cm. sec.$^{-1}$ (about 0.5 m.p.h.), the computed value of relative humidity would be about 1 to 2 percent too high and at 0 cm. sec.$^{-1}$, the value would exceed true relative humidity by 1 to 4 percent. Thus, calculations of vapor pressure gradients from relative humidity data gathered by using this psychrometer in the field or in a growth chamber will be quite accurate.

Table 1.-- *The influence of windspeed on wet sensor temperature depression under different relative humidities. Air temperature was 21° C. Values represent °C. above the Assmann psychrometer response*

Windspeed (cm. sec.$^{-1}$)	Relative humidity (%) 58	40	28
90	0	0	0
45	0	0	0
36	+0.2	+0.2	+0.2
23	+0.4	+0.3	+0.2
0	+0.5	--	+1.2

[2] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

The importance of the radiation shield was illustrated by the effect of direct solar radiation on the sensors. With a radiation load of 1.2 cal. $cm.^{-2}$ $min.^{-1}$(measured by a Star pyranometer) and at a windspeed of 45 cm. $sec.^{-1}$, the unshielded dry sensor output exceeded the ambient air temperature by 1° C.; the unshielded wet sensor was 2° C. above the true wet bulb temperature. Errors of this magnitude under average conditions would lead to high estimates of relative humidity, exceeding the true values by 5 to 10 percent. However, when the sensors are shaded with the stainless steel radiation shield (fig. 1), accurate measurements of temperature and relative humidity can be made. Reflected shortwave radiation (albedo) from plant and soil surfaces does not influence the sensors sufficiently to affect their output. However, albedo from a highly reflective surface, such as snow, may require use of a lower shield as well.

This psychrometer has been used extensively in a controlled-environment growth chamber to measure the relative humidity of the air within the canopies of growing plants (fig. 2). Although only a limited amount of experience has been gained from its use in the field, the psychrometer appears well adapted for this purpose. Psychrometers of this design could easily be used to measure the relative humidity profile above the soil surface by stacking them on a mast at different heights. A dual-channel recording potentiometer, equipped with a temperature compensator, would provide for continuous recordings of both dry and wet sensors. Normally, the water reservoir will maintain adequate moisture for a period of about 2 or 3 days, but the reservoir could be easily enlarged during construction. The wick can be easily cleaned periodically by dipping the entire sensor-end of the psychrometer into boiling water containing a mild detergent and then dipping it in boiling distilled water.

Figure 2.--The fine-wire psychrometer can be used in controlled-environment growth chambers, or in the field, to measure the relative humidity of the air within the canopies of growing plants.

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RAINFALL INTERCEPTION IN A DENSE UTAH ASPEN CLONE

Robert S. Johnston[1]

ABSTRACT

Interception by high-elevation aspen and herbaceous vegetation averaged 10.3 percent of gross summer rainfall, but totaled only 1.43 inches for four summers. Stemflow from aspen averaged 1.4 percent of gross rainfall. Removal of aspen or structural changes in aspen clones would not greatly benefit water yield by reducing rainfall interception losses.

Interception and the redistribution of precipitation by vegetation can be an important part of the water budget and could significantly affect water yield. It can account for reductions to 35 percent in gross precipitation or--as in the case of single, small storms--all precipitation could be intercepted and evaporated back to the atmosphere (Ven Te Chow 1964; Zinke 1967). Interception is influenced by a number of precipitation and vegetation characteristics (i.e., storm size and intensity, form of precipitation, and wind movement, and the species, structure, form, and canopy density of vegetation).

Numerous reports concerning interception have led at least one author (Patric 1966) to conclude that interception studies "...probably outnumber those of any other aspect of hydrology." Despite this, few studies have been made of interception by communities of western aspen, an important vegetation type in the Rocky Mountain and Intermountain regions.

STUDY AREA AND METHODS

This study of rainfall interception by aspen and related herbaceous understory vegetation was conducted on the Davis County Experimental Watershed during the summers of 1962 through 1965. It was part of a seasonal water budget investigation on the Parrish Plots, an intensively studied area at an elevation of 8,400 feet, a short distance below the crest of the Wasatch Range

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near Bountiful, Utah. The study was conducted on a 1/10-acre plot characterized by a stand of scrubby aspen and a lush herbaceous understory. The aspen had a basal area of 100 square feet per acre and an average height of 17 feet. Stem diameters at breast height varied from 1.4 to 4.9 inches and ages ranged from 28 to 46 years. Ground cover was 73 percent vegetation (exclusive of aspen) and 12 percent litter. The remaining area was bare ground.

Annual precipitation there frequently exceeds 50 inches and most of that occurs as snow. Analysis of 22 years of data shows that total summer rainfall is quite variable, ranging from 0.93 inch to 15.38 inches. This rainfall usually occurs as high-intensity, convective storms of short duration.

For this study, interception was considered to be the difference between gross precipitation measured in the open and net precipitation, or throughfall, measured in the trough gages beneath the aspen-herbaceous canopy. Rainfall was measured for each storm during the 1962 through 1965 summer seasons. Eight trough gages, each 66.6 inches long, 1.5 inches wide, and 3 inches deep, were randomly located under the aspen-herbaceous canopy and two gages were placed in an adjacent opening. The gages were placed on ground that had an average slope of 23 percent. A recording intensity gage, located in the opening, was mounted in the customary manner (i.e., the orifice was level).

Stemflow was collected from eight aspen trees on the plot during the 1964 and 1965 seasons. Collars were attached to the trees about 4 feet above the ground. All stemflow was diverted into collecting tanks and measured after each storm. An estimate of average stemflow per unit area was derived by converting the volume of stemflow to inches per projected crown area of the average tree and multiplying this figure by the canopy density. No attempt was made to measure stemflow from the herbaceous vegetation.

RESULTS

Interception was calculated for 33 storms that produced a total of 14.91 inches of rain during the study. Precipitation from individual storms varied from 0.02 inch to 2.30 inches. Nearly a third of the storms produced less than one-tenth inch of rain; only four storms produced more than 1 inch.

The average catch in the trough gages in the open was highly correlated with the catch in the recording gage (R^2=0.99). In most instances, the trough gage caught more rain than did the recording gage.

Throughfall was quite variable between storms, reflecting differences in canopy structure, in time, and in space, as well as in storm characteristics. Throughfall (Pn) averaged 89.2 percent of gross rainfall and could be estimated from measured gross rainfall (Pg) by the equation:

$$Pn = 0.9346 Pg - 0.019$$

Standard error for the regression is 0.134 for these 33 observations.

If stemflow was neglected, interception per season averaged 10.3 percent of gross rainfall, but totaled only 1.43 inches for the four summers. The percent interception by storm size varied from 3 percent for a storm that produced 2 inches of rain to 50 percent for several storms that produced 0.1 inch or less. As expected, the percent intercepted generally varied inversely with storm size; however, there was considerable variation in the amount intercepted from a storm of given size, too. Stemflow was only 0.065 inch (1.43 percent) for the 11 storms measured in 1964 and 1965; total rainfall for these storms was 4.55 inches.

DISCUSSION

Interception by an aspen community appears to be quite variable both for a storm of given size and for different measurement periods, as is shown by the variability of these data and by their comparison with data reported by other authors. Dunford and Niederhof (1944), Monninger (1951), and Croft and Monninger (1953) reported average aspen-herbaceous interception to be 15.7 percent, 36 percent, and 15.8 percent, respectively, compared to 10.3 percent reported in this study. It is particularly interesting to note that Monninger's figures are more than double those reported by Croft and Monninger for the same area. Monninger's analysis was based on only 2 of the 4 years of data later reported by Croft and Monninger. These variations reflect the influence of storm intensity, storm size, and seasonal rainfall totals on interception.

Aspen stemflow measurements in this study compare well with those recorded in Colorado by Dunford and Niederhof. Net stemflow was 1.43 percent of gross precipitation during this study and 1.04 percent for the Colorado study. Analysis of the data from this study indicates that 18 gages would be sufficient to provide an estimated throughfall with a confidence interval of ±10 percent at the 95-percent probability level for storms greater than 0.15 inch.

Aspen are not efficient interceptors of rainfall. A waxy cuticle on the upper surface of aspen leaves makes them difficult to wet. Water applied to the surface forms large droplets, which are easily shaken from the leaf by the slightest breeze. Also, the smooth bark of aspen has a much smaller surface storage potential than rough-barked trees. By contrast, the dense grass and forb understory in western aspen communities has a high interception potential due to the large leaf-to-ground surface area ratio. Croft and Monninger reported that this herbaceous canopy without an aspen overstory intercepted two-thirds as much rainfall (10.5 percent) as did an adjacent undisturbed aspen community. Stemflow and possible reduced transpiration during the period that intercepted water is evaporated from the leaf surface tend to reduce the estimate of gross interception loss from herbaceous vegetation.

Soil moisture measurements on the Parrish plots indicate that summer rainfall seldom contributes to the recharge of soil moisture beyond the surface few inches. This moisture is quickly lost by evapotranspiration (Johnston 1970). Hence, from the standpoint of water yield alone, it makes little difference whether summer rainfall is lost by evaporation from the leaf surface, the ground surface or withdrawn from the root zone and transpired by the plants. However, summer rainfall plays an important role in the water relations of shallow-rooted grasses and other herbaceous vegetation. Even though summer rainfall is meager, it contributes to the growth and survival of many plant species that otherwise would be subjected to severe summer drought conditions.

Recent evidence supports the theory that evaporation of intercepted water tends to reduce transpiration loss (Goodell 1963; Thorud 1967; and Rutter 1968). The resultant net water loss from a site is less than the calculated interception loss. This evidence lends further support to the contention already presented in this paper that interception loss by aspen-herbaceous communities does not account for a very significant amount of summer rainfall.

Summer rainfall on the Parrish Plots averaged 4.54 inches over 31 years. Results of this study indicate that average interception would be less than 0.5 inch per season and that this amount would not be greatly reduced by altering stand characteristics or removing the aspen overstory. Although interception in the aspen-herbaceous community may be important in detailed water balance analysis, this study indicates that interception by this vegetation type does not significantly affect water yield.

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SUITABILITY OF *CEANOTHUS PROSTRATUS* BENTH. FOR THE REVEGETATION OF HARSH SITES

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ABSTRACT

*Rooted stem cuttings of squaw carpet (*Ceanothus prostratus *Benth.) were planted on a number of natural and manmade harsh sites from southern Utah to central Idaho. Percent survival and growth data indicate that this species supports considerable genetic variation among individual plants. Also, squaw carpet is incapable of competing with native vegetation and so is best used as a pioneer plant on particularly severe "harsh" sites. It is recommended that squaw carpet be planted in well-aerated and well-drained soils, preferably of granitic origin. Because this species is capable of supporting nitrogen-fixing micro-organisms in root nodules, it can be expected in time to improve the mineral nutrients of harsh sites. This contention is substantiated by the fact that mulching and fertilizing treatments did not improve survival or growth of squaw carpet.*

In the Intermountain Region of the Western United States many high-elevation mountain slopes and drainage channels are the watersheds above population centers and important recreation areas. Extensive logging and overgrazing have left many of these slopes severely eroded and sparsely vegetated. As a result, these areas are potentially destructive in terms of soil erosion and overland water flow. Attempts to rehabilitate denuded areas by means of revegetation have been marginally successful at best, primarily because the plant species used were physiologically unadapted to severe microenvironments. Denuded slopes that persist as potentially dangerous erosion and runoff hazards due to severe environmental conditions are referred to as "harsh" sites. This paper discusses the potential suitability of squaw carpet (*Ceanothus prostratus* Benth.) for

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the revegetation of such harsh sites. This paper also represents the first phase of a joint effort, centered both at Logan and Reno, to research the physiology, ecology, and possible uses of squaw carpet for revegetation in the Intermountain Region.

Ideally, a suitable species for revegetation of harsh sites would be both physiologically adapted to the environment and morphologically suitable in terms of providing adequate ground cover. Such a plant would be capable of producing an extensive, but deep, root system and the above-ground shoots necessary for a thick ground cover. More specifically, the ideal plant would be capable of reproducing both sexually and vegetatively, of spreading laterally over the slope surface, and of producing roots from its lateral layering branches. Such a plant should also be capable of vigorous growth in infertile dry soils and be unpalatable to livestock and game.

Although not necessarily ideal, squaw carpet does appear to meet many of these criteria. Squaw carpet is a prostrate, low-growing, woody shrub that supports extensive, trailing lateral branches that root at the nodes when in contact with the soil. Single plants form dense mats, 5 to 20 cm. high and as much as 3 m. or more in diameter. Its native range extends south from the Cascades in Washington and Oregon to the Sierra Nevada in California and western Nevada (Hitchcock et al. 1961). It is found primarily in the drier forest types under ponderosa pine stands and is often associated with chaparral. In its native range, squaw carpet forms isolated mats on the forest floor. These mats may intermingle and grow together, forming a dense, extensive ground cover. Within the native range, a great deal of genetic variation occurs among individual plants (e.g., adjacent plants show distinct phenotypic differences in terms of shape, color, and leaf size).

Squaw carpet is found primarily on coarse granitic soils in the Sierra Nevada. It extends over an elevational range of about 3,500 to 8,500 feet (1,065 to 2,600 m.) and occupies dry to mesic forest sites. Although Dunning (1925) felt that squaw carpet was not a particularly drought-tolerant species, it does develop both a fibrous, spreading root system and a deep taproot system.

Squaw carpet supports nitrogen-fixing actinomycete fungi in root nodules (Stewart 1967). For this reason, it appears to be capable of vigorous growth on infertile soils and of providing a suitable microenvironment for the establishment of other woody and herbaceous species. Delwiche et al. (1965) measured the nitrogen-fixation rate of squaw carpet to be 93.0 nanomoles/per gram of fresh tissue per hour. However, they point out that the maximum could be higher, since their experimental conditions were not optimal. They speculated that *Ceanothus* shrubs can contribute about 60 kg. nitrogen per hectare (53.5 pounds per acre) per year. Wollum and Youngberg (1964) found that snowbrush (*Ceanothus velutinus* Dougl.) plants were able to fix a minimum of 35 p.p.m. of N, which later became available for growth of other plant species. Other species, such as ponderosa pine, woody shrubs, and grasses, apparently have little difficulty growing up through the canopy of squaw carpet mats. In addition, squaw carpet tends to die back when crowded by other developing vegetation; therefore, it is not believed to be a highly competitive species.

Although a detailed ecological study of the life history of squaw carpet has not been completed, its ecology on the east slope of the Sierra Nevada has been investigated (Skau et al. 1970, Townsend 1966). Squaw carpet appears to be stimulated by fire (Townsend 1966) and is often the first woody species to move back into a burned area. It does not sprout easily and its root crown is relatively near the surface (Townsend 1966). Germination of untreated seed is low, usually less than 5 percent. However, Frolich (1967) found that various vigorous treatments (e.g., boiling in water or soaking in acetone), greatly increased the germination percentage. Ruf[4] found that germination can be increased to 50 percent or more by boiling and stratifying seed,

[4]Robert H. Ruf, Jr. (Unpublished data.)

then by soaking seed in gibberellic acid, and finally in thiourea. The presence of a chemical inhibitor was suspected and Frolich et al.[5] attempted to isolate this compound. They concluded that successful germination is dependent on the removal or destruction of the inhibiting material by soaking the seed in acetone for 5 minutes or by boiling the seed in water. Either treatment should be followed by stratification at 10° C. for 60 days or more.

METHODS

All of the plants used in this study were propagated from stem cuttings of squaw carpet collected in midsummer from a large number of plants native to the Sierra Nevada near Reno, Nevada. The cuttings were taken from the current year's leader growth and were usually about 15 to 20 cm. long. The leaves were stripped off the basal 5 or 6 cm. and the stem tip dipped in Hormodin No. 3 (indolebutyric acid).[6] The cuttings were rooted in perlite on a laboratory mist bench at the University of Nevada. Usually, about 4 weeks were required before root formation could support the plant. The cuttings were then transplanted to 4.5- by 20.3-cm. (1-3/4- by 8-inch) asphalt-paper tubes containing a Cornell mix. The plants were allowed to grow in a shaded portion of the greenhouse through the summer and to overwinter outdoors, where they remained dormant until the following spring. During the late spring, the plants were transported to the various planting sites throughout the Intermountain Region.

Planting sites were chosen in a number of locations throughout the Intermountain Region, from southern Utah to central Idaho (fig. 1). Only harsh sites that exhibited severe environmental conditions were selected. These included exposed natural slopes, road cuts and fills, logged or overgrazed slopes, and strip mine tailings. Except for high-elevation meadows or unlogged areas, all sites were free of competing vegetation. Table 1 summarizes the topographical characteristics, the number of plants planted, and the year of planting for each site at each location.

The southernmost planting location is on the Dixie National Forest in southern Utah, just west of Bryce Canyon National Park along the East Fork of the Sevier River. This area occupies a portion of the Paunsaugunt Plateau and is characterized by steep breaks and many open bare slopes surrounded by ponderosa pine forests. The striking red color of the geological material in this area is responsible for the name "Pinks" applied to these bare, open slopes. Two natural slopes, a road cut, and two manmade scraped areas adjacent to a reservoir were planted.

The Wasatch Plateau location occupies a portion of a large subalpine plateau on the Wasatch Mountains in central Utah. This location, which has a long history of sheep grazing, is an important watershed to several small population centers at the base of the mountains. A steep side wall of a deep erosion channel, a meadow, an exposed rocky ridge, and a subalpine flat on the top of the plateau were planted, all at elevations greater than 9,900 feet.

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[5]M. Frolich, R. H. Ruf, Jr., and Paul E. Packer. Germination inhibition in seed of *Ceanothus prostratus* Benth. (USDA Forest Serv. Res. Note INT- ___, in preparation.)

[6]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

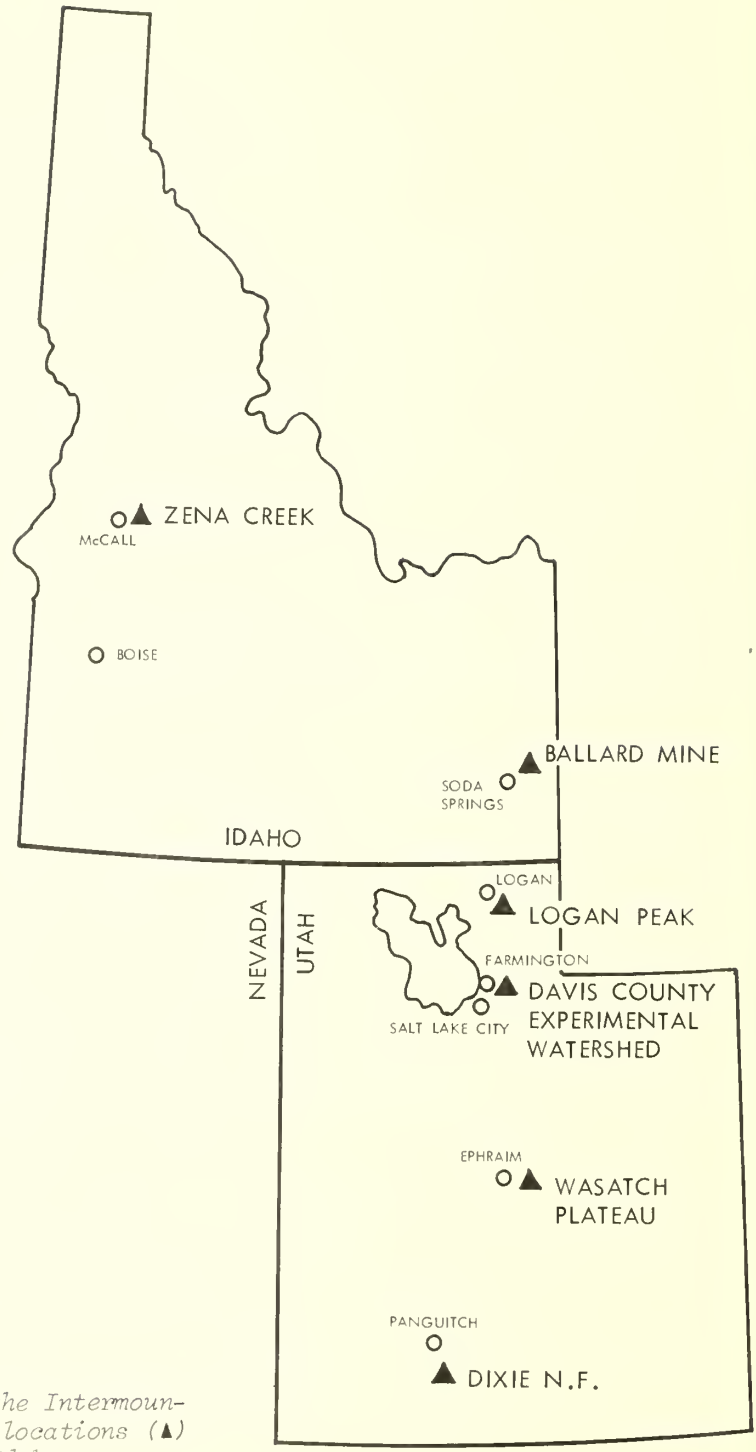

Figure 1.--Map of a portion of the Intermountain Region showing planting locations (▲) of squaw carpet in Utah and Idaho.

Table 1.--Summary [illegible] locations, [illegible], [illegible] cuttings planted [illegible]

Site	Elevation	Exposure	Slope	Soil type	Number of plants	Year planted
	Feet		*Degrees*			
			DIXIE NATIONAL FOREST			
Scraped 1	7,920	East	5	Gravelly clay	100	1966
Natural 1	9,300	S20W	22	Gravelly clay	100	1966
Road cut	7,890	N75W	36	Silty clay	100	1966
Natural 2	8,020	South	26	Gravelly clay	736	1967
Scraped 2	7,920	East	5	Gravelly clay	736	1967
			WASATCH PLATEAU			
Meadow	9,900	N50W	8	Clay	100	1965
Channel-cut	10,080	S40E	27	Silty clay	95	1966
Ridge	10,230	N50W	8	Clay-silt	98	1966
Alpine flat	10,260	SSE	13	Clay	96	1966
			DAVIS COUNTY EXPERIMENTAL WATERSHED			
Road cut	8,400	S65W	35	Sandy loam	100	1966
Chicken Creek	7,600	S45W	30	Silt loam	100	1966
Trench	9,000		--	Silt loam	100	1966
			LOGAN PEAK			
Peak	9,713	S10E	30	Silt loam	100	1966
			BALLARD MINE			
Cliff base	6,550	S22W	13	Gravel	50	1966
Lower road	6,310	South	9	Clay loam	50	1966
Road fill	6,670	N60W	41	Gravel	50	1966
Road bed	6,670		--	Gravel	50	1966
Scraped	6,670	S47W	11	Sandy silt	50	1966
Fill top 1	6,700	N85W	3	Gravel	50	1966
Fill top 2	6,680	S10W	6	Gravel	736	1967
			ZENA CREEK			
Road fill 1	4,600	West	38	Decomposed granite	100	1965
Logged	4,680	S40E	36	do.	100	1965
Unlogged	4,670	S30E	29	do.	100	1965
Road bed 1	4,790	N60E	6	do.	99	1966
Road bed 2	4,790	S75W	4	do.	99	1966
Road fill 2	4,400	S30E	36	do.	100	1966
Road fill 3	4,600	West	38	do.	99	1966
Road fill 4	4,800	S60W	36	do.	100	1966
Road fill 5	4,410	S30E	32	do.	736	1967
					5,130	

Two planting locations in northern Utah were chosen; one was on the Davis County Experimental Watershed near Farmington, the second on Logan Peak near Logan. The Davis County Experimental Watershed is characterized by steep slopes that (prior to the construction of contour trenches) have contributed to several historically significant and destructive floods. One contour trench and two road cuts were planted at this location. On Logan Peak, one high-elevation bare slope was planted.

The phosphate strip mines of southern Idaho are of interest because many of them are on or adjacent to National Forest land, represent potential sources of extensive erosion, and are offensive scars on the landscape. The Monsanto Chemical Co., in cooperation with the USDA Forest Service, consented to the establishment of seven different planting sites, representing a range of severe environmental conditions, on the Ballard Phosphate Mine near Soda Springs, Idaho.

The northernmost location is on the Payette National Forest on Zena Creek near the Secesh River. It occupies a portion of the Idaho Batholith and is composed of extensive areas of unstable decomposed granitic soils. This area has been logged-over and is laced by many unstable logging roads with steep cuts and fills. The nine planting sites chosen represented a wide range of environmental conditions.

Two different planting techniques were used. The first, used during the 1965 and 1966 planting seasons, merely involved the planting of rooted cuttings still in the asphalt tubes. These cuttings were planted at 2-foot intervals, 10 plants to each of 10 parallel rows spaced at 2-foot intervals up and down the slope. Thus, 100 plants were usually established at each site (table 1). Each plot was about 20 feet long on a side and covered an area of about 400 square feet. Holes were just large enough to accommodate the asphalt tube. The tube containing the plant was inserted and the soil packed around the tube to provide firm contact between the soil and the tube containing the root system. The second planting technique, used during the 1967 planting season, involved various site pretreatments, including mulching and fertilizing, and an untreated control to evaluate effects on squaw carpet survival. Seven treatments and a control were used:

1.--Control (no site treatment).

2.--Plastic mulch (clear, 0.004-inch-thick plastic film over the surface).

3.--Burlap mulch.

4.--Fertilizer (200 lbs. N, 20.8 lbs. phosphorus, and 41.5 lbs. potassium, per acre, as 12-6-6).

5.--Jute-straw mulch (straw covered by jute netting).

6.--Plastic mulch + fertilizer.

7.--Burlap mulch + fertilizer.

8.--Jute-straw + fertilizer.

The asphalt tubes were removed from all plants planted in the 1967 season.

Each plot treatment was replicated twice for each of two planting intensities: (1) plants spaced on 1-foot centers and (2) plants spaced on 2-foot centers. Thus, at each planting site there were 16 plots for each planting intensity, or a total of 32 plots. In the 1-by 1-foot planting-intensity plots, 28 plants were used and in the 2-by 2-foot planting-intensity plots, 18 plants were used. At each of the locations planted in 1967, 736 plants were established.

After planting, survival data were collected at various times for several years. Only live plants were counted and survival has been expressed as a percentage of the total number of plants originally planted in each plot.

RESULTS

The percent survival over two planting seasons (1965 and 1966) was generally low at all locations (table 2). By the fall of the 1970 growing season, all plants in Utah had died and only 7.3 and 20.9 percent remained alive at Ballard Mine and Zena Creek, respectively. At all locations, the severest mortality occurred during the first growing season after planting. At the Utah locations (Dixie N.F., Wasatch Plateau, Davis County Experimental Watershed, and Logan Peak), survival declined each succeeding year and, in most cases, all plants died within 2 to 3 years following planting.

On the Dixie National Forest, the primary cause of mortality appeared to be summer drought. Each season after planting, plants appeared to be subjected to extreme drying conditions; leaves turned a yellowish color and became brittle. No evidence of grazing, insect attack, or frost heaving was found. Only one plant survived through the 1969 growing season.

Table 2.--*Average percent survival of squaw carpet for each successive year following 1965 and 1966 plantings*

Location	Year 1966	1967	1968	1969	1970
Dixie N.F.	18.0	7.3	0.3	0.3	0
Wasatch Plateau	7.3	.8	0	0	0
Davis County	19.0	3.0	0	0	0
Logan Peak	0	0	0	0	0
Ballard Mine	56.0	25.7	16.3	8.0	7.3
Zena Creek	30.9	28.4	28.4	25.3	20.9

At the Wasatch Plateau and Logan Peak locations, mortality resulted primarily from gopher activity and heavy sheep trampling. None of the plants survived longer than 2 years. On Logan Peak, all plants died during the first growing season. Apparently, gophers attacked the root systems of most plants by burrowing into the asphalt tubes and nipping off young roots. Many of the plants on the alpine flat location on the Wasatch Plateau and on Logan Peak were severely trampled by sheep. However, the total number of plants killed by trampling represents only 3.8 percent of the total number of plants established in this study (table 1).

At the Davis County Experimental Watershed, gopher activity was not a primary cause of mortality, although some damage was noted. A number of factors accounted for low survival in this area (e.g., drought, frost heaving, and slumping of loose soil from road cuts). At all Utah locations where plants were planted on road cuts or steep loose soil, a certain amount of mortality occurred when plants were buried after slumping.

At the Idaho locations, Ballard Mine and Zena Creek, percent survival was higher each successive year after planting than it was in Utah. The two main causes of mortality at the Ballard Mine were drought and heavy overland water flow that channeled through the plots washing out the plants. At Zena Creek, mortality was caused by slumping of the loose granitic slopes, competition from annual and biennial weeds, and perhaps drought. At this location, some plots were located on natural, undisturbed, or logged-over slopes that supported relatively dense stands of native vegetation; so mortality of squaw carpet was particularly high.

It is noteworthy that the surviving plants at Ballard Mine and at Zena Creek are now beginning to show significant growth. This is reflected in the declining rate of mortality at both of these locations (table 2). The plants are now beginning to develop deep, extensive root systems and wide, spreading crowns. Such growth is most evident at Zena Creek where squaw carpet now provides more than 30 percent ground cover on some plots (fig. 2). Also, the root systems at Zena Creek are deep, extensive, and support many root nodules. No significant growth was made by any of the Utah plants prior to death and no root nodules have been found at any location except Zena Creek. At the Zena Creek location, particularly on the loose granitic road-fill slopes, squaw carpet is now beginning to contribute significantly to slope stabilization. On several such sites, mats of squaw carpet are effectively forestalling soil washouts. In some cases,

Figure 2.--A photograph shows the prostrate growth habit of squaw carpet on a granitic slope at Zena Creek, Idaho. At this location, squaw carpet provides about 30 percent ground cover after 4 years of growth.

where several plants have formed solid mats several feet across and 10 or 12 feet long, the plants appear to be occupying mounds of stable soil. The bare slope around the outer edges of these mounds has been visibly eroded and deeply channeled. Thus, the plants appear to be effectively reducing soil erosion.

The survival of the 1967 squaw carpet plantings, involving the plot treatments and the control replicated twice for each of two planting intensities, was relatively low also. The survival data for these plantings are illustrated in figure 3 and represent the average percent survival at the end of the 1970 growing season. The data in figure 3 were averaged for the two planting intensities (1 by 1 foot and 2 by 2 feet) because there was no apparent difference in their percent survival. The high mortality rates on both the Dixie National Forest and at the Ballard Mine reflect both the influence of drought and the washing-out of the plots by surface water flow following storms. The gravelly clay soils on the Dixie National Forest sites became extremely dry during the summer months and drought was the main reason for the high mortality rate. Survival was highest on plots that had been treated with either plastic fertilizer or burlap fertilizer mulch treatments. However, after four growing seasons, the survival on these plots was not over 4 percent. Average percent survival of all plots on the Dixie National Forest was only 1.6 percent. At the Ballard Mine, survival was somewhat better, particularly on the mulched and fertilized plots. The highest survival (6.9 percent) was reached on the jute-straw-fertilized plots. However, extreme channeling disrupted many plots and was a main reason for mortality. An average of only 2.3 percent of the plants survived through the 1970 growing season.

The most significant results were recorded at the Zena Creek location, where an average of 14.1 percent of the 1967 plantings survived through the 1970 growing season. The data illustrated in figure 3 show that the highest percent survival was reached on the control plots (39.9 percent) and the lowest, on the jute-straw-fertilized plots (4.9 percent). The data indicate that the more intensive the treatment, the lower the percent survival. Competition appears to be the primary cause of mortality on these plots. Within one growing season after planting, treated plots were rapidly invaded by annual and biennial plants, but control plots remained relatively free of competing vegetation. Percent survival on mulched and fertilized plots decreased rapidly in

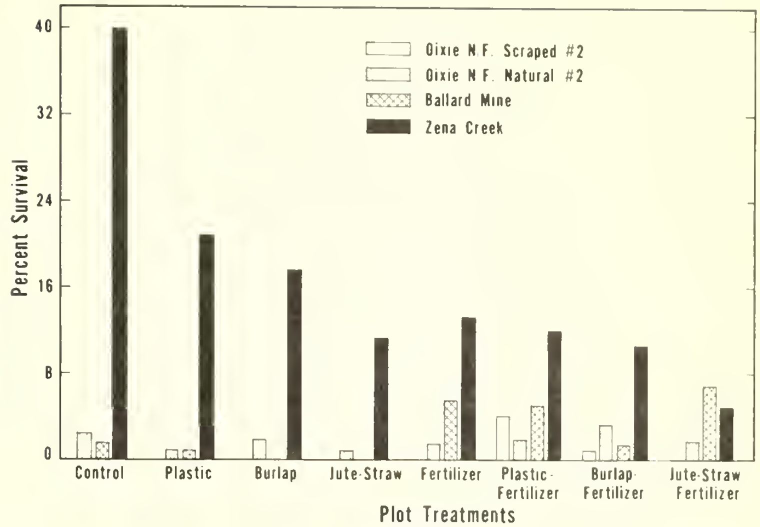

Figure 3.--Average percent survival of the 1967 squaw carpet plantings for each location and plot treatment. The data of the two planting intensities (1 by 1 foot and 2 by 2 feet) were averaged.

succeeding years, a reflection of increasingly severe competition. Also, squaw carpet plants on the control plots have grown more than those on treated plots and after four growing seasons provide about 15 percent ground cover. Squaw carpet provides less than 5 percent cover on treated plots after the same period of time.

Squaw carpet produced flowers and seeds only at the Zena Creek location. The 1965 and 1966 plantings produced a profusion of flowers and seeds in June and July of both 1969 and 1970. The 1967 plantings flowered for the first time in 1970. Thus, it appears that about four growing seasons following planting are required for squaw carpet to flower in this area.

DISCUSSION

Although the overall survival of squaw carpet was low, the plantings at the Ballard Mine and particularly at Zena Creek are considered successful. The percent survival data for those two locations are somewhat misleading because they do not adequately illustrate the vigorous growth of the surviving plants. In fact, the authors feel that percent survival data for these squaw carpet plantings are no longer truly relevant and that percent ground cover and growth should be the main criteria of relative success for these plots. The significance of these criteria is illustrated by the fact that in its natural range squaw carpet is an endemic plant and restricted to a rather narrow geographical range. Study plants were planted several hundred miles east of their natural range on harsh environmental sites and yet many of them have grown vigorously and are contributing to slope stabilization. At the Zena Creek location, plants have successfully flowered and produced seed.

One of the most striking observations made during this study was of the degree of phenotypic variation among squaw carpet plants. Morphologically this variation is obvious when gross differences in size, color, and leaf shape exist between different plants. This variation probably is of genetic origin, but no quantitative data were collected to substantiate this supposition. However, variation is common throughout the plant's natural range and is readily noted between adjacent plants growing in the same microenvironment (fig. 4). The two plants shown in that figure, natives growing in Nevada on the east slope of the Sierra Nevada, show distinct phenotypic differences.

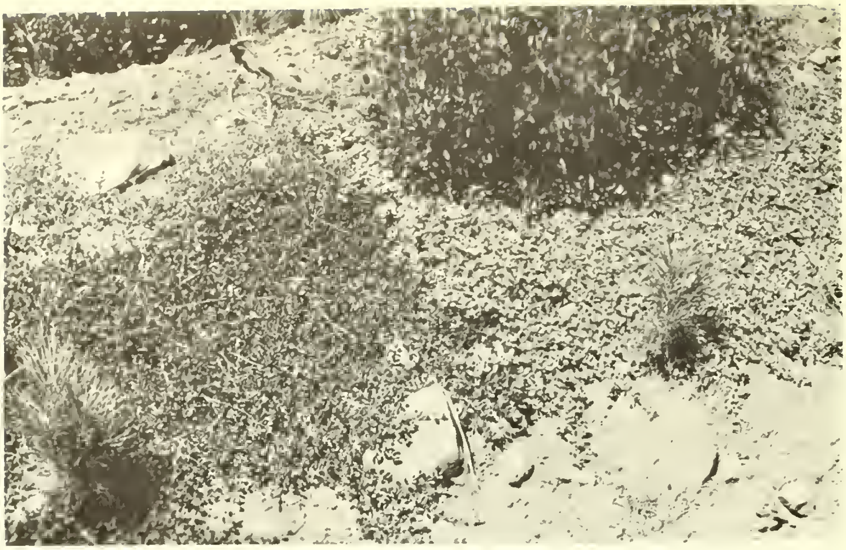

Figure 4.--A photograph of two adjacent squaw carpet plants that display different phenotypic characteristics. These two plants are growing in Nevada in their native habitat on the east slope of the Sierra Nevada.

Phenotypic variation is also obvious at Zena Creek among the study plants and strongly suggests genetic variation among the squaw carpet cuttings. Certain rows of plants in the 1966 planting plots were planted with rooted cuttings originally cut from the same mother plant. In some cases, entire rows of such plants died without showing growth within one growing season after planting. However, plants in an adjacent row 2 feet away that were taken from another mother plant grew vigorously and eventually flowered and produced seed. These vigorously growing plants have spread laterally into the adjacent rows of dead plants, have rooted from lateral branches, and are continuing to grow. Thus, it appears that the dead plants were from physiologically unadapted mother plants and that genetic variation is indeed an important consideration for future selection of planting stock.

It is possible that a great deal of the mortality experienced at the Idaho locations can be explained in terms of unadapted genotypes. A large number of stem cuttings were taken from the surviving plants at Zena Creek during July 1970 and were rooted in a mist bench with about 90 percent success. Some of these plants will be used in future back-planting experiments at Zena Creek.

At the Utah locations, however, the influence of severe environmental stress obviously concealed the survival abilities of different squaw carpet genotypes. At these locations, the harsh environmental conditions represent completely dissimilar habitats from those in the Sierra Nevada. In particular, cyclic weather patterns, vegetation types, soils, and parent materials in southern Utah are unrelated to those of the Sierra Nevada. Therefore, an evaluation of different genotypes would be unrealistic under these conditions.

Squaw carpet apparently has its highest survival and makes its best growth in loose, coarse-textured soils that are well aerated and well drained. Coupled with this is its ability to grow well in infertile soils due to its symbiotic relationship with actinomycetes and the resultant buildup of nitrogen in the soil. There may be a direct relationship between well-aerated soil and the ability of squaw carpet to support an actinomycete population. Although a relationship between soil type and root nodules containing nitrogen-fixing organisms has not been established for squaw carpet, nodules were formed only on plants in granitic soils, even though none of the plants had been pre-inoculated.

Squaw carpet appears to occupy an early stage of successional vegetation development and is capable of vigorous growth on sites free of competing vegetation. This inability to compete with other plants may relegate use of squaw carpet to revegetation of slopes denuded of native vegetation or recently disturbed. For the most part, data from the 1967 plantings on treated plots are statistically inconclusive. However, data from Zena Creek do substantiate the importance of competition; plots that received mulch and/or fertilizer were rapidly invaded by annual and biennial plants and squaw carpet's percent survival steadily decreased (fig. 3). During the first growing season following planting, treated plots supported lush stands of native forbs and grasses but control plots remained bare, except for young squaw carpet plants.

From these observations, several interesting speculations about squaw carpet revegetation can be made. First, care should be taken to use stock from physiologically adapted genotypes only. Unfortunately, our experience is limited, but it is evident that morphological differences alone cannot be used to distinguish between adapted and unadapted types. Second, because of its inability to compete with rapidly invading species, squaw carpet should be used as a pioneer plant on particularly severe harsh sites. It is recommended that squaw carpet be planted on well-aerated and well-drained soils, that the plants be left with the asphalt tubes around their root systems, and that no mulching or fertilizing treatments be used. Squaw carpet can be expected to improve the microenvironment over a period of time, thus encouraging the establishment of a stable native plant cover. This contention is substantiated on the Zena Creek plots, where young grasses, forbs, and trees are beginning to grow through the squaw carpet canopy. Third, its ability to grow well on infertile soils can be particularly beneficial on severely disturbed sites. Its nitrogen-fixing abilities suggest that squaw carpet is an excellent pioneer species.

Certainly, if extensive use of squaw carpet is made for revegetation of harsh sites, reproduction and planting will have to rely on seeding. From a purely economic standpoint, planting of large areas with rooted cuttings would be prohibitive. However, the use of rooted cuttings may be valid and advantageous in the revegetation of small, critical harsh sites on road cuts and fills or at the heads of important watersheds. During the cotyledon and young seedling stage, survival under field conditions can be expected to be much lower than in the greenhouse. With rooted cuttings, however, growth has begun and a well-established root system is an advantage. Research on squaw carpet is investigating: (1) ways of improving seed germination and seedling survival and (2) means of improving survival and growth of rooted cuttings. Before any final and complete analysis can be made, an extensive amount of quantitative physiological research on squaw carpet will be required.

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Research Note

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FOREST ROAD STANDARDS AS RELATED TO ECONOMICS AND THE ENVIRONMENT

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ABSTRACT

Planning a truly optimum forest road system is not possible at this time primarily because data needed as input for such an analysis is either inadequately defined or nonexistent. However, it is appropriate to use whatever rational means are available to give greater weight to protecting the quality of the environment. This paper discusses the problem in a general way and recommends a procedure that might be used to help decide on appropriate standards until better methods are available.

Today, widespread concern for the environment necessitates reorientation of the economic analyses and methods that are being used to determine forest road standards. Most of the design standards and techniques for forest road location were borrowed from methods that evolved from values associated with major freeways and highways. This former approach emphasized the cost to the user assessed over a predetermined economic life of the structure. In regard to forest roads, present-day thinking definitely minimizes this direct-cost-to-user concept and also tends to outmode related concepts or standards regarding the economic life of the road.

If we accept this present-day thinking, then it does not seem reasonable to assign a relatively short economic life of 15 to 20 years to any road that will be added to the permanent system of forest roads. Such short terms have been considered appropriate for many modern highways because of the rapid evolution of faster vehicles and greater volumes of traffic. In the relatively flat and less scenic locations of most modern highways, it may be reasonable to continually upgrade alinements, grades, and widths (even this process must someday slow down); but for the environment-conscious public, which now insists upon protection from over-development, this approach is no longer acceptable for most forested areas.

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The thought of building a forest road and assuming a relatively long life of 50 to 100 years would probably be considered unrealistic by many engineers and economists; however, this may be more realistic than using a short period of 15 to 20 years if we decide that protection of the environment should be given major consideration. This approach will force us to sacrifice some economic values, mostly short-term ones. Such sacrifices are always necessary when environmental protection decisions take priority over purely economic ones. Economic values related to speed of travel and vehicle maintenance are examples of values that many users would consider giving up in favor of environmental protection.

Construction, maintenance, and vehicle-use costs of highways or roads are considered when economic analyses are made; then these costs are compared with the benefits accruing to the users. Road priorities are usually decided upon either a benefit-cost or rate-of-return basis. Construction costs are amortized over an assumed design life, using some appropriate interest rate. Maintenance costs for the road standards being considered are derived from past maintenance cost records. Vehicle-use costs include maintenance, operation, depreciation, and cost of the *time* of the driver and passengers. How these costs affect total annual costs for an average forest road are shown in table 1, assuming an annual traffic volume of 10,000 vehicles. Annual traffic volumes rather than daily volumes are generally used for forest roads because of the seasonal nature of the traffic and relatively low volumes during some periods.

As the traffic volumes increase, there is justification for higher levels of road standards, as would be expected. Comparison of costs for traffic volumes of 20,000 and 40,000 vehicles per annum (VPA) are shown in table 2.

Vehicle use costs for increased vehicles per annum play an increasing role in the total costs, as would be expected--the difference is more pronounced for a very low standard road carrying high traffic volumes. The appropriate standard of road, if vehicle use is considered to be the predominant criteria, for the traffic volumes of 10,000 to 20,000 and 40,000 VPA is a 1-lane gravel, 2-lane chip-seal, and 2-lane paved road, respectively. It should be noted in this example that a change in the amortizatio period from 20 to 50 or 100 years has no effect on the most economical road standard when this criteria is used. This is because vehicle use costs for 50- and 100-year depreciation periods are greater than the depreciation costs for all road standards; thus, the higher standard road is always favored. It should also be noted that we have not yet considered the impact of these various standards on the environment, the social and economic impacts of safety, or the indirect benefits from recreation and other uses.

At this point in the analysis we have some of the inputs, but other required inputs are either not well established or nonexistent. For example, possible damages to the environment are either not well established or unknown quantitatively. Here, we refer to instances where there may be appreciable damages to the environment because of the influence of a road on the hydrology of a watershed that in turn may result in accelerated erosion or undesirable flood peaks in a stream.

If we used our analysis at this point (where some inputs are lacking) in a direct comparison of benefits versus damages (negative benefits) these quantities that are difficult to calculate would have to be reduced to an annual dollars-per-mile basis. To do this, it would be necessary to assume some useful or ultimate life for the road and/or some end point (or termination of the positive and negative benefits) that are quantifiable. It should also be noted that many negative benefits, such as those chargeable to esthetics, changes in streamflow rates, etc., continue beyond any known assumed economic road life.

Table 1.--*Comparison of annual road costs per mile, 10,000 vehicles per annum (VPA)*

Cost distribution	Road standard					
	2-lane paved	2-lane chip-seal	2-lane gravel	1-lane gravel	1-lane spot stabilization	1-lane primitive
	Dollars per mile					
Initial construction	50,000	40,000	30,000	20,000	15,000	10,000
	Annual dollars per mile (20-year period)					
[1]Depreciation	4,360	3,490	2,610	1,740	1,310	870
Maintenance	200	400	600	800	1,100	500
Vehicle use	2,200	2,300	2,700	3,000	4,400	8,500
Total annual	6,760	6,190	5,910	[2]5,540	6,810	9,870

[1]20 years at 6% using capital recovery.
[2]Lowest annual cost.

Table 2.--*Comparison of annual road costs per mile for 20,000 and 40,000 vehicles per annum (VPA)*

Cost distribution	Road standard					
	2-lane paved	2-lane chip-seal	2-lane gravel	1-lane gravel	1-lane spot stabilization	1-lane primitive
	Dollars per mile					
Initial construction	50,000	40,000	30,000	20,000	15,000	10,000
	(20,000 VPA)					
[1]Depreciation	4,360	3,490	2,610	1,740	1,310	870
Maintenance	400	800	1,200	1,600	2,200	1,000
Vehicle use	4,400	4,600	5,400	6,000	8,800	17,000
Total annual	9,160	[2]8,890	9,210	9,340	12,310	18,870
	(40,000 VPA)					
Depreciation	4,360	3,490	2,610	1,740	1,310	870
Maintenance	800	1,600	2,400	3,200	4,400	2,000
Vehicle use	8,800	9,200	10,800	12,000	17,600	34,000
Total annual	[2]13,960	14,290	15,810	16,940	23,310	36,870

[1]20 years' depreciation at 6% using capital recovery.
[2]Lowest annual cost.

Table 3.--*Comparison of single-lane versus double-lane costs for three different vehicle-per-annum (VPA) categories*

VPA	Total annual cost per mile		Difference
	1-lane gravel	2-lane paved	
	Dollars		
10,000	5,540	6,760	-1,220
20,000	9,340	9,160	+ 180
40,000	16,940	13,960	+2,880

Since we lack much of the data needed for accomplishing this total analysis now, we must try to use the information at hand and make a subjective, but hopefully rational, approach to a solution. It is almost certain that most of the negative benefits will be minimized using a lower standard road (lower standard because of reduced width and alinement, primarily). The lower standard road should produce less impact on the total environment--hydrology, soils, esthetics, etc. From the point of view of user cost (the *time* portion of this cost is questionable for most forest roads that serve significant recreation traffic because speed of travel is not of primary concern), what is given up in dollars for the 3 VPA's looked at earlier (10 to 20 to 40,000) for a single-lane gravel road versus a 2-lane paved road? See table 3.

The differences in cost per mile for the two standards of road reveal that for the estimated traffic over a 20-year amortization period, the single-lane road would be preferred. Admittedly, making predictions about the future is risky business. However, if increased anticipated (or allowed) use was extended on the basis of past trends, 40,000 VPA would probably be near the maximum for 50 years or more. Increased use, of course, could be controlled significantly by limiting recreation facilities, timber harvesting, and other uses; it is likely that some limitations may be required sometime in the near future. At the 40,000 VPA level, about $2,900 annually per mile would be "charged the users," in a manner of speaking, for anticipated preservation of environmental values. This would amount to 25¢ or 30¢ per user per mile annually.

Since the likelihood of limiting use of roads at some time in the near future is probably quite good (this is already being done in some Federal and State parks), and the direct, rather easily calculated cost of such roads to the users is relatively small, it seems reasonable to consider single-lane roads adequate for about 50 years.

Past studies of accident records for single-lane roads (mostly rural county roads) show only a slight increase in accident frequency between low standard 2-lane and single-lane roads. These figures are for average daily traffic (ADT) totals of 100 to 200 vehicles (20,000 to 40,000 VPA)--traffic volumes of the same general magnitude as most typical forest access roads. The critical period for accident potential, of course, would be the maximum expected peak hourly traffic. For these few critical periods during the year, some form of traffic control could be used. These same accident rate studies referred to above also show that fewer accidents occurred on curves than on tangents, and also that widening or adding extra lanes cannot be *economically* justified to prevent accidents. If loss of life from accidents were to be considered of primary concern, then there would be no limit to the money that could be justifiably spent for traffic control by adding features such as extra lanes, land dividers and surveillance.

We realize that every road is unique and requires a separate analysis. When potential traffic volumes may be high for a through road, and environmental impacts may be obviously low for a high standard road, then user costs could be heavily weighted. Although we may not be able to assign values to some uses with great confidence and in a manner agreeable to everyone, it is possible to subjectively give weight to some of these values. For example, economists are divided in their opinions about assigning values to some recreation experiences. Many feel that attempting to do so is an exercise in futility--others will attempt to do it. In either case, the weight of public opinion cannot be ignored. It is clear that these experiences have value to the general public and must be weighted in some fashion. New and better methods for accomplishing this are currently being studied and, hopefully, better solutions will be forthcoming.

In the meantime, it would seem clear that analyses to determine forest road standards cannot end when the direct cost to the user has been determined, as has been the general practice in the past. This too often results in many indirect costs to environment quality. Greater emphasis must be given to other values in some rational manner.

Research Note

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FIELD LEVELS OF INFECTION OF PROGENIES OF WESTERN WHITE PINES SELECTED FOR BLISTER RUST RESISTANCE

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ABSTRACT

Western white pine trees resulting from crosses of parents selected for phenotypic resistance to Cronartium ribicola *J.C. Fisch. ex Rabenh., the white pine blister rust, were inspected for rust infection after 11 to 15 years in two field plots. When compared to controls and to natural reproduction, the progenies of crosses involving trees that exhibited general combining ability for resistance transmission in nursery tests were much less heavily infected (20 percent on the average, as opposed to 58 and 71 percent for controls and natural reproduction, respectively).*

Nursery testing to determine levels of resistance in western white pine seedlings to the blister rust fungus, *Cronartium ribicola* J.C. Fisch. ex Rabenh., has been conducted by the USDA Forest Service for 20 years (Bingham and others 1953; Bingham and others 1969). A study designed to test levels of resistance of first and second generation progenies in the field was established in 1969, but will not yield results for several years. However, considerable quantities of first-generation seed are now being produced in an experimental grafted seed orchard (Bingham and others 1963). Also, second-generation seed is being produced in a breeding arboretum.

This paper will present data gathered from first-generation progenies planted for another study that give an early indication of field levels of resistance after 11 to 15 years of natural exposure to the rust disease.

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The young trees examined were grown from seeds that were in excess of those needed for nursery tests of transmission of blister rust resistance in first-generation progenies from crosses among phenotypically resistant "candidate trees." The young trees were outplanted to assess the heritability of growth and quality traits. Statistical interpretation and extraction of heritability estimates are difficult and of doubtful value because the original crossing program was unbalanced, and the number of crosses containing excess seed varied from year to year as did the number of seeds per cross. Detailed analysis of the blister rust infection data was unjustified for the same reasons. Nevertheless, we feel the gross data are of value as indicators of possible future progress and as possible justification for interim use of first-generation seed in reforestation.

MATERIALS AND METHODS

Three-year-old seedlings were planted at two locations in northern Idaho [Priest River Experimental Forest (P) and Deception Creek Experimental Forest (D)] during 1955, 1956, 1957, and 1959. The plantations included trees resulting from: (1) Crosses of rust-free trees (phenotypically resistant candidates) in natural stands; (2) self-pollinations of rust-free trees; (3) wind-pollinated seed from the same rust-free trees; and (4) control lots of seed from presumably nonresistant trees. The number of lots planted per year varied from 22 to 45 and the number of seedlings per lot ranged from two to 24 on each site.

Casual observations of obvious blister rust cankers and blister rust mortality have been recorded over the years, but a systematic examination was not made until the summer of 1970--after the trees had been exposed to natural infection for 11 to 15 years. In addition to the plot trees, we also examined a number of naturally reproduced trees of about the same age within the plots or around their borders.

The infection data were grouped in the following ways on the basis of progeny type: (1) Seedlings from crosses where both candidates were subsequently rated as exhibiting general combining ability (GCA) for a high level of resistance transmission in the nursery trials; (2) seedlings from crosses between candidates rated below average for resistance transmission (non-GCA); (3) seedlings from crosses of GCA X non-GCA candidate trees; (4) seedlings from wind-pollinated GCA trees; (5) seedlings from wind-pollinated non-GCA trees; (6) seedlings from control lots (wind-pollinated infected trees); and (7) naturally reproduced seedlings growing within or around the plots.

RESULTS AND DISCUSSION

Efforts were made to control blister rust by eradicating the alternate host, *Ribes* spp., in the general area of the plantations prior to, during, and after plantation establishment. Even so, the present infection levels of nearby natural reproduction suggest that most trees have undergone fairly high levels of exposure to *Cronartium ribicola* since outplanting (table 1). The most encouraging aspect of the data was that the regular progression of resistance for progenies in various categories on both plots paralleled that expected from their nursery performance.

Thus, the progeny from crosses of parents subsequently rated as possessing GCA for resistance transmission were the least infected (table 1). Crosses of non-GCA parents produced progenies that showed about 1-1/2 times as much infection as GCA X GCA crosses, whereas the GCA X non-GCA progenies exhibited an intermediate amount of infection.

Seedlings resulting from wind-pollinated GCA or non-GCA parents were infected about twice as often as GCA X GCA or non-GCA X non-GCA progenies, respectively.

Table 1.--*Field levels of blister rust infection of progenies of western white pines after 11 to 15 years of exposure to* Cronartium ribicola

Types of crosses	Number of parents	Number of crosses	Location[1]	Number of trees inspected	Percent infected	Cankers per infected tree
GCA[2] X GCA	16	40	D	453	20.9	2.3
			P	460	18.5	1.7
GCA X non-GCA	25	30	D	298	31.9	1.8
			P	261	21.1	1.6
Non-GCA X non-GCA	5	7	D	55	33.2	1.6
			P	48	26.4	2.0
GCA X wind	13	?	D	269	44.4	2.3
			P	253	34.3	2.0
Non-GCA X wind	16	?	D	152	55.3	2.2
			P	158	47.1	2.0
Controls	[3]13	?	D	138	68.0	2.4
			P	113	48.4	2.1
Natural reproduction	?	?	D	196	80.1	2.0
			P	131	62.5	2.5

[1]D = Deception Creek Experimental Forest
P = Priest River Experimental Forest

[2]Parents were rated in subsequent nursery tests as exhibiting general combining ability (GCA) for transmission of above average levels of resistance or, as not exhibiting such ability (non-GCA).

[3]Thirteen collections, each containing seed from five to 10 trees.

When compared to the control seedlings and to those naturally reproduced, progenies of the GCA X GCA crosses were noteworthy. They were infected only one-third or one-fourth as much as control progenies and natural reproduction, respectively. However, comparison of GCA X GCA progenies with natural reproduction could lead to an overestimate of resistance. Planted trees were not exposed to the disease during their first 3 years in the nursery, but some naturally reproduced seedlings were exposed during those early years. On the other hand, early infection might have led to early death; so the infection level of surviving natural reproduction might underestimate actual damage. In fact, among planted trees, postestablishment mortality that can definitely be attributed to blister rust has been less than 1.5 percent, but losses to natural reproduction trees appear to be much higher.

Individual infected trees of the best crosses averaged approximately the same number of cankers per tree as infected trees among the controls or the natural reproduction.

To relate results of this study and those following artificial inoculations of the same progenies in earlier nursery trials, we calculated the correlation between the percent still uninfected in the field and the percent survival in the nursery. The calculations yielded a correlation coefficient of 0.33, which is just significant at the 5 percent level. Thus, the correspondence between nursery and field results for individual progenies is rather poor. Factors that could have contributed to the low correlation include: (1) The combination of low numbers of individuals per progeny (a maximum of 81 in the nursery and 48 in the field, and mean numbers of about 40 and 24, respectively) and minor variations in amounts of inoculum could have changed either nursery or field data several percentage points; (2) nursery tests involved inoculation at age 2 or ages 1 and 2, when seedlings were highly susceptible, but planted seedlings in the field tests were not exposed to inoculum until they were at least 3 years old; and (3) infection (or the absence of infection) might not be directly related to survival since resistant trees might overcome infection.

The first generation progenies of crosses involving two rust-free trees known to exhibit GCA for resistance transmission were much less infected (20 percent for GCA crosses as opposed to 58 percent for control crosses and 71 percent for natural reproduction). Whether or not this degree of improvement will be sufficient to make economical plantings of first-generation materials remains to be seen. If healthy trees in the plantations are infected at the average annual rate (ca. 1.5 percent/year) recorded for these first 11 to 15 years, then 90 percent will have become infected at 60 years. However, the percentage of trees infected is usually far greater than the percentage of trees killed by the rust (MacLeod 1940; Slipp 1953). We will have to follow the incidence of the rust and of rust mortality in the plantations for many years to see how many trees are harmlessly infected and whether most future infections occur on currently healthy or on currently infected trees. Nevertheless, these preliminary results are sufficiently encouraging for the Northern Region of the USDA Forest Service to commence interim planting of first-generation nursery stock from a grafted orchard of GCA-parents at Sandpoint, Idaho (Bingham and others 1963).

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Research Note

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RELATIVE ABUNDANCE OF MICE ON SEEDED SAGEBRUSH-GRASS RANGE IN RELATION TO GRAZING

Hal L. Black[1] and Neil C. Frischknecht[2]

ABSTRACT

The kinds and relative abundance of small rodents were studied in relation to various kinds of grasses and different intensities of grazing by cattle. Deer mice, Great Basin pocket mice and western harvest mice comprised over 98 percent of the total catch. Deer mice were most abundant in heavily grazed seeded areas and native areas having relatively light cover. Great Basin pocket mice and western harvest mice were most abundant in areas of relatively light grazing. No definite correlation was found between relative abundance of any rodent and species of grass.

Sagebrush-grass vegetation has been greatly modified by man and his animals in the Intermountain region. Some abortive attempts at dryland farming resulted in a considerable amount of abandoned land by the early 1930's. Also, heavy grazing by livestock in both spring and fall contributed to depletion of vast areas in this zone situated mainly between the higher summer ranges and the lower salt desert shrub winter ranges. Fortunately, many abandoned and depleted areas have been rehabilitated by seeding with adapted grasses. The effects of such modifications and subsequent grazing by livestock on small mammals are not well known. This paper reports results of a study designed to determine the kinds and numbers of rodents present in relation to various kinds of grasses and different intensities of grazing by cattle.

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This study was conducted during summer and early fall of 1966 and 1967 on the Benmore Experimental Range in southeastern Tooele County, Utah, which is typical of much improved spring-fall range in the Intermountain region. Elevations of the area range from 1,700 to 1,890 m. (5,600 to 6,200 ft.). Annual precipitation is approximately 33 cm. (13 in.). Originally, the experimental area was part of the natural sagebrush-grass community bordering the lower edge of the pinyon-juniper. Modifications of the area by man have produced a sizable number of pastures for grazing of livestock, 15 of which were involved in this study as follows: (1) 8 units, heavily grazed, that had been fenced from abandoned dry-farm land and seeded in 1939 to crested wheatgrass (*Agropyron desertorum* [Fisch.] Schult.) and fairway wheatgrass (*A. cristatum* [L.] Gaertn); (2) 5 units, moderately grazed, that had been plowed, fenced and seeded to different introduced grasses in 1949; and (3) 2 units, ungrazed, containing native species, one of the units also having been interseeded with a mixture of introduced grasses following burning of both areas in 1953.

METHODS

In the study, short term removal-trapping was accomplished by using snap traps for three consecutive nights in both early summer and early fall of 1966 and 1967. Museum special and standard mousetraps were set in three concentric circles having radii of 11.95 m. (39.2 ft.), 23.93 m. (78.5 ft.), and 35.91 m. (117.8 ft.), respectively, from a common center. The outer circle enclosed an area of 0.4047 ha. (1 acre). Twenty-four traps were set on the outer circle, 16 on the middle, and 8 on the inner circle, making a total of 48 traps per acre. The distance between traps along the circumference of each circle was approximately 9.45 m. (31 ft.). Two 1-acre plots were sampled in each of the 15 pastures.

Traps were baited each night before dark using a peanut-butter and rolled-oats mixture. With few exceptions, traps were checked and set off each morning prior to 8 a.m. to prevent catching unwanted species such as birds.

RESULTS

Over the two years, a total of 17,280 trap nights yielded 587 rodents. Three species comprised over 98 percent of the total catch as follows: deer mouse (*Peromyscus maniculatus sonoriensis* Le Conte), 65.5%; western harvest mouse (*Reithrodontomys megalotis megalotis* Baird), 19.0%; and Great Basin pocket mouse (*Perognathus parvus olivaceous* Merriam), 14.3%. In addition to these major species, three grasshopper mice (*Onychomys leucogaster utahensis* Goldman) were caught during this study, plus one each of the following species: chisel-toothed kangaroo rat (*Dipodomys microps bonnevillei* Goldman), pinon mouse (*Peromyscus truei nevadensis* Hall and Hoffmeister), desert wood rat (*Neotoma lepida lepida* Thomas), long-tailed meadow mouse (*Microtus longicaudus latus* Hall), and house mouse (*Mus musculus domesticus* Rutty). Subsequent discussion involves only the three most abundant species.

Heavily Grazed Units

The eight units grazed heavily by cattle in early spring (April 20 to May 20) prior to trapping in both 1966 and 1967 had been grazed at different seasons during the previous 5 years. As a result (prior to 1966), five of these units contained a considerable amount of old, dry, standing grass resulting from grazing after maturity in summer or fall. Little or no dry grass occurred in the three units that had been grazed in spring previous to our trapping study. Under heavy stocking in the five units in the spring of 1966, cattle ate a small amount of the old, dry grass, the remainder being dispersed on the ground as litter. Generally, fairway wheatgrass produced less litter than crested wheatgrass.

In the heavily grazed units, deer mice were caught most often of any species in both years of trapping (table 1). Pocket mice were never abundant in these units but were taken quite consistently. Their relatively small numbers appeared unrelated to season or year of trapping. Harvest mice were caught least consistently of the three species; the first year they were caught mostly in localized areas where either grass or brush, or both, were most dense, and none were caught the second year. Whereas numbers of both deer mice and harvest mice increased between early summer and fall trappings in 1966, this was not the case in 1967.

Apparently, old grass litter left lying on the ground in certain units following heavy spring grazing in 1966 had little effect, if any, on numbers of mice present (table 1). If differences due to past grazing existed prior to 1966, they were erased by the heavy spring grazing that year. There were no consistent differences between crested and fairway wheatgrasses as to number of mice trapped.

Table 1.--*Numbers of three mice species caught in eight heavily grazed units according to season of past grazing by cattle*

Season of past grazing	Deer mice 1966 Summer	Deer mice 1966 Fall	Deer mice 1967 Summer	Deer mice 1967 Fall	Pocket mice 1966 Summer	Pocket mice 1966 Fall	Pocket mice 1967 Summer	Pocket mice 1967 Fall	Harvest mice 1966 Summer	Harvest mice 1966 Fall	Harvest mice 1967 Summer	Harvest mice 1967 Fall
Spring:												
Agcr[1]	0	22	2	8	0	2	0	1	0	2	0	0
Agde[2]	4	6	6	4	2	1	2	1	0	0	0	0
Summer:												
Agcr	2	18	3	3	1	0	0	1	0	0	0	0
Agde	4	31	1	3	2	2	1	2	1	4	0	0
Fall:												
Agcr	7	29	0	1	1	2	2	0	0	1	0	0
Agde	3	17	4	3	0	1	0	0	0	3	0	0
Spring + Fall:												
Agde	4	38	5	1	1	0	0	0	1	2	0	0
Summer (Brush):												
Agde	0	29	0	4	0	1	0	0	0	2	0	0

[1]*Agropyron cristatum.*
[2]*Agropyron desertorum.*

Moderately Grazed Units

The five moderately grazed units contained individual stands of crested wheatgrass, pubescent wheatgrass (*A. trichophorum* [Link] Richt.), intermediate wheatgrass (*A. intermedium* [Host] Beauv.), Russian wildrye (*Elymus junceus* Fisch.), and a mixture of the first three grasses plus tall wheatgrass (*A. elongatum* [Host] Beauv.). These units were ungrazed prior to the first trapping in early summer of 1966, but were grazed moderately prior to the second trapping in fall of 1966 and again prior to first trapping in early summer 1967. They had been grazed moderately by cattle for several years, and during this study considerably more dry, standing grass was present in each of them than in the heavily grazed units described earlier (fig.1).

Figure 1.--Typical heavily grazed crested wheatgrass unit at left, contains less dry grass than moderately grazed pubescent wheatgrass at right.

Table 2.--*Numbers of three mice species in moderately grazed units, according to kind of grass*

Grass species	Deer mice 1966 Summer	Deer mice 1966 Fall	Deer mice 1967 Summer	Deer mice 1967 Fall	Pocket mice 1966 Summer	Pocket mice 1966 Fall	Pocket mice 1967 Summer	Pocket mice 1967 Fall	Harvest mice 1966 Summer	Harvest mice 1966 Fall	Harvest mice 1967 Summer	Harvest mice 1967 Fall
Pubescent wheatgrass	3	24	3	1	0	3	0	0	13	7	0	0
Intermediate wheatgrass	0	5	3	0	2	1	1	0	0	2	0	0
Wheatgrass mixture	1	6	0	2	1	0	0	1	5	4	0	0
Crested wheatgrass	0	6	2	2	2	6	1	1	9	8	0	0
Russian wildrye	1	11	0	1	3	3	4	1	2	0	0	0

During the early summer trapping of 1966, harvest mice were the most numerous species in the moderately grazed units (table 2). Their greater abundance in pubescent and crested wheatgrasses coincided with greater volumes of dry, standing grass. Although harvest mice showed an overall decline at time of fall trapping, deer mice had increased substantially and pocket mice slightly. By early summer of 1967, numbers of deer mice and pocket mice had characteristically returned to the approximate levels shown for the same period in 1966, and again, no harvest mice were caught. Possible reasons for numbers remaining relatively low through the fall trapping period of 1967 are discussed later.

Nongrazed Units

The two units containing native grasses that had never been plowed were essentially ungrazed by livestock during this study. On one unit a mixture of crested, intermediate, and tall wheatgrasses had been seeded into the native remnant following burning of sagebrush in 1953; this unit contained more dry, standing grass than any unit during this study (fig. 2). Much less dry grass occurred on the adjacent unit containing mainly native thickspike wheatgrass (*Agropyron dasystachyum* [Hook.] Scribn.), bluebunch wheatgrass (*A. spicatum* [Pursh] Scribn. & Smith), Sandberg bluegrass (*Poa secunda* Presl.), and bottlebrush squirreltail (*Sitanion hystrix* [Nutt.] J. G. Smith).

Striking contrast existed in the mice catches on these two areas (table 3). Deer mice were most abundant in the unit of relatively short cover containing only native plants, but harvest mice were most abundant in the unit of tall cover having a mixture of native and introduced species.

Figure 2.--Mixture of introduced and native grasses at left provides denser cover for mice than area at right which contains only native species.

Table 3.--*Numbers of three mice species in nongrazed units in relation to kind of vegetation*

Vegetation	Deer mice				Pocket mice				Harvest mice			
	1966		1967		1966		1967		1966		1967	
	Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall	Summer	Fall
Native only	10	24	0	2	2	6	0	5	1	0	0	0
Introduced + native	1	10	0	5	3	9	0	3	22	21	0	0

DISCUSSION

We don't know to what extent weather may have been responsible for lack of substantial fall increases in numbers of mice on the heavily and moderately grazed units in 1967. However, precipitation totaling 4.1 inches during May and June, 1967, was considerably higher than the 1.1 inches for the same period in 1966, and also higher than the long term average of 1.99 inches for these two months. Blair (1948) reported that above-average rainfall during April, May, and June had an adverse effect on small mammals in Michigan. He suggested that above-average rainfall causes flooding of nest sites. Our data indicated that the breeding season at Benmore may be at a peak during April, May, and June, which encompassed the period of relatively high rainfall.

Pocket mice were seemingly least affected by factors that caused a general decline in densities of mice in 1967. These mice are known to undergo periodic torpor in response to low food supplies and/or low temperatures (Bartholomew and Cade 1957; Tucker 1962). They also become less active during winter months (Scheffer 1938). This ability of pocket mice to "remove" themselves from periods of environmental stress may explain, in part, why they appeared to be least affected by those factors responsible for the generalized decline in 1967.

Deer mice were caught most frequently in heavily grazed areas and areas with the least amount of cover. Other investigators have presented data suggesting that various species of *Peromyscus* avoid and may be at some disadvantage in areas of abundant cover (Hooper 1939; Andrewartha and Birch 1954; LoBue and Darnell 1959). Dambach (1944) found *Peromyscus leucopus noveboracensis* (Fischer) to be commoner in the grazed than in the ungrazed woodlands of Ohio.

Deer mice eat numerous kinds of arthropods and a wide variety of plant material (Jameson 1952; Williams 1959; Johnson 1961; Frischknecht 1965). Whitaker (1966) found lepidopterous larvae to be the ". . . single most important food throughout the summer and fall." Some studies have shown that insects increase where grazing is heavy (Smith 1940a, 1940b). This may explain, in part, the abundance of these mice in heavily grazed sites in the study area.

Harvest mice were noticeably rare in the nongrazed native grasses which were generally shorter than the introduced grasses on the adjacent area (fig. 2). Since these mice nest essentially above ground (Smith 1936; Hooper 1952), habits of growth of grasses and patterns of accumulation of litter would appear to be important factors for their success. Other investigators have found these mice to be associated with heavy plant cover (Blair 1943; Fautin 1946; Verts 1960; Brant 1962). From available information on food habits of harvest mice, it appears that seeds are the most important item in their diet plus considerable quantities of arthropods when available (Smith 1936; Johnson 1961). Of course, in addition to taller cover, seed production of the introduced wheatgrasses was much greater than that of most native grasses.

Pocket mice were most abundant in the nongrazed area where there was a mixture of seeded and native grasses and where cover and seed production were heavier than on any other site. Examination of the contents of cheek pouches of 33 pocket mice from all areas showed that seeds of grasses were the commonest food taken. Studies of pocket mice food habits by various workers have revealed a diet consisting primarily of seeds, especially those of grasses (Scheffer 1938; Johnson 1961). However, Jameson (1954) found insect remains to be common in a sample of 18 *P. parvus* taken in California in April. Other workers have found grazing to be detrimental to four other kinds of pocket mice (Quast 1948; Reynolds and Haskell 1949).

The study suggests that seeding programs increase pocket and harvest mice numbers where subsequent grazing by cattle is of light intensity. In contrast, seeding programs increased numbers of deer mice where utilization of forage by cattle was heavy. No correlation is evident between relative abundance of any rodent and species of grass.

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HAND PREPARATION OF SEEDBEDS IMPROVES SPOT SEEDING OF LODGEPOLE PINE IN WYOMING

James E. Lotan and Allen K. Dahlgreen[1]

ABSTRACT

Hand-prepared, 12-inch-square seed spots greatly reduced the amount of seed required to spot seed lodgepole pine on slopes less than 45 percent in the Abies lasiocarpa/Vaccinium scoparium *habitat type in Wyoming. Viable seed:seedling ratios after 3 years were 5:1 on scalped 12-inch-square seed spots on the level and along the slope, 12:1 on scalped 5-inch-square seed spots along the slope; and 60:1 for seed sown in the ash and duff left by broadcast burning of logging slash. Percentages of spots stocked were as follows: 72 percent for scalped 12-inch squares on the level; 64 percent for the scalped 12-inch squares on the slope; 38 percent for the scalped 5-inch squares on the slope; and 10 percent for the ash-duff seedbeds.*

The ability to successfully direct seed lodgepole pine (*Pinus contorta* Dougl.) will provide a useful and flexible alternative in regenerating stands, especially where serotinous cones do not store enough seed to regenerate the area. Spot seeding success depends largely upon proper selection of favorable sites as well as maintaining minimal levels of seed-eating animals and of competing vegetation. A major cause of lodgepole pine seedling mortality seems to be soil-moisture depletion caused by competing vegetation (Wagg and Hermann 1962, Lotan 1964, Stermitz 1968).

Spot seeding usually insures greater regeneration success than broadcast seeding because seed is placed on favorable microsites and directly covered with soil. Moreover, spot seeding requires far less seed than broadcast seeding (Smith 1962). This paper reports regeneration success of lodgepole pine three growing seasons after spot seeding four different seedbeds.[2]

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[1]Respectively, Research Silviculturist, stationed in Bozeman, Montana, at the Forestry Sciences Laboratory, maintained in cooperation with Montana State University; and Forester, Branch of Silvicultural Practices, Intermountain Region, USDA Forest Service, Ogden, Utah.

[2]This paper is the result of an Administrative Study conducted by the junior author, in cooperation with Bridger National Forest personnel.

LOCATION AND METHODS

The test was conducted in the *Abies lasiocarpa/Vaccinium scoparium* habitat type in western Wyoming on the Greys River drainage of the Wyoming Range. All sites are on northerly slopes at an elevation of 7,900 ft. The slope and aspect of each site are given below.

	Percent slope	*Aspect*
Site 1	35	N
Site 2	45	WNW
Site 3	15	WNW

The areas were logged in 1966 and the slash broadcast burned in late September 1966.

Seeds (90 percent viable) were sown June 15-16, 1967, using a Panama seeder. The machine used was calibrated to place 12 seeds (1) in approximately one-half to 1 inch of ash and duff, (2) on scalped 5-inch squares along the slope, (3) on scalped 12-inch squares along the slope, and (4) on scalped 12-inch squares on level benches (fig. 1). On the scalped areas, seed was covered with approximately one-eighth inch of mineral soil, but on the remaining areas it was mixed into the ash and duff about one-eighth inch. Each set of treatments was replicated systematically 50 times on each of the three sites. Replicates were spaced approximately 6 to 8 feet apart along a transect randomly placed across the harvested area.

Rodents were controlled by means of poison baits. Treatment consisted of distributing one-half pound of treated wheat per acre throughout the study area and surrounding 100-foot-wide buffer zones. Both the wheat and the tree seed had been treated by application of 1 pound of 50% W. P. endrin and 5 pounds of anthroquinone, with latex sticker and aluminum powder coating.

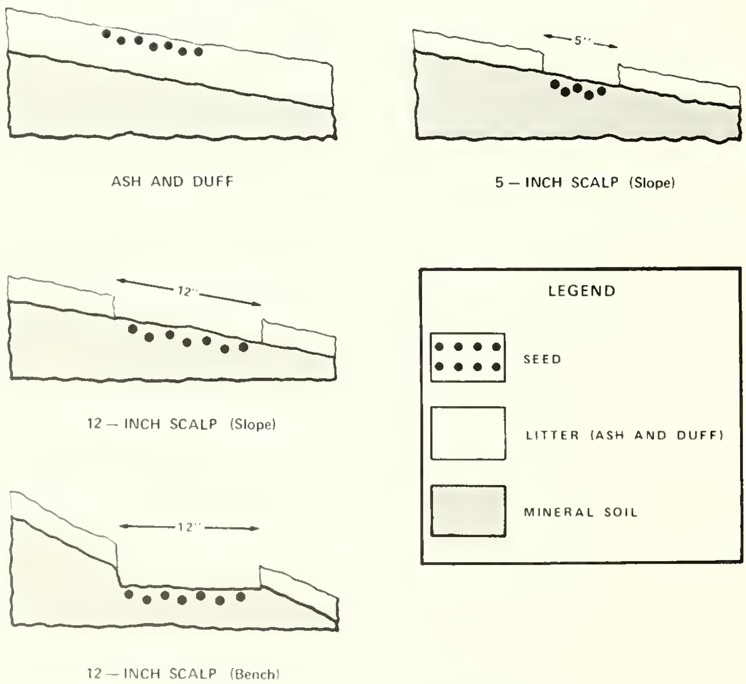

Figure 1.--Four seedbed treatments used in spot seeding lodgepole pine. (Schematics are not scaled proportionately.)

Seedlings were tallied twice during the first year, August 8 and September 25, 1967, and once during the third year, September 15, 1969. Data were analyzed by analysis of variance and treatment means compared by using Scheffé's *S* test for multiple mean comparisons (Scheffé 1959).

RESULTS

Lodgepole pine seedling establishment increased significantly when seed spots were placed on scalped areas rather than in the ash and duff. As shown, both the number of surviving seedlings (fig. 2) and the percentage of stocked plots (fig. 3) increased with the size of the scalp.[3] There were no real differences between the 12-inch slope and 12-inch bench treatments; however, it was beneficial to increase the size of the scalped areas from 5 to 12 inches. Viable seed:seedling ratios after three growing seasons were also most favorable on the scalped spots (fig. 2)--5:1 for both 12-inch treatments (2.35 seedlings per spot); 12:1 for the 5-inch treatment (0.89 seedlings per spot); and 60:1 for the ash and duff treatment (0.18 seedlings per spot).

One of the most important considerations of spot seeding is the percentage of stocked spots. Here, too, there was no difference between the two 12-inch treatments, but stocking on both 12-inch treatments was approximately double that on 5-inch scalps.

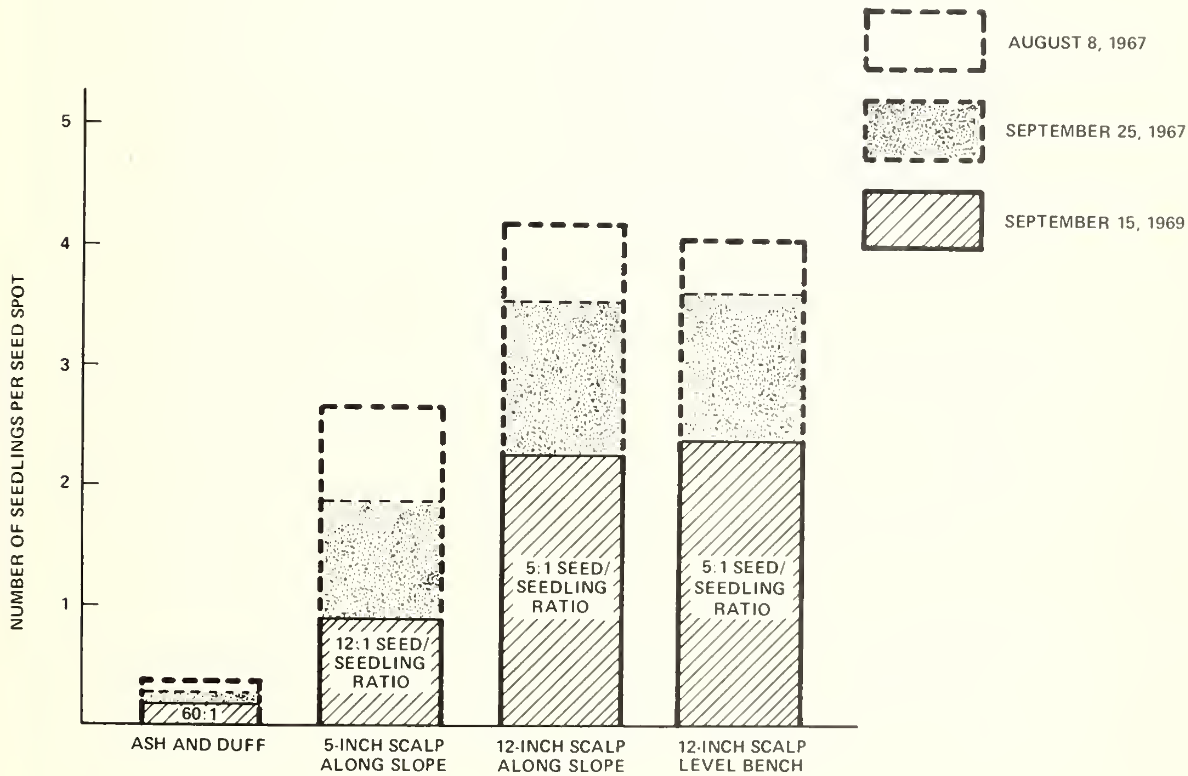

Figure 2.--Average number of seedlings per seed spot by treatment and date examined.

[3]Data from the three sites were pooled because there were no significant treatment X site interactions.

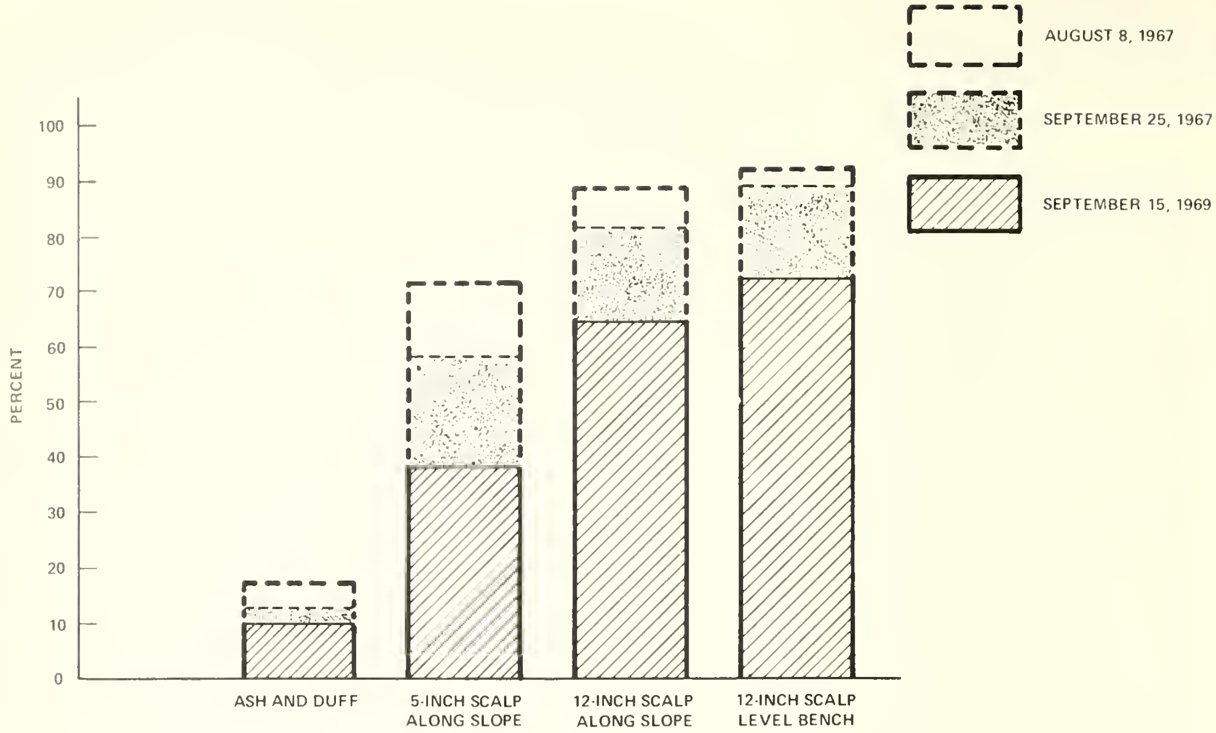

Figure 3.--Percentage of stocked spots by treatment and date examined.

DISCUSSION AND CONCLUSIONS

Although we have no supporting data, we assume that the preparation of sites by hand reduced competing vegetation (largely graminoids and forbs). We have observed that the largest and most vigorous seedlings in the field are those that grow free of competing vegetation (fig. 4); seedlings that grow in or near a clump of grass are stunted and spindly. We believe that the test reported clearly demonstrates the importance of reduced competition to successful spot seeding of lodgepole pine. Further, it demonstrates that spot seeding can be successful in the *Abies/Vaccinium* habitat type in this area.

We also believe that removal of competing vegetation from the 12-inch-squares will permit successful spot seeding in other areas in this habitat type. The 60:1 viable seed:seedling ratio obtained here in the ash and duff was similar to those obtained by broadcast seeding this seedbed and habitat type in Idaho.[4]

Roe and Boe (1952) and Tackle (1961) also successfully spot seeded lodgepole on scalped, 6- to 12-inch areas in the Little Belt Mountains of central Montana. Here, too, seed:seedling ratios were comparable, about 5:1 for established (10-year-old) seedlings. When a decision to direct seed has been made we recommend removal of competing vegetation on scalped areas about 12 inches square prior to spot seeding lodgepole pine in the *Abies/Vaccinium* habitat type in Wyoming. It is likely that the treatment will also be successful on *Abies/Vaccinium* type elsewhere.

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[4]Data on file, Intermountain Forest and Range Experiment Station, Bozeman, Montana.

Figure 4.--Eight-week-old lodgepole pine seedling growing free of competing vegetation. Marker is a plastic toothpick.

Costs of seed for spot seeding should be less than those for broadcast seeding. Seed costs for spot seeding should also be less than planting stock costs. Rodent control, fencing, and other protection costs would be additional and will vary with the situation on the planting site. Thus, the cost advantage of spot seeding largely depends upon the placement of seed in favorable microenvironments. In addition, if seed spots are prepared by hand, spot seeding results improve.

Seed requirements can be calculated (depending upon the forester's stocking objectives) from an estimate of the number of stocked spots desired, viable seed:seedling ratios, and the viability of seed used.

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GERMINATION INHIBITION IN SEED OF *CEANOTHUS PROSTRATUS* BENTH.[1]

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ABSTRACT

Studies revealed that seed dormancy in squaw carpet (Ceanothus prostratus) *could be due to a chemical inhibitor and to physiologically immature embryos. Isolation of chemical compounds in the developing seed was done by paper and gas chromatography. Inhibition was tested by germination assay. Metabolism in the after-ripening seed was indicated by changes in the lipid ratios in the seed. Successful germination is dependent on removal or destruction of the inhibiting material by a pretreatment consisting of either boiling for 10 minutes in water or soaking in acetone for 5 minutes, followed by after-ripening at 10° C. for 60 or more days.*

Land denuded of vegetation by natural disaster or disturbed by the activities of man is subject to accelerated erosion. It is desirable, therefore, to rapidly establish a plant cover to minimize erosional damage. The ideal cover would be relatively low growing and spreading but not to the extent of excluding other species. Squaw carpet *(Ceanothus prostratus)*, a native of the Sierra Nevada, offers such possibilities. However, for purposes of economy, a plant must establish itself readily from seed (Brown and others 1971). Without treatment, germination of squaw carpet is slow and generally less than 5 percent; thus, treatment of the seed may be required.

Treating the seed with acetone for 5 minutes followed by rinsing in cold water, or boiling in water for 10 minutes and allowing to steep until cool, increased the germination to 24 and 16 percent, respectively. Subjecting the seed to after-ripening at 0° C.

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and 10° C. for periods of 60 or more days without pre-treatment did not result in significant increases over the control. Pre-treatment followed by after-ripening at only 0° C. was not effective in increasing germination above that for pre-treatment alone. However, germination was increased when pre-treatment was followed by after-ripening at 10° C. for periods of 60 or more days. Sixty-five percent germination was obtained by boiling the seed and then holding them for 68 days of after-ripening at 10° C.

The germination obtained with these pre-treatments strongly indicated the presence within the seed of some substance that blocks metabolism. Removal or destruction of this material is necessary before the after-ripening process can occur.

MATERIALS AND METHODS

Each treatment required 10 grams of *C. prostratus* seed collected in the Sierra Nevada for this study. The test seed was boiled and soaked in acetone in the light and then subjected to varying periods of after-ripening at 10° C. and compared to the control which received no treatment and was stored dry at room temperature.

Metabolic changes were studied by analysis of the lipid fraction obtained from periodic extraction of the seed samples. The method of Mirocha and DeVay (1961) was used to esterify the fatty acids before analysis by gas chromatography. Changes in the proportions of the fatty acids were considered to be an indication of metabolism.

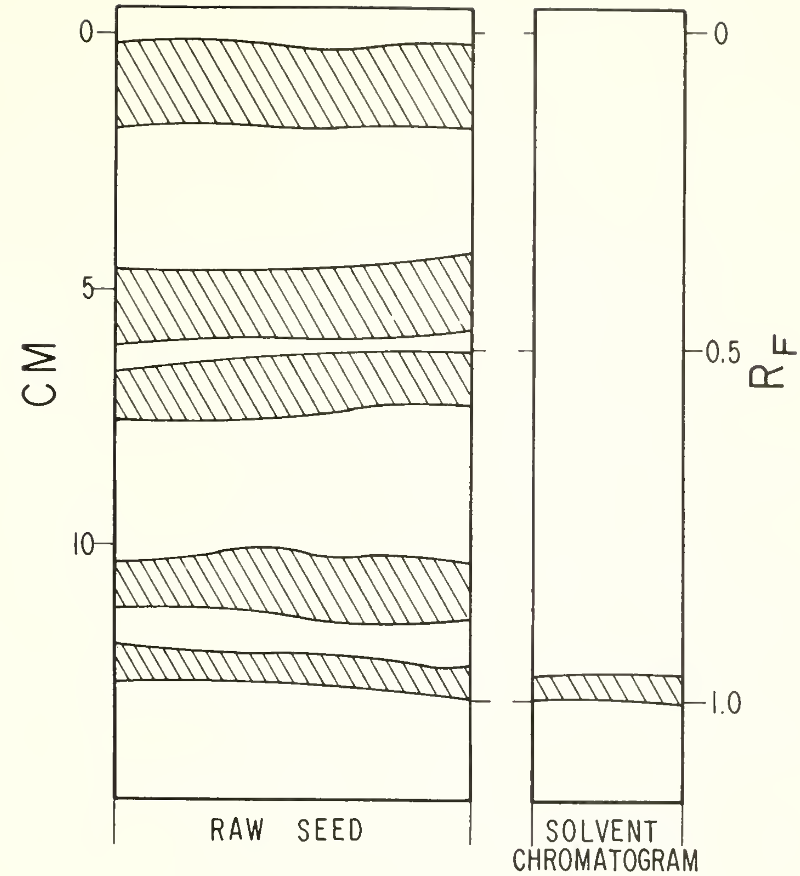
The water used for boiling, and the acetone used to soak the seed, were examined by paper and gas chromatography to determine if any material had been removed from the seed during treatment.

The method outlined by Hilton and others (1965) was used to prepare and chromatograph the seed extract. The seed capsule of *C. prostratus* normally contains three seeds which are forcefully ejected when mature. This factor contributes to the difficulty of harvesting large quantities of seed. Untreated *C. prostratus* seed germinates irregularly over a period of several weeks and at a rate of less than 5 percent. Therefore, for the bioassay, seed of the common tomato *(Lycopersicon esculentum)* was selected as a dependable responsive organism to test the effect of any substance found on the chromatograms. These seeds were germinated individually on 1-cm.^{2} pieces of filter paper having the following characteristics: control (no treatment); blank chromatogram (solvent system); and chromatograms of raw seed extract (aqueous suspension of macerated untreated seed). The pieces of filter paper were placed in individual cells of miniature polyethylene ice-cube trays. After placement of the tomato seed, the filter paper was moistened and the trays were wrapped in a sheet of household Saran. The seed was held at room temperature and the percent of germination recorded at 12-hour intervals for a total period of 156 hours.

RESULTS

When observed under longwave ultraviolet light, five fluorescent bands were detected in the untreated seed extract that included the solvent front (fig. 1). Only the solvent front was detectable on the blank (solvent) chromatogram (fig. 1). The bioassay revealed germination inhibition at the solvent front of both chromatograms, indicating the presence of some substance in the filter paper that was concentrated by the solvent and inhibitory to the germination of tomato seed. Inhibition was also found in two bands of the raw seed extract. A band located at approximately R_f 0.7 had a transitory effect on germination. The band located at approximately R_f 0.9 was inhibitory throughout the entire period of testing (fig. 2). The analysis of variance of the 156-hour data reveals a treatment difference that is significant at the 10-percent level of probability. Therefore, it is probable that the R_f 0.9 band contained an unknown germination inhibitor that was active on tomato seed. The molecular weight of this inhibiting substance at band R_f 0.9 was not determined. However, the substance characteristically increases the solution vapor pressure when dissolved in absolute ethanol. Therefore, it is one of relatively few compounds.

Figure 1.--Chromatograms of raw seed extract and solvent system. White fluorescence is indicated by the shaded bands.



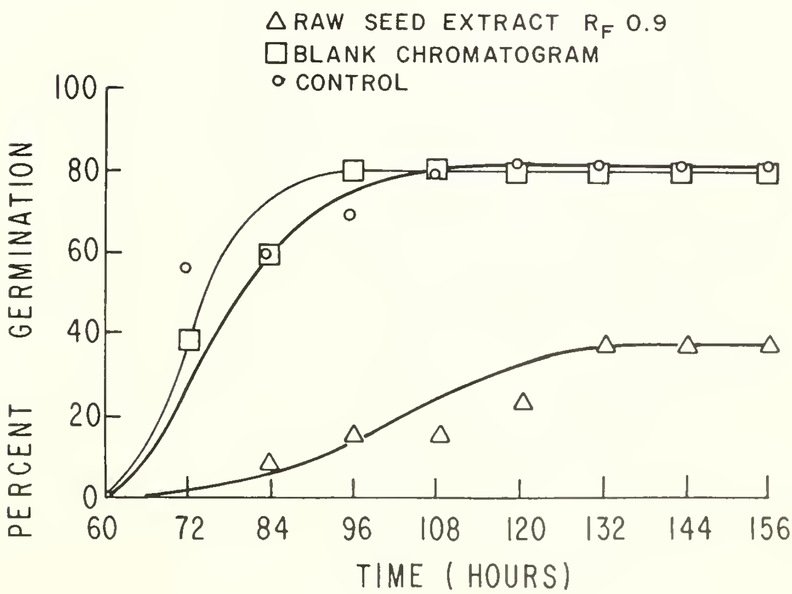


Figure 2.--The effect of band R_f 0.9 on the germination of tomato seed.

Table 1.--Effect of boiling and after-ripening on the comparative amounts of fatty acids in the seed of C. prostratus

Treatment	Fatty acids			
	Palmitic	Oleic	Linoleic	Linolenic
	- - - - - - - -	- - - - *Percent*	- - - -	- - - - - - - -
Raw seed	40	81	100	60
Boiled	48	82	100	52
Boiled plus 7 days at 10° C.	54	79	100	32
Boiled plus 14 days at 10° C.	54	71	100	29

Detectable changes in the amounts of fatty acids in the seed occurred during the after-ripening process when this process was preceded by boiling (tables 1 and 2).

No lipids were detectable in the water that had been used for boiling or in the acetone used for soaking the seed. Both the water and the acetone were chromatographed by a procedure identical to that employed for the seed extract. Furthermore, no materia except the solvent front was found in the water when examined under ultraviolet light, and this could not be distinguished from the solvent front of the blank chromatogram. The solvent front of the chromatogram prepared from the acetone was somewhat wider and more intense than that of the blank chromatogram.

Table 2.--A comparison of the utilization of fatty acids during after-ripening of C. prostratus *seed*

Treatment	Fatty acids			
	Palmitic	Oleic	Linoleic	Linolenic
	- - - - - - - -	- - - - *Percent*	- - - -	- - - - - - - -
Raw seed	100	100	100	100
Boiled	130	112	105	96
Boiled plus 7 days at 10° C.	88	65	67	36
Boiled plus 14 days at 10° C.	76	50	57	28

DISCUSSION

Previous studies showed that successful germination of squaw carpet is dependent on treatment of the seed and a period of after-ripening at a temperature that permits occurrence of metabolic processes. Bioassay of the raw seed extract did show at R_f 0.9 the presence of a material that is inhibitory to the germination of tomato seed. Although there is no direct evidence that this material is inhibitory to *C. prostratus*, the changes in the total amounts of fatty acids and their ratios to the amounts of linoleic acid after treatment indicate that the extract could be involved in the metabolism of this species. Destruction or removal of this inhibiting material is necessary before the metabolic changes that result in germination can take place during the after-ripening process. The dormancy of this species appears, then, to be attributable to two factors: the presence of an inhibitor; and physiologically immature embryos (Amen 1964).

Wareing and Foda (1956) reported the occurrence of fluorescent inhibitors in *Xanthium* and *Lactuca* seed; also, it was noted that these inhibitors lost their fluorescent properties when subjected to high oxygen tension in the presence of a cell-free extract of the seed. The reduction or modification of the lipid content of the testa would allow a greater exchange of gases to take place between the embryo and the environment; however, since the analysis of the agents used was negative for lipids, such an exchange would seem unlikely in the present study. Chromatographic studies of the seed extracts before and after treatment indicate a different mechanism for the two treatments used in this study. Band R_f 0.9 is not detectable on chromatograms made immediately following treatment with boiling water or acetone (fig. 3); this indicates destruction or removal of this band by the two agents without the involvement of an enzyme-controlled system.

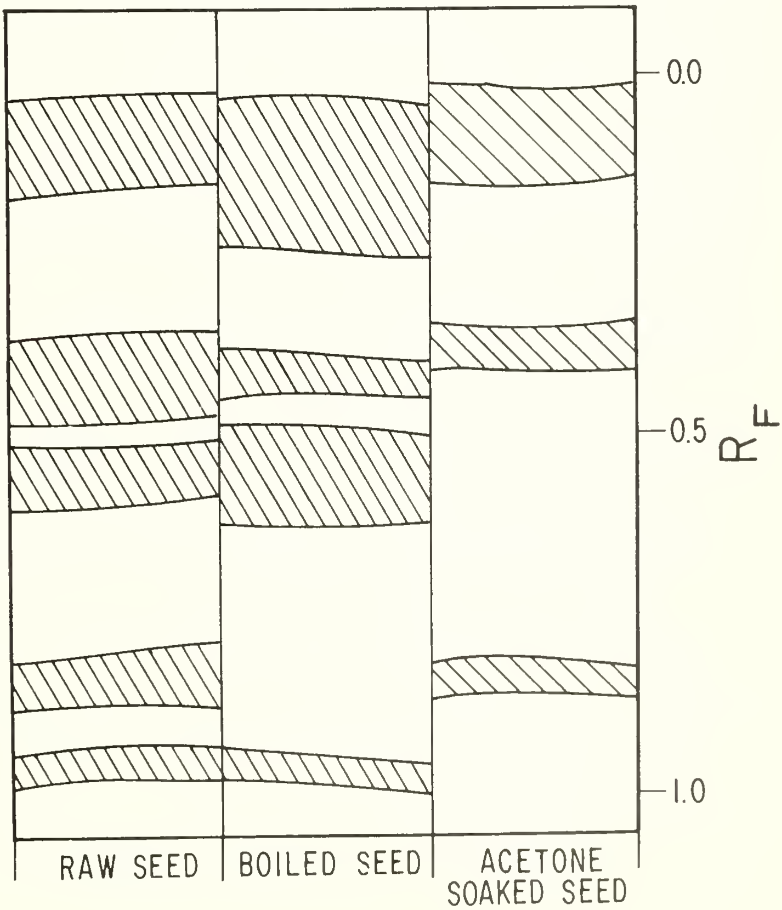


Figure 3.--Chromatograms showing the effect of boiling and acetone soak on detectable fluorescent bands in C. prostratus *seed.*

Chromatography of the water used to boil the seed was negative for any fluorescent material other than the solvent front; thus, boiling the seed in water must be responsible for the destruction of the material in band R_f 0.9. This destruction could be a direct action such as hydrolysis of the substance. A report by Nutile (1943), however, indicates that boiling water might be only indirectly involved in the destruction of the inhibitor. For example, he was unable to induce dormancy in lettuce seed with coumarin if the seed was exposed to light while still wet. Furthermore, since all the treatments in this study were carried out in the light, there is a possibility that the boiling treatment only serves to moisten the seed sufficiently to allow light, as a direct agent, to destroy the fluorescent and inhibitory properties of the material of band R_f 0.9.

The mechanism of acetone, on the other hand, differs from that of boiling water. The acetone treatment removes the materials that appear as fluorescent bands at R_f 0.7 and R_f 0.9 (fig. 3). The chromatogram of the acetone used for treatment does show an increase in the intensity of fluorescence at the solvent front in comparison with the blank chromatogram, but there is a difference in the position of the material. Milborrow (1963) suggested that acetone could be used to remove inhibitory materials from seed. In this study, the difference in position on the chromatogram could indicate that removal might be accompanied by simultaneous modification of the inhibitory substance.

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Research Note

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A CUBIC-FOOT STAND VOLUME EQUATION FOR LODGEPOLE PINE IN MONTANA AND IDAHO

Dennis M. Cole[1]

ABSTRACT

Presents a total cubic-foot volume equation and table, and merchantable volume conversion factors for lodgepole pine stands in Montana and Idaho.

Foresters and landowners often have need for quick, reliable estimates of stand volumes. The use of stand volume equations can provide such estimates while eliminating much of the computational work involved in the traditional individual-tree volume approach. In addition, the need for obtaining tree diameter measurements is eliminated when point sampling methods are used.

Stand volumes can be determined rapidly and efficiently from basal area and height data. Spurr (1952) made numerous tests on a number of volume equations and found the product of stand basal area and height to be strongly related to stand volume. Reliability of estimates was adequate for management needs and compared closely with estimates obtained by traditional stand volume sampling methods based on volumes of individual trees. Other workers have since used the basal area-height relationship in developing stand volume equations (Buckman 1961; Brinkman 1967; Myers 1967).

This paper presents a stand volume equation and table, and table of merchantable volume conversion factors for lodgepole pine (*Pinus contorta* Dougl.) in Montana and Idaho, and describes their development and application. The stand volume equation and table provide estimates of total, gross cubic-foot volume per acre and are applicable to even-aged stands. The table of conversion factors provides merchantable cubic-foot volume estimates for specified stump height and minimum upper stem diameters. The equation and tables are suggested for use with point sampling methods.

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METHODS

A stand volume equation was developed by using plot data from 125 unmanaged lodgepole pine stands located in Montana and Idaho. The stands represented a broad range of stand structures. Basal areas per acre ranged from 30 to 250 square feet and height of dominant trees ranged from 21 to 83 feet. Stand ages ranged from 22 to 125 years.

Cubic-foot volumes for stands were available from 125 permanent plots; merchantable volumes were available from 116 of these plots. Minimum tree sizes included were 0.5 inch d.b.h. for total volume and 4.6 inches d.b.h. for merchantable volume.

Volumes of individual trees were based on an equation developed for forest survey purposes by James Brickell, using stem analysis data from 226 lodgepole pines from western Montana and 606 lodgepole pines from Wyoming and Colorado.[2]

Covariance analysis indicated data from the two geographical areas were not statistically different, so the data were pooled in developing a tree volume equation:

$$V = 0.002782\, D^2H\, (H^{0.0488}/D^{0.0959})$$

where:

V = Total cubic-foot volume
D = Diameter at breast height, outside bark, in inches
H = Total tree height in feet

Although the nonlinear volume function could have been made linear by logarithmic transformation, iterative fitting of the function was chosen to allow nonlinear experimentation with the ratio of height to diameter as an expression of the cylinder form factor. The final equation was obtained, using Marquardt's (1966) Fortran IV computer program for least squares estimation of nonlinear parameters. The equation was weighted in fitting, using weights inversely proportional to the variance about the regression surface.

Merchantable cubic volumes of individual trees were based on the following volume distribution function for lodgepole pines (Honer 1967):

$$V_m = V_t\ (0.9658 - 0.1278X - 0.8108X^2)$$

where:

V_m = Volume in merchantable cubic feet
V_t = Volume in total cubic feet
X = $d^2/D^2\ (1 + h/H)$
d = Top diameter, inside bark, in inches
D = Diameter at breast height, outside bark, in inches
h = Stump height in feet
H = Total tree height in feet

Merchantable volumes were computed for minimum top diameters of 3 and 4 inches diameter inside bark (d.i.b.) and stump height of 0.5 foot.

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[2]Unpublished data from Idaho and Montana are on file at Intermountain Forest and Range Experiment Station, Moscow, Idaho. Colorado and Wyoming data were furnished by courtesy of Clifford Myers, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, and were discussed in a previous publication (Myers 1964).

Table 1.--*Stand volume table for lodgepole pine in Montana and Idaho*[1]

Basal area (ft.^{2})	Average height of dominant trees (Feet) 10	20	30	40	50	60	70	80	90	100
	Stand volumes in cubic feet per acre[2]									
30	108	249	390	531	671					
50	202	437	671	906	1,141	1,376				
70	296	625	953	1,282	1,611	1,939	2,268	2,597		
90	390	812	1,235	1,657	2,080	2,503	2,925	3,348	3,770	
110	484	1,000	1,517	2,033	2,550	3,066	3,583	4,099	4,615	5,132
130		1,188	1,798	2,409	3,019	3,629	4,240	4,850	5,461	6,071
150		1,376	2,080	2,784	3,489	4,193	4,897	5,601	6,306	7,010
170		1,564	2,362	3,160	3,958	4,756	5,555	6,353	7,151	7,949
190		1,751	2,643	3,536	4,428	5,320	6,212	7,104	7,996	
210		1,939	2,925	3,911	4,897	5,883	6,869	7,855	8,841	
230			3,207	4,287	5,367	6,447	7,526	8,606		
250			3,489	4,662	5,836	7,010	8,184	9,358		
270			3,770	5,038	6,306	7,573	8,841			
290			4,052	5,414	6,775					

[1]Block indicates extent of basic data.
[2]Includes entire stem volume of all trees larger than 0.5 inch d.b.h.

A stand volume equation was obtained by linear regression of volume per acre in cubic feet on the product of basal area per acre and average height of dominant trees (BH). The equation was weighted in fitting by the quantity $1/(BH)^2$, to compensate for nonhomogeneous variance about regression. Average heights of dominant trees were based on 10 dominant trees per plot. Basal areas were computed from plot diameter-class tallies. The equation is:

$$V_T = 0.46952(BH) - 32.79$$

$$r^2 = 0.995$$

$$S_{y.x} = 82.9 \text{ ft.}^3\text{/acre (2.4\% of the mean)}$$

where:

V_T = Gross volume in cubic feet per acre of all trees greater than 4.5 feet in height
B = Basal area per acre in square feet
H = Average total height of dominant trees in feet

A volume table based on this equation is presented in table 1.

Factors for conversion of stand volume in total cubic feet to merchantable cubic feet per acre were determined graphically (fig. 1) by plotting ratios of merchantable to total cubic-foot volumes over average stand diameters (diameters of trees of average basal areas). They are presented in table 2.

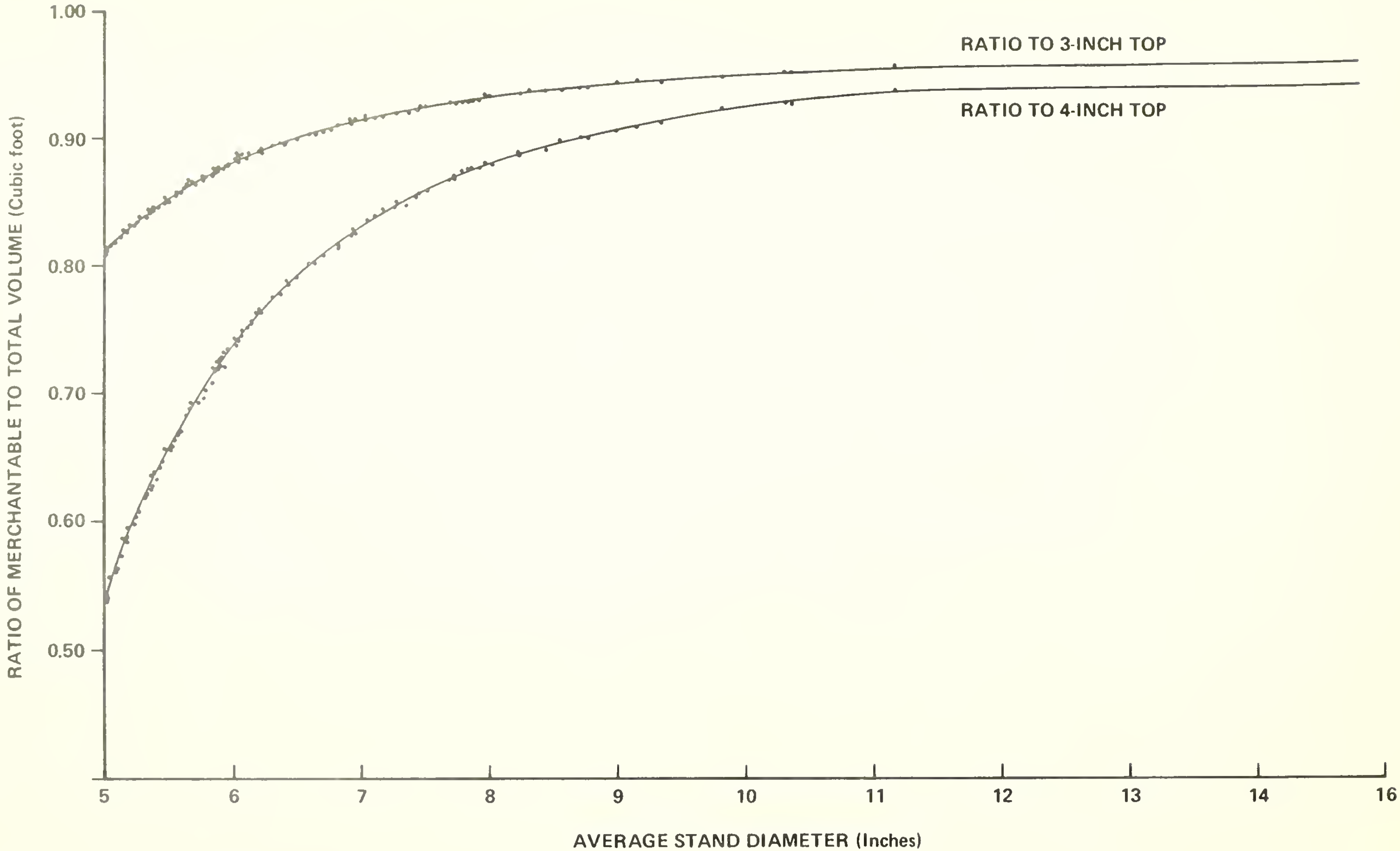

Figure 1.--Ratios of merchantable to total cubic-foot volumes over average stand diameters. (Merchantable volumes were calculated for a stump height of 0.5 foot and minimum top diameters of 3 and 4 inches, inside bark, using Honer's (1967) volume distribution function for lodgepole pines.)

Table 2.--*Factors for conversion of stand volumes in total cubic feet to merchantable*[1] *cubic feet per acre, lodgepole pine in Montana and Idaho*

Average stand diameter (inches)	Ratio of merchantable to total volume		Average stand diameter (inches)	Ratio of merchantable to total volume	
	3-in. top	4-in. top		3-in. top	4-in. top
5.0	0.810	0.541	8.2	0.933	0.884
5.2	.828	.596	8.4	.935	.890
5.4	.844	.639	8.6	.937	.895
5.6	.857	.675	8.8	.939	.900
5.8	.868	.708	9.0	.941	.904
6.0	.878	.736	9.2	.943	.908
6.2	.887	.762	9.4	.944	.912
6.4	.896	.783	9.6	.945	.916
6.6	.903	.800	9.8	.946	.919
6.8	.907	.815	10.0	.947	.922
7.0	.914	.828	10.5	.949	.928
7.2	.917	.841	11.0	.951	.933
7.4	.921	.852	11.5	.952	.935
7.6	.924	.862	12.0	.953	.937
7.8	.927	.871	13.0	.954	.938
8.0	.931	.878	14.0	.955	.939

[1]Stump height 0.5 foot in trees 4.6 inches d.b.h. and larger.

APPLICATION

The stand volume equation and tables presented here should be applicable to any managed or unmanaged lodgepole pine stands that are within the ranges of average dominant height and basal area classes reported in this paper.

Total gross cubic-foot volume of a lodgepole pine stand can be found by obtaining stand basal area and average height of dominant trees and substituting them in the stand volume equation, or by referring to the stand volume table (table 1). Merchantable gross cubic-foot volume is obtained by multiplying the total cubic-foot volume estimate by the appropriate conversion factor from table 2.

Basal area per acre can be determined from a diameter tally of fixed-radius plots, or from variable-radius plots using an angle gage or wedge prism. The latter method is recommended for efficiency.

For variable-plot cruising, an angle factor should be chosen to give about seven "count" trees per point. Generally, an angle factor of 10 will give satisfactory results. Only those trees with diameters larger than the minimum size of interest should be included in the point tally. When merchantable cubic-foot volume is desired, it is also necessary to count trees of the sizes of interest at each sample point to obtain average stand diameter for use with table 2. A 1/20-acre fixed-radius plot superimposed on the variable plot sampling point can be used for sampling trees per acre. A range-finder set for the radius of a 1/20-acre plot (26.33 ft.) allows plot limits to be defined optically by providing a check on borderline trees. Knowing basal area and trees per acre, the corresponding average stand diameter can be found in a standard basal-area table.

Height of average dominant trees should be measured to the nearest foot at each variable-plot sampling point. One or two height measurements per plot will furnish a representative height of dominant trees if sampling design of cruise is adequate for basal area purposes. To avoid overestimates of volume resulting from the tendency to measure outstandingly tall trees in the stand, one should scan surrounding trees and select one or two "average-appearing" dominants for height measurements. These heights will then be comparable to the "10-tree" average dominant heights used in the development of the stand volume equation.

Determination of sample size is a sampling problem dependent on the stand variability and degree of precision desired. Where experience in similar stands is lacking, a preliminary survey to estimate basal area variation is recommended to determine a suitable sample size in the conventional manner.

To illustrate use of the equation and conversion factors, consider the following examples:

(1) Assume that a stand having diameter classes ranging from 2 to 8 inches is cruised to determine total cubic-foot volume (V_T). Stand basal area is 110 square feet per acre and average height of dominant trees is 55 feet. The calculation is made as follows:[3]

$$\begin{aligned} V_T &= 0.46952(BH) - 32.79 \\ &= 0.46952\ (110 \times 55) - 32.79 \\ &= 2{,}807.8 \text{ cubic feet} \end{aligned}$$

(2) Assume that a stand is cruised to determine merchantable cubic-foot volume to a 4-inch minimum top diameter, inside bark. Diameter classes range from 3 to 11 inches; however, minimum size of merchantable trees included in the cruise is 4.6 inches d.b.h. Trees 4.6 inches d.b.h. and larger represent stand basal area of 120 square feet per acre and an average stand diameter of 8.2 inches. Average height of dominant trees is 72 feet. Merchantable cubic-foot volume is determined as follows:

$$\begin{aligned} V_T &= 0.46952(BH) - 32.79 \\ &= 0.46952\ (120 \times 72) - 32.79 \\ &= 4{,}023.86 \text{ cubic feet} \end{aligned}$$

From table 2 for an average stand diameter of 8.2 inches, the conversion factor is 0.884. Merchantable stand cubic-foot volume (V_M) is computed as:

$$\begin{aligned} V_M &= 0.884\ V_T \\ &= 0.884 \times 4{,}023.86 \\ &= 3{,}557.09 \text{ cubic feet} \end{aligned}$$

[3]Alternatively, total cubic-foot volume can be obtained from table 1, interpolating between height and basal area classes as necessary.

LIMITATIONS

The stand volume equations and tables presented here are intended for estimation of gross stand volumes in Montana and Idaho. No deductions for cull or defect were included in their development. Therefore, stand defect or cull factors (determined by a concurrent survey or past experience) must be applied to the gross volume estimates to obtain net stand volumes.

Limited extrapolations beyond the range of the basic data (as in table 1) seem reasonable; however, no actual tests of the accuracy of such extrapolations have been made.

Where experience shows the equation or table to result in consistently high or low estimates, minor adjustments should be made for the local condition.

SUMMARY

A stand volume equation is presented for even-aged lodgepole pine stands in Montana and Idaho. The equation gives direct estimates of total gross cubic-foot volume of stands from measurements of stand basal area and average height of dominant trees.

A table of conversion factors is presented to provide estimates of merchantable cubic-foot volume. Based on average stand diameters, use of these factors allows conversion of total gross cubic-foot stand volumes per acre to merchantable gross cubic-foot volumes per acre, for specified utilization limits.

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