973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 228

REST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Ponderosa Pine Needle Miner in the Colorado Front Range

Robert E. Stevens[1]

A population of *Coleotechnites* needle miners (Lepidoptera: Gelechiidae) caused noticeable defoliation to ponderosa pines in the Boulder area in 1971 and 1972. Although not assignable to it, this population exhibits life history and habits similar to those reported for *C. pinella* Busck, notably a 1-year life cycle and apparently markedly varied infestation rates between individual trees. Serious tree injury is not expected.

Keywords: *Coleotechnites* needle miners, *Pinus ponderosa*.

During midsummer 1971, Colorado State Forest Service foresters were asked to investigate a band of discolored ponderosa pines stretching along the foothills south of Boulder. The foresters first suspected a foliage disease, but a close look showed that most of the needles had been hollowed out from within by tiny moth larvae—needle miners.

The infestation attracted further attention in 1972, and was noted from Boulder as far south as Golden, in an altitudinally restricted belt of 200 to 300 feet centered at about the 6,200-foot contour level. I observed the infestation Southwest of Boulder near the National Center for Atmospheric Research (NCAR) on several occasions throughout the summer of 1972. This Note describes the main features of the moth's life history and habits, and the amount and kind of damage we expect it to cause.

Taxonomy

Adult moths were identified[2] as a species of *Coleotechnites* (Lepidoptera: Gelechiidae), a well-known genus of needle miners. Only two species, *C. moreonella* Heinrich and *C. pinella* Busck, have been described from ponderosa pine in Colorado (Freeman 1960). The current taxonomic status of the genus is such that the species we are dealing with cannot be precisely determined; it is not *moreonella*, and does not fit Busck's original description of *pinella*. However, biological notes presented in a short paper by Gillette (1922) on moths identified by Busck as *pinella* agree generally with my observations. More work will be needed before the taxonomic status of this and related species can be resolved.

Life Stages

Adult needle miners are tiny moths, with a wing span of about 10-12 mm. The forewings and abdomen of this species are mottled with black and white scales, giving the moths a generally gray appearance. The hind wings, heavily fringed behind, are silvery white.

Fully developed larvae are dark reddish brown with black head capsules, and measure about 8-10 mm. in length. Pupae are dark brown, about 5 mm. long. The eggs are initially yellow orange, nearly spherical, and about 0.5 mm. in diameter. They become more flattened as embryological development proceeds, and the larvae can eventually be seen inside.

---

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

[2] *Moths identified by R. W. Hodges, U. S. National Museum, Washington, D. C.*

Life History and Habits

This ponderosa pine needle miner has one generation per year. Adult moths fly, mate, and lay eggs from late July through September (fig. 1). The moths are extremely quick, and run rapidly about the foliage. If disturbed, they fly readily.

Eggs are laid singly or (most often) in clusters up to 10 or 12, mainly in old mined-out needles, near the opening in the needle through which an adult moth has emerged. After the eggs hatch, in 6-8 weeks, the larvae move to green needles and bore in near the needle tips. They overwinter in these needles, probably feeding little, if any. Development resumes with the onset of warm weather, and larvae pupate within the mined needles around mid-July. Before the larva pupates, it provides for the emergence of the adult by cutting a round hole in the needle and furnishing a silk ramp to direct the adult out through the exit hole.

There is generally one larva per infested needle; each larva requires only one needle to satisfy nutritional requirements. About three-fourths of the needle — usually the central portion — is mined.

The limited observations made so far indicate that the moths prefer needles older than the current year's growth. Thus, the older needles bear the majority of the damage, leaving the new green foliage on the branch tips.

Individual branches from eight heavily infested trees bearing foliage produced from 1968-72 were examined on July 19, 1972. Since adults had not yet emerged, the current year's needles (1972) had no opportunity to become infested, and therefore were discarded. Degree of infestation of 1968-71 needles was as follows:

Year needles were produced	Needles examined	Percent infested
1971	620	13
1970	639	60
1969	484	74
1968	420	74

Presumably all these needles had been infested in summer 1971, because most mined-out needles fall in the autumn after adults have emerged.

There was also considerable variation in defoliation between individual trees: within the infested area, some trees were heavily infested, while adjacent ones were not. A similar situation was also mentioned by Gillette (1922). We do not presently have any explanation for this phenomenon, nor do we have data describing it more precisely. At NCAR in summer 1972, it was estimated that about one-third of the trees were infested enough to be considered severely defoliated.

Not all brown needles, even in the most heavily infested trees, were the result of needle miner activity. Some needles fade due to unknown causes, and natural needle drop throughout the year is normal in pines and accounts for some dead needles. Mined needles are readily separated from others by holding them up to the light. Mined needles are translucent, and if larvae or pupae are present, they can often be seen moving inside the needles.

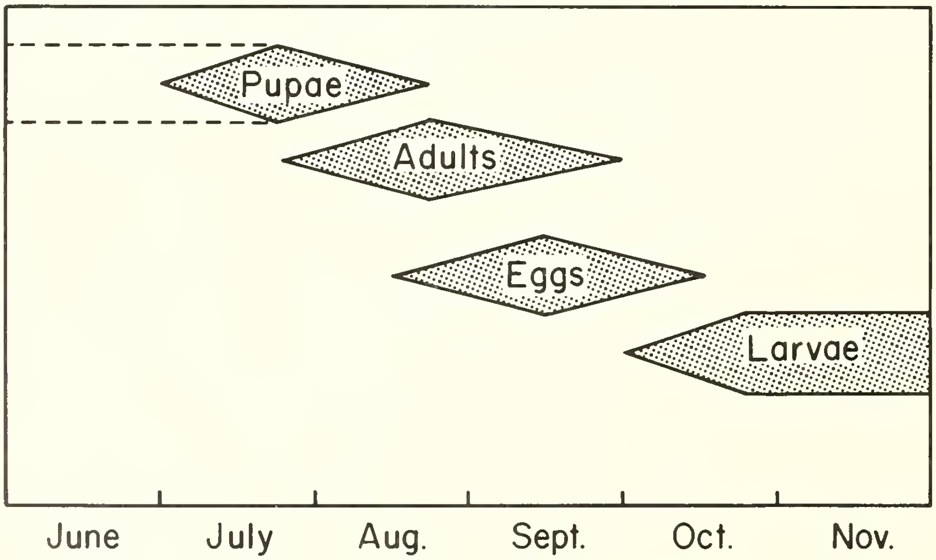


Figure 1.—Ponderosa pine needle miner life history, Boulder, Colorado, 1971-72.

Occurrence of Infestations and Their Expected Effects

While this is the first time within recent years that these needle miners have been studied carefully, conversations with foothill residents, along with unpublished forest insect survey reports, indicate that evidences of defoliation have been observed many times before. Occurrence seems to be sporadic, and the outbreaks short lived. W. F. Bailey, U.S. Forest Service, Denver, reports needle miner outbreaks both northwest and southwest of Colorado Springs in 1961, probably (but not definitely) of the present species. Needle miners have also been occasionally reported from ponderosa pine in the Durango area; these may also be the same species we are considering here.

The mechanisms by which insect populations rise and fall are complex interactions of physical and biological elements of the ecosystem. Many factors are involved. We have collected four species of hymenopterous (wasp) parasites from the needle miners, which undoubtedly have some influence in regulating needle miner numbers. There is evidence of other kinds of parasitic insects also. One would expect that temperature is an important factor; it may be responsible for the "band" effect, since the defoliation occurs in a clearly restricted elevational zone.

If we can establish that we are looking at the same species Gillette was, our records can be extended back nearly 70 years. Gillette (1922) indicated that defoliation was severe at Colorado Springs in 1905 and 1906, but between then and 1922 moths were "never . . . abundant enough to cause noticeable injury."

Defoliation by needle miners can be damaging; the lodgepole needle miner in California (Koerber and Struble 1971)[3] is a persistent and very destructive pest. In our situation, however, unless the present outbreak is more long lasting than previous ones, we would not expect any serious damage to the trees. To some observers the reddish cast given the trees may be considered objectionable from an esthetic standpoint; however, it can also be looked at as an interesting example of the "balance of nature," in which the trees are serving as hosts for the needle miners, and in which both the trees and the insects have been coexisting in the area for many generations.

---

[3] *Struble, George R. Biology, ecology, and control of the lodgepole needle miner. (In preparation as U.S. Dep. Agric. Tech. Bull. 1458.)*

Literature Cited

Freeman, T. N.
  1960. Needle-mining lepidoptera of pine in North America. Can. Entomol. Suppl. 16, 51 p.
Gillette, C. P.
  1922. The pine leaf-miner, Recurvaria pinella Busck. Thirteenth Annu. Rep. State Ent. of Colo., Circ. 36, p. 26-28.
Koerber, Thos. W., and G. R. Struble.
  1971. Lodgepole needle miner. U.S. Dep. Agric., For. Pest Leafl. 22, 8 p.

U S D A FOREST SERVICE
RESEARCH NOTE RM-229

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Instrument for Measuring Tree Crown Width

Wayne D. Shepperd[1]

A small, handheld instrument for measuring tree crown widths has proved to be accurate, and has several advantages over existing equipment. A materials list and construction diagram are included.

Keywords: Forest survey instrument, tree measurement.

Several instruments have been developed to measure tree crown diameters, among them the "Moosehorn" (Robinson 1947), the Reflecting Crownmeter (Holdsworth, Curtis, and McCleary 1936) and the modified Abney level (Buell 1936). Field conditions in the Rocky Mountains require an instrument that is small, of simple design, accurate, easily used, and lightweight, but durable. None of the existing instruments meet all of these requirements. The instrument described here is based on design principles of existing instruments, but meets the above requirements.

Description

The body of the instrument is a wooden case, 7 by 3-3/4 by 3-1/2 inches (fig. 1). A mirror is mounted inside the case at a 45° angle to the line of sight through the tapered eyepiece. The plexiglass top protects the mirror and has the sighting crosshair scribed upon it. Two level bubbles, which can be seen through the eyepiece, are mounted above the plexiglass plate; this enables the user to level the instrument on a horizontal plane.

Figure 1.--The completed instrument.

Use

Positioning himself under the approximate edge of the crown, the user peers through the eyepiece, maneuvering the instrument until the edge of the crown appears in the field of view. He then adjusts his position, keeping the level bubbles centered, to place the image of the crown edge on the crosshair. The instrument is then directly under the edge of the crown (fig. 2). Marking the position, the user repeats

---

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

Figure 2.--The instrument in use.

the process on the opposite side of the tree. The distance between the two points is the crown diameter in that dimension. Two measurements at right angles will give an adequate average crown width.

Construction

The instrument can be constructed in a few hours with easily available materials at a cost under 10 dollars (fig. 3). The case is constructed from 1/4-inch plywood; oak or other wood paneling is preferable for a better appearance. Beveled corners, recommended for strength and appearance, will require a miter saw for properly fitted joints. All dimensions are outside measurements, including the 1/4-inch bevels. Epoxy glue is used to join all parts except the mirror, which is fastened with rubber cement to facilitate removal if it breaks. Best results are obtained if jigs are fashioned to hold the parts until dry. The tapered eyepiece parts should be glued first, then joined to the other parts; otherwise the pieces are difficult to manage.

The back is fastened with wood screws and can be removed. The plexiglass then slides out so the mirror can be cleaned or replaced. The level bubbles are glued to plexiglass strips which are bolted to the case for easy removal. A spray-on oil-type finish is recommended to protect the wood.

An optional handle can be fixed to the case. The removable handle used here is a replacement trowel handle into which a sawed-off 3/8-inch stovebolt has been glued. The handle screws into a tapped 1/8-inch aluminum plate mounted inside the bottom of the case.

Advantages

The small size and large field of view enable this instrument to be handheld and easily positioned under the edge of the tree crown. Since the two bubbles level the instrument on a horizontal plane, the user can stand in any direction with respect to the tree and still obtain an accurate measurement. The instrument is rugged enough to survive jostling in a pack or vehicle without damage, since it has no moving parts or delicate mechanism. After considerable field use, it has proven to be a quick, accurate means of measuring tree crown widths.

Literature Cited

Buell, J. H.
1936. Crown mapping simplified by the use of an Abney level and a mirror. J. For. 34: 77-78.

Garrison, George A.
1949. Uses and modifications for the "Moosehorn" crown closure estimator. J. For. 47: 733-735.

Holdsworth, R. P., James D. Curtis, and Daniel McCleary.
1936. The reflecting crownmeter. J. For. 34: 528-530.

Robinson, Mark W.
1947. An instrument to measure forest crown cover. For. Chron. 23: 222-225.

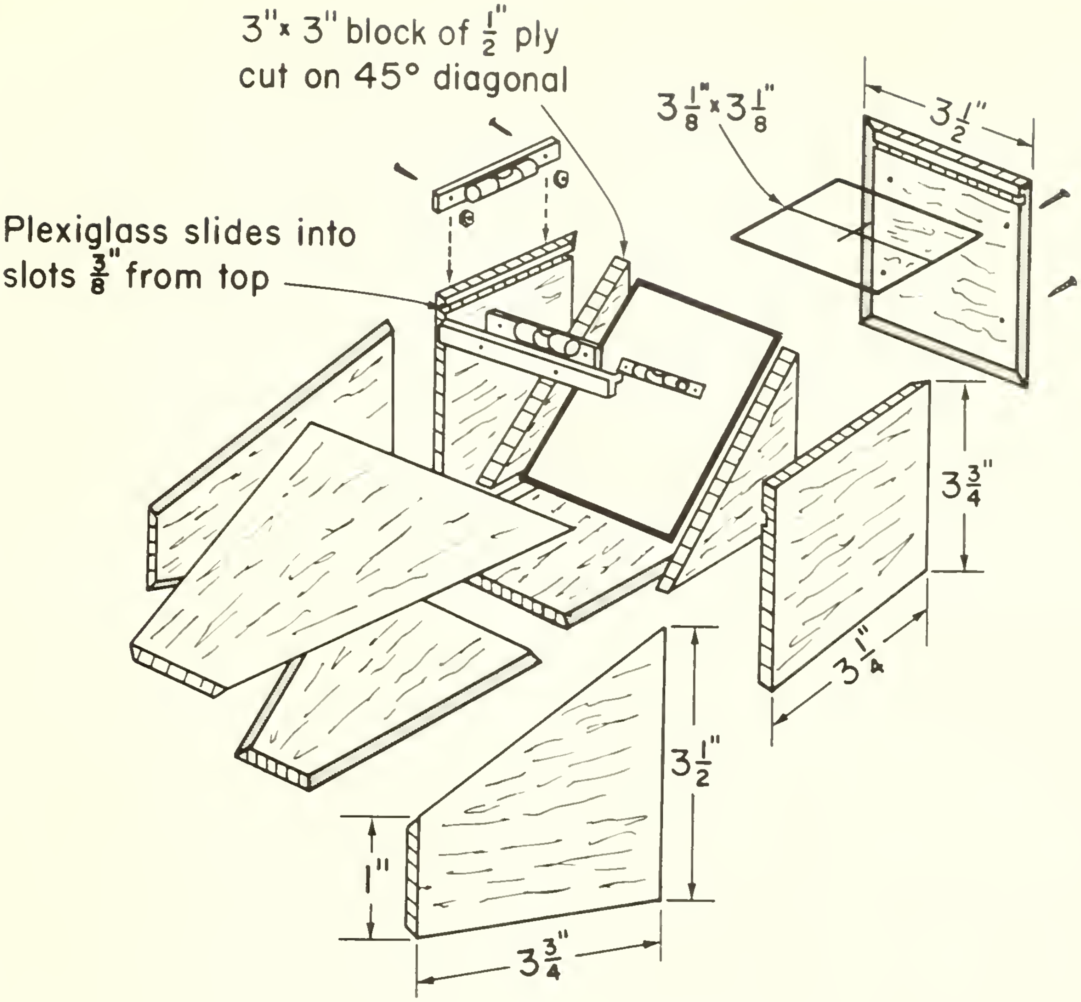


Figure 3.--Blowup diagram of the instrument.

MATERIALS USED

1 wood paneling piece, 2 by 2 feet, 1/4 inch thick

1 plexiglass piece, 3-1/8 by 3-1/8 inches, 1/8 inch thick

2 plexiglass strips, 3/8 by 2-1/2 inches, 1/8 inch thick

2 replacement bubbles for a Stanley carpenter's level

1 mirror, 3 by 4 inches

1 plywood scrap, 3 by 6 inches, 1/2 inch thick

4 wood screws, 3/4 inch long

4 number 2 machine screws, 1/2 inch long with nuts and washers

Epoxy glue

Rubber cement

Optional Handle: 1 replacement trowel handle
1 3/8-inch stovebolt, 2 inches long
1 aluminum plate, 2 by 2 inches, 1/8 inch thick

1973

U S D A FOREST SERVICE
RESEARCH NOTE RM-230

OREST SERVICE
.S DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Notes on Weevils from Trees and Shrubs in North Dakota[1]

M. E. McKnight[2] and D. G. Aarhus[3]

Weevils are common tree-feeding insects in windbreaks in North Dakota. The red elm bark weevil breeds in American elm in plantings, mainly in trees of low vigor. Eight species of parasitoids, listed herein, were reared from elm wood infested with this weevil. The white pine weevil is localized in a plantation of blue spruce. The poplar-and-willow borer, an ash seed weevil, the strawberry root weevil, the sweetclover weevil, the lesser alfalfa weevil, and an acorn weevil are widespread and abundant on their respective tree hosts.

Keywords: Shelterbelt insects, Great Plains forestry, windbreaks.

A recent taxonomic study (Aarhus 1970) revealed that at least 40 species of weevils are found on trees and shrubs in North Dakota. The weevils can be a serious threat to their hosts, because larvae and adults may attack flowers, fruit, and seed, and feed in the cambium, on the foliage, and on the roots. Entomologists working on pest detection, evaluation, and control need more biological data on this important group of tree-feeding insects. The objective of the work reported here was to survey the field situation to identify the most important pests in this group.

Methods

Many plantings of trees and shrubs sheltering fields or farmsteads, as well as plantings at Denbigh Experimental Forest, near Denbigh (McHenry County), North Dakota, were examined by the second author for weevils or damage in June, July, and August 1969. Adults were taken with a sweep net or by hand picking, and considerable infested material was held in the laboratory for emergence of adults or natural enemies.

Observations

The red elm bark weevil, Magdalis armicollis (Say), was found to be an important pest of American elm (Ulmus americana L.). In most situations the weevil is a natural pruner of lower branches. It was evident, however, that trees injured by lightning, mechanical damage, or girdling by rodents, or trees of low vigor are most likely to be attacked. Brood is produced in living branches and the main stem, sometimes down to the groundline. The larvae feed in the cambium (fig. 1) and eventually girdle and kill trees. In the laboratory, adult weevils fed on the leaves of Siberian elm (Ulmus pumila L.) as well as American elm (fig. 2), but they oviposited only on American elm. No weevils were found on Siberian elm in the field. The life history of the red elm bark weevil in North Dakota appeared to be similar to that in Wisconsin (Goeden and Norris 1963) and in New Jersey (Hoffmann 1939).

---

[1] *This investigation was supported in part by a cooperative research grant to North Dakota State University-Bottineau Branch, from Forest Service, U.S. Department of Agriculture.*

[2] *Principal Entomologist, Rocky Mountain Forest and Range Experiment Station, assigned to the Shelterbelt Laboratory, Bottineau, in cooperation with North Dakota State University-Bottineau Branch. Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[3] *Director, Science Division, North Dakota State University-Bottineau Branch, Bottineau.*

Figure 1.—Larvae of the red elm bark weevil in mines beneath the bark of American elm.

Figure 2.—Adult red elm bark weevils and shot-hole defoliation on American elm leaves.

The red elm bark weevil was suspected by several workers to be a vector of Ceratocystis ulmi (Buis.) Moreau, the causal agent of Dutch elm disease. It is often reared from dead and dying elms with the well-known vectors, the smaller European elm bark beetle, Scolytus multistriatus (Marsham), and the native elm bark beetle, Hylurgopinus rufipes (Eichhoff) (Collins et al. 1936, Jones and Moses 1943, Roberts 1958). Goeden and Norris (1963) concluded that the red elm bark weevil and the black elm bark weevil, Magdalis barbita (Say), were not significant vectors in Wisconsin because of their feeding habits and very low degree of contamination with the fungus. The black elm bark weevil has been collected in North Dakota, but it is not as common as the red elm bark weevil. It is possible that the bark weevils might provide additional host material for the bark beetle vectors through additional weakening of elms in plantings on droughty soils or plantings suffering from lack of cultivation and other maintenance.

The following parasitoids[4] were reared from elm wood infested with the red elm bark weevil: Braconidae - Eubadizon rotundiceps (Cress.); Ichneumonidae - Dolichomitus sp.; Chalcidoidea - Rhaphitelus maculatus Walker, Eurytoma sp., Eupelmella vesicularis (Retz.), Metapelma schwarzi Ashm., Trigonura ulmi Burks, and Euchrysia hyalinipennis Ashm. This is a new distribution record for the last two species (Burks, personal communication).

The white pine weevil, Pissodes strobi (Peck) (fig. 3), was first detected in North Dakota in a 10-year-old planting of Colorado blue spruce (Picea pungens Engelm.) near Cavalier in Pembina County in 1962.[5] This

[4] *Identification provided by Systematic Entomology Laboratory, USDA-ARS, U. S. Natl. Mus. Nat. Hist., Smithson. Inst., Wash., D. C., as follows: Braconidae, P.M. Marsh; Ichneumonidae, R. W. Carlson; Chalcidoidea, B. D. Burks.*

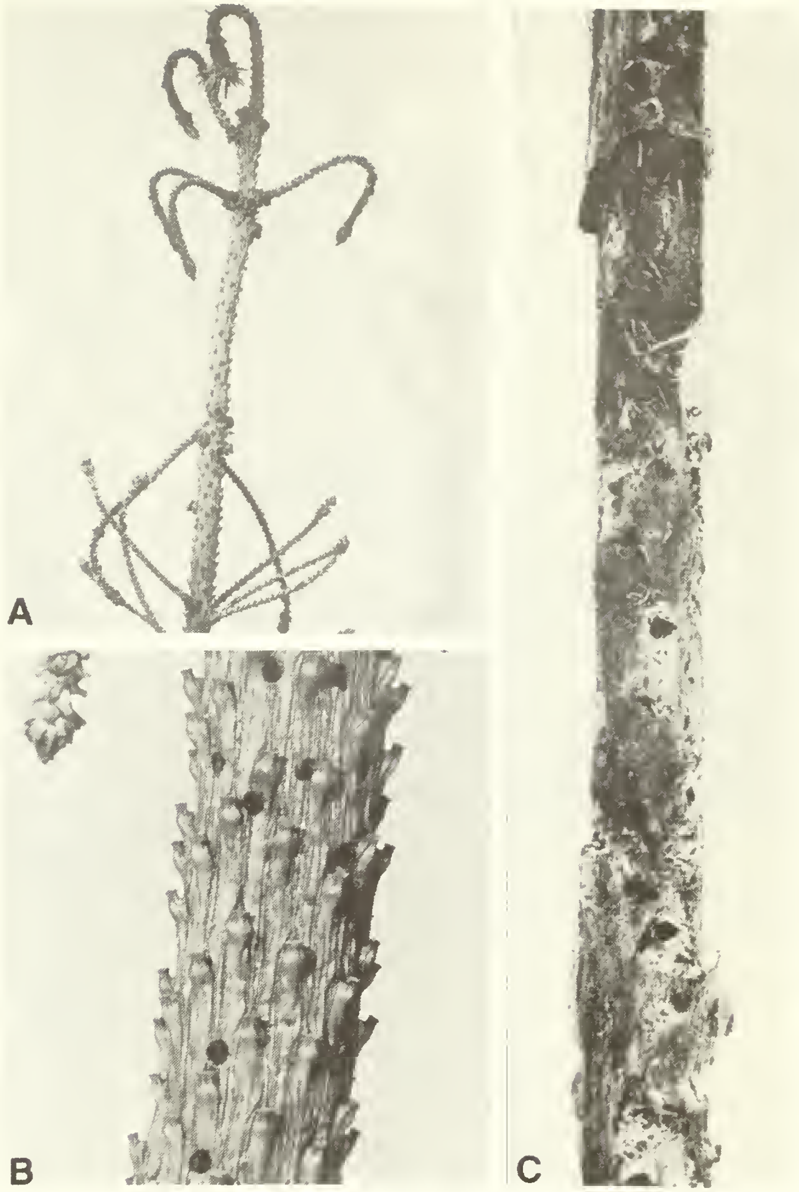
[5] *Memorandum (4500) from Paul E. Slabaugh, Shelterbelt Laboratory, Bottineau, to James H. Taubman, District Forester, Walhalla, N.D., May 21, 1964.*

Figure 3.—White pine weevil:

A, dead spruce terminal;

B, emergence holes;

C, bark removed to expose chip cocoons beneath the emergence holes.



planting and 14 others within 5 miles were inspected in 1969. One infested leader was found at the original site, but none were found in the other plantings. Apparently a small population of the white pine weevil has sustained itself in one planting without dispersing to nearby plantings, some within 0.5 mile. This insect could be an important pest in Christmas tree plantations in the area, and the situation should be watched closely.

Adults of the poplar-and-willow borer (Cryptorhynchus lapathi (L.) (fig. 4) were taken in pit traps at the base of willows (Salix humilis Marsh.) at Denbigh Experimental Forest throughout June and July. Last instars and pupae were found in tunnels in willow stems on July 24. The tunnels made by feeding larvae started at the surface of the willow stem, extended in a long loop, and ended directly at the center of the stem. The stems were not girdled except at the entrance hole where frass was pushed out. Tunneling by the poplar-and-willow borer can result in wind breakage due to the weakening of the stems. The borer was not found in Salix alba L. which is commonly used in windbreak plantings.

An ash seed weevil, Thysanocnemis sp., was common on green ash (Fraxinus pennsylvanica Marsh.). It is a problem insect when green ash seed is scarce for tree nurseries. The strawberry

Figure 4.—Poplar-and-willow borer and damaged twig.

root weevil, *Brachyrhinus ovatus* (L.), is sometimes reported as a pest in tree nurseries, and it is a common household pest in North Dakota. It is polyphagous, feeding on grass roots as well as tree roots. The sweetclover weevil, *Sitona cylindricollis* Fahraeus, and the lesser alfalfa weevil, *S. scissifrons* Say, are common on Siberian pea shrub (*Caragana arborescens* Lamarck) (Kennedy 1968). These foliage feeders are seldom considered problems. An acorn weevil, *Curculio* sp., was reared from acorns, and adults were found feeding on oak leaves. Three *Curculio* species have been collected in North Dakota (Gibson 1969): *C. sulcatulus* (Casey); *C. strictus* (Casey); and *C. iowensis* (Casey). Propagation of bur oak (*Quercus macrocarpa* Michx.), a desirable tree species for windbreaks in some parts of the Great Plains (Read 1958), has sometimes been hindered in tree nurseries by weevil infestation of acorns.

Literature Cited

Aarhus, David Gerard.
1970. Curculionidae of North Dakota. Ph. D. Diss. 261 p. N.D. State Univ., Fargo.

Collins, C. W., W. D. Buchanan, R. R. Whitten, and C. H. Hoffmann.
1936. Bark beetles and other possible insect vectors of the Dutch elm disease, *Ceratostomella ulmi* (Schwarz) Buisman. J. Econ. Entomol. 29: 169-176.

Gibson, Lester P.
1969. Monograph of the genus *Curculio* in the New World (Coleoptera: Curculionidae). Part I. United States and Canada. Entomol. Soc. Am. Misc. Publ. 6:241-285.

Goeden, Richard D., and Dale M. Norris.
1963. The potential of *Magdalis* spp. in the transmission of *Ceratocystis ulmi* (Buis.) Moreau. J. Econ. Entomol. 56: 238-239.

Hoffmann, Clarence H.
1939. Observations on the biology of *Saperda tridentata* Oliv. and *Magdalis armicollis* Say (Coleoptera). J. Econ. Entomol. 32: 848-851.

Jones, T. H., and C. S. Moses.
1943. Isolation of *Ceratostomella ulmi* from insects attracted to felled elm trees. J. Agric. Res. 66: 77-85.

Kennedy, Patrick C.
1968. Insects and diseases of Siberian pea shrub (caragana) in North Dakota, and their control. U. S. For. Serv. Res. Note RM-104, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Read, Ralph A.
1958. The Great Plains shelterbelt in 1954. Nebr. Agric. Exp. Stn. Bull. 441, 125 p.

Roberts, A.
1958. Insect vectors of the Dutch elm disease in the province of Quebec. Tenth Int. Congr. Entomol., Proc. 4: 433-436.

U S D A FOREST SERVICE
RESEARCH NOTE RM- 231

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Cost Analysis of Clearing a Ponderosa Pine Watershed

Robert L. Miller and Frederic R. Larson[1]

Costs of clearing a ponderosa pine watershed following a commercial logging operation are analyzed. Cost of felling unmerchantable small trees and windrowing slash was $72.09 per acre. Costs could probably be reduced 40 percent or more by changes in treatment prescription, choice of equipment, and removal of pulpwood and firewood where markets are available.

Keywords: Forest conversion, forestry business economics, production function, watershed management, *Pinus ponderosa*.

The development of many communities in the semiarid Southwest may be curtailed by insufficient water for agriculture, industry, and home use. One possibility to alleviate the water shortage problem is to increase streamflow by manipulating vegetation on upstream watersheds (Worley 1965).

The Beaver Creek Project was initiated to pilot test alternative land management treatments, and evaluate the effects on water and sediment yields, timber and forage production, and wildlife use. The costs associated with establishing these treatments are tabulated, analyzed, and compared with costs from other treatments.

The Beaver Creek watershed is divided into small pilot watersheds, 200 to 2,000 acres in size, and a single treatment has been applied or is planned for each of these areas. The specific treatment described in this cost analysis was designed primarily to increase water yield. It involved removal of all the timber overstory and windrowing the resultant slash. Other treatments being evaluated include stripcutting and thinning of various intensities, as well as livestock grazing. One watershed is scheduled for moderate thinning to maximize timber production, and another will be cut in patterns to enhance wildlife habitat. The treatments are designed to determine levels of production and environmental effects associated with a range of cutting intensities.

This report, the third of a series (Miller and Johnsen 1970, Miller 1971), presents costs incurred during a clearing treatment designed to increase water yield. The 455-acre watershed was treated by first removing merchantable ponderosa pine (Pinus ponderosa Laws.) saw logs and poles through a commercial timber sale, then by felling the remaining trees with chain saws, and bulldozing trees and slash into windrows. The stand remaining after the timber sale consisted of about 500 trees per acre, mainly ponderosa pine poles below 10 inches diameter breast height (d.b.h.), and scattered Gambel oak (Quercus gambelii Nutt.) and alligator juniper (Juniperus deppeana Steud.) ranging in size up to about 50 inches d.b.h.

Treatment Procedures

The study was concerned only with costs to the land management agency over and above normal timber sale administration. Because logging operations generally are self-supporting,

---

[1] *Associate Economist and Associate Silviculturist, respectively, Rocky Mountain Forest and Range Experiment Station. Larson is located in Flagstaff in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins in cooperation with Colorado State University. Miller is now with the Department of Forestry, Oklahoma State University, Stillwater.*

this study was limited to the clearing operations subsequent to logging. For cost collection and analysis, these operations were separated into component jobs (Worley et al. 1965): (1) felling of small unmerchantable trees with chain saws, (2) layout of windrow locations, and (3) windrowing slash by bulldozer. Data were collected on supervision, labor, equipment, and vehicle use.

Felling was done by three sawyer crews of five to six men per crew. Working conditions for felling were generally good. The watershed is relatively flat, with less than a third of the total area having slopes of more than 10 percent. While the soil surface is rocky, this was not ordinarily a limitation in any of the jobs. All trees to a minimum d.b.h. of about 1 inch were felled. The felling job required 12.31 man-hours per acre (table 1) and included 80 percent of total labor inputs.

Windrows were spaced 100 feet apart and oriented generally with the slope. Spacing and orientation were designed exclusively for the experimental purposes of influencing snow accumulation, snowmelt, and runoff, without regard to cost factors (fig. 1). The work of laying out windrows was a relatively minor job, and was carried out by the bulldozer swamper with part-time help of another worker during the pushing operation.

Table 1.--Labor and supervision inputs in man-hours per acre for the felling and windrowing jobs

Inputs	Felling	Windrowing slash (includes layout)	Total
Supervision	3.09	0.37	3.46
Labor	9.22	2.24	11.46
Total	12.31	2.61	14.92

Three different types of bulldozer equipment were used in the windrowing job: (1) a crawler tractor of 140 drawbar horsepower with cable-controlled dozer blade, (2) a crawler tractor of 100 drawbar horsepower with a hydraulically controlled blade with rake teeth, and (3) a four-wheel-drive, articulated-frame, rubber-tired tractor with hydraulic blade. The small crawler tractor was found least costly and most efficient at 1.01 hours per acre.

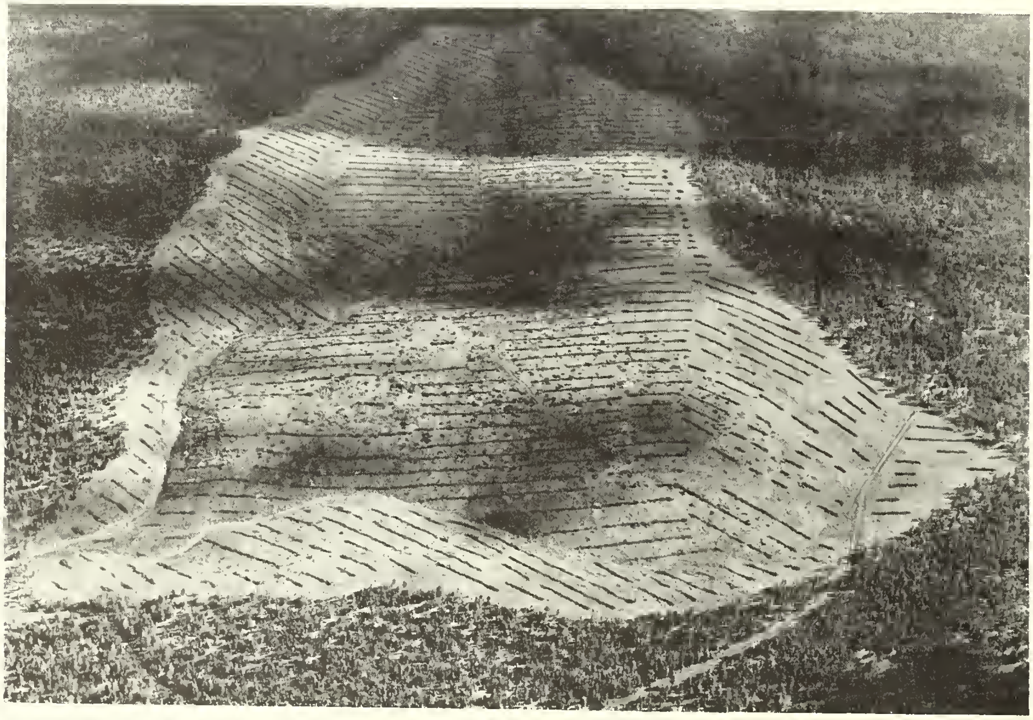


Figure 1.—Aerial view of the 455-acre clearcut watershed. The "herringbone" pattern is the result of slash windrows oriented to enhance snowpack accumulation, snowmelt, and runoff.

Figure 2.—Leaving large Gambel oak and alligator juniper trees would reduce treatment costs without appreciably reducing water yields or forage production, and may improve wildlife and recreational values.

Figure 3.—Experienced thinning crews felled unmerchantable trees.

Treatment Costs

Total costs of clearing operations subsequent to logging were $72.09 per acre (table 2). Felling costs were $32.88, windrowing $28.96, and travel $10.25.

The variation in input per unit output among job work periods can indicate possible opportunity for improving efficiency. The coefficient of variation is a useful measure for this purpose, since it permits direct comparisons in variability between jobs. Coefficients of variation were computed by standard techniques using cost per acre for each work period. For the felling and windrowing jobs, the coefficients were relatively high at 39.6 and 32.8 percent, respectively. In a continuing operation, such large coefficients would strongly suggest the need for detailed study to determine causes of variation, particularly for jobs that account for large parts of the costs of the operations.

Variation can be caused by vegetation differences, working conditions, or by factors related to methods and performance. Analysis of vegetation and other physical variables can lead to greater efficiency by altering prescriptions for particular conditions. Stand density and composition varied considerably on the watershed, and some grouping of stands would have been possible. The particular effects of these variables were not studied, however.

Other results indicate that felling costs could be reduced by a change in prescription to leave large Gambel oaks and alligator junipers uncut. Large alligator junipers are extremely costly to fell, requiring 20 minutes to 2.5 manhours (Miller and Johnsen 1970). Felling costs for large oaks may be similar. There were approximately 1.5 trees of these species per acre greater than 24 inches d.b.h. Assuming an average of 1 hour to cut each large tree, a savings of 12 percent or $3.95 per acre could be realized by leaving these trees.

Many of these larger trees were overmature, with low vigor and generally sparse crowns. Leaving such trees uncut would not likely reduce water yield or forage production appreciably, and would improve conditions for wildlife (Reynolds et al. 1970, Clary and Larson 1971) and recreation (fig. 2).

It does not appear likely that costs of felling small trees can be substantially reduced, since felling was done by crews who were experienced in, and equipped for, pine thinning operations (fig. 3). Costs could be greatly reduced, however, if markets existed for pulpwood and firewood. These products were largely unmerchantable because of size in this case, since the treated area was 55 miles from the nearest firewood market and pulp collection yard. Approximately 1,000 cords were available and left standing after the logging operation. This material accounted for approximately 60 percent of the remaining slash; utilization of it probably would have reduced the cost of felling small pine trees by that percentage.

If the original felling cost of $32.88 per acre (table 2) is decreased $3.95 per acre by not felling large oak and juniper, and another 60 percent ($17.36) by utilizing pulpwood and firewood, felling costs would drop to $11.57 per acre.

During the windrowing job, advantages were found for each machine. The production rate of the articulated rubber-tired dozer was median, and cost per acre on the basis of the contract price was favorable (table 3). During the 6 days of operation, however, stumps of small trees caused about $250 in tire damage. If this hazard could be eliminated at small cost by more care in felling, this type of equipment could be quite efficient for the purpose.

The automatic transmission of the smaller crawler enabled it to outperform the larger crawler dozer. This feature maintains gear ratio more nearly at optimum, eliminates shifting

Table 2.--Dollar costs per acre, by component jobs, for the entire treatment

	Felling	Windrowing slash	Travel	Total	Percent of total
MANPOWER:					
Supervisory	$ 8.79	$1.21	$2.13	$12.13	17
Labor	20.87	7.36	5.07	33.30	46
Subtotal	29.66	8.57	7.20	45.43	
EQUIPMENT	3.22	20.39	3.05	26.66	37
Total	32.88	28.96	10.25	72.09	100

Table 3.--Production rates and dollar costs for the three equipment units used

Equipment	Acres per hour	Total cost per acre	Percent of area treated
Large tractor with manual shift and cable dozer	0.38	53.33	12
Smaller tractor with automatic transmission and hydraulic dozer	.99	25.45	81
Articulated, four-wheel-drive rubber-tired dozer	.68	27.10	6

gears manually, and greatly reduces time for shifting between forward and reverse. The automatic transmission was a disadvantage, however, whenever a large rock or stump was encountered by the blade during pushing, since the automatic down-shifting often caused track slippage and digging. When the dozer with the manually controlled transmission encountered such an object, the operator would shift to prevent stalling, and there would usually be little track slippage. Thus surface disturbance was substantially greater on areas worked by the smaller tractor. The blade linkage of the smaller tractor also did not provide sufficient lift to avoid fairly frequent contact with stumps while windrowing (fig. 4).

The production rate with the smaller tractor would be somewhat higher under ordinary operational conditions. Because of time factors related to the experimental treatment, it was necessary to work under very wet ground conditions during a 3-week period, which slowed production. In normal operations, work under such conditions would not be advisable because of excessive soil disturbance.

These considerations indicate that a large tractor with automatic transmission and hydraulic high-lift dozer would probably prove most efficient in the windrowing job.

Opportunities for reducing windrowing costs are quantified in table 3. If the small crawler

Figure 4.—Tractor with automatic transmission and a hydraulically controlled blade with rake teeth windrowing slash.

had been used exclusively, for instance, windrowing costs for the total area would have been $25.45 per acre or 12 percent less than the $28.96 reported in table 2. Other possible cost reductions are summarized in table 4.

Assuming the above reductions in operating costs could be achieved, travel costs would also be lowered due to less work and fewer trips to the watershed. By prorating travel costs to the amount of time spent on each job, a savings of 55 percent or $5.59 could also be obtained. It is evident that travel costs, which made up approximately 14 percent of total treatment costs, should be taken into account in evaluating management alternatives. Because of the substantial travel distances involved in most western forest operations, such costs need to be considered in deciding between areas to treat and in locating roads and field headquarters for large operations. In this case, distance between headquarters and the watershed was 21 miles.

Summary and Conclusions

Several vegetative treatments on upstream watersheds are being evaluated in terms of water and sediment yields, timber and forage production, and wildlife use. A series of stripcuts and thinning intensities are being studied as well as special treatments designed to maximize either water production, timber growth, or wildlife habitat.

This report presents costs incurred while treating a watershed to maximize water production. The watershed was cleared by first removing merchantable saw logs and poles through a normally conducted timber sale, then by felling the remaining trees with chain saws and bulldozing slash into windrows. Cost information was collected and analyzed on the noncommercial operations following the timber sale to determine what costs were incurred by the land management agency over and above a normal logging sale administration, and what cost reduction could be obtained through modification in equipment or treatment.

The cost of felling unmerchantable small trees and windrowing slash was $72.09 per acre. This figure could probably be reduced approximately 42 percent to $41.71 by not cutting large alligator junipers and Gambel oaks which are costly to fell, by selling pulpwood and firewood, and by using a more efficient tractor to pile slash. The availability of pulpwood markets would offer the largest potential for reducing treatment cost, with a possible reduction of 60 percent in the cost of felling small unmerchantable trees.

These data can be compared with similar information from other treatments to determine

Table 4.--Estimated dollar costs and opporutnities for reducing costs in clearing a ponderosa pine watershed following a commercial logging operation

Opportunities for reducing costs	Original	Cost reduction		Final cost/acre
		Dollars/acre	Percent	
PRESCRIPTION CHANGES:				
Leave large alligator juniper and Gambel oak uncut during the felling job	$ 3.95	$ 3.95	100	$ 0
Reduce felling job by selling pulpwood and firewood	28.93	17.36	60	11.57
Use most efficient tractor for all slash windrowing	28.96	3.48	12	25.48
Subtotal	61.84	24.79		37.05
TRAVEL COSTS	10.25	5.59		4.66
Total	72.09	30.38	42.1	41.71

the optimum treatment mix to apply over large watersheds or basins, given ecological, economic, and physiographic constraints.

Literature Cited

Clary, Warren P., and Frederic R. Larson.
1971. Elk and deer use are related to food sources in Arizona ponderosa pine. USDA For. Serv. Res. Note RM-202, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Miller, Robert L.
1971. Clearing an alligator juniper watershed with saws and chemicals: A cost analysis. USDA For. Serv. Res. Note RM-183, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

_______, and Thomas N. Johnsen, Jr.
1970. Effects of tree and sawyer factors on costs of felling large alligator junipers. USDA For. Serv. Res. Pap. RM-56, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Reynolds, Hudson G., Warren P. Clary, and Peter F. Ffolliott.
1970. Gambel oak for southwestern wildlife. J. For. 68: 545-547.

Worley, David P.
1965. The Beaver Creek pilot watershed for evaluating multiple use effects of watershed treatments. U.S. For. Serv. Res. Pap. RM-13, 12 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Worley, David P., Gerald L. Mundell, and Robert M. Williamson.
1965. Gross job time studies—an efficient method for analyzing forestry costs. U.S. For. Serv. Res. Note RM-54, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Agriculture—CSU, Ft. Collins

1973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 232

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Age of Engelmann Spruce Seedlings Affects Ability to Withstand Low Temperature: *A Greenhouse Study*

Daniel L. Noble[1]

Spruce seedlings were expased to 5°, 15°, and 25°F. cold treatments at 6 development stages—2 weeks through 12 weeks at 2-week intervals. All seedlings survived the 25°F., but no seedlings survived 5°F. At 15°F. few seedlings 2 to 8 weeks old survived, but most seedlings 10 to 12 weeks old survived. No correlation could be found between cold resistance and moisture content.

Keywords: *Picea engelmannii*, cold-hardiness, seedling moisture content.

Natural regeneration of Engelmann spruce (Picea engelmannii Parry) following clearcutting has been highly variable in the Rocky Mountains (Alexander 1966, 1968; Roe and Schmidt 1964). Research experience and general observations have indicated that lack of regeneration is often due to environmental factors associated with germination and first-year seedling survival (Roe et al. 1969). Environment is a complex integration of physical and biological factors which may be grouped in three broad categories: climatic, edaphic, and biotic. Climatic factors are most important (Roe et al. 1969, Ronco 1970).

Spruce grows in a cold, humid climate characterized by extremes (Alexander 1958). The average frost-free period for spruce at the Fraser Experimental Forest in the Central Rockies is less than 60 days, and below-freezing temperatures can occur during any month of the growing season. Weather records show that temperatures from mid-June to late September frequently reach a minimum of 26°-28°F., occasionally to 16°-18°F., and rarely drop to 6°-8°F. Furthermore, these temperatures may occur anytime during the period, although minimums below 20°F. are more likely to occur in late summer. Because of these extremes, low temperatures during the first few weeks of a seedling's life may limit regeneration success (Ronco 1967).

Spruce germination requires viable seed, favorable seedbed conditions, adequate soil moisture, air temperatures above freezing at night, and at least 60°F. during the day. The normal germination period is late June and early July, when these requirements are most likely to be met. However, if the seedbed is too cold or dry, germination may be delayed until midsummer rains in August. Furthermore, seedlings that germinate late in the growing season usually do not have time to harden off before late summer frosts. Generally, these seedlings are killed or severely damaged by low temperatures (Ronco 1967).

The purpose of this study was to determine: (1) if spruce seedlings become more resistant to low temperature as they develop during their first growing season, and (2) the relationship between cold-hardiness and moisture content.

---

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

Methods and Materials

Two controlled-environment chambers were used. The greenhouse was the rearing-recovery chamber, and a walk-in refrigeration unit the low-temperature chamber.

Engelmann spruce seeds collected in 1966 on the Fool Creek drainage of the Fraser Experimental Forest were used. Forty seeds were sown in each of 120 standard, 6-inch plastic greenhouse pots filled with sandy loam soil collected from the spruce-fir zone in central Colorado. The pots were soaked twice daily for 3 days before seeding to insure that soil was near saturation. After initial watering, water was applied at the rate of 2.0 inches per month — 0.25 inch per application, eight times a month. Ten seedlings of the same germination date (± 1 day) were allowed to become established in each pot.

Seedlings were raised in a controlled greenhouse, with environmental conditions maintained as close as possible to field conditions in the spruce-fir zone during the growing season. The temperature regime was 70°F. days and 40°F. nights, with a photoperiod of 16 hours (natural light supplemented by artificial light of approximately 5,000 ft.-c.). The transition period for temperatures coincided with the photoperiod change. Relative humidity was held at approximately 20 percent during the day and 70 to 80 percent at night. Temperature and humidity were monitored by a hygrothermograph.

The design of the experiment was a two-factor factorial. Seedling development stage at six levels was arranged in a randomized block, with temperature treatments at four levels in a split plot. Each treatment combination was replicated five times. Seedling development stages were 2-week intervals from 2 weeks to 12 weeks after germination. Temperature treatments were 5°, 15°, and 25°F., and the greenhouse control.

When seedlings reached specified treatment ages, they were removed from the greenhouse and placed in the refrigeration unit for the prescribed low-temperature treatments. A hygrothermograph monitored ambient air temperature in the walk-in cooler. A telemeter with an air-temperature probe was used to check air temperatures within 1 mm. of the seedlings.

The pots were placed in a styrofoam container that provided a 2-inch layer of insulation on the sides and bottom of the pots. This styrofoam had an ambient temperature of 70°F. at the beginning of each low-temperature treatment. Therefore, only the soil surface and aerial portions of seedlings were immediately subjected to the low temperatures. The temperatures of the soil at 1-, 2-, and 3-inch depths were measured at 1-hour intervals during the 8 hours that seedlings were subjected to cold treatments. The telemeter with a soil probe was used for these soil temperature measurements. Soil temperatures were also measured while the seedlings were in the greenhouse.

Following each of the low-temperature treatments, seedlings were returned to the greenhouse for a 30-day recovery period. At the end of this recovery period, seedling survival, dry weight, and moisture content were measured.

Results and Discussion

Resistance to low temperature was related to development stage only at 15°F. At that temperature, 92 to 96 percent of the seedlings 10 and 12 weeks old survived, but only 2 percent or less survived at other development stages. On the other hand, all seedlings survived the 25°F. and control treatments, whereas no seedlings survived the 5°F. treatment.

There were no significant differences in moisture content or seedling dry weight between control seedlings, seedlings treated at 25°F., nor the last two development stages of the 15°F. treatment. Average seedling water content decreased (fig. 1) and dry weight increased (fig. 2) as seedlings grew older. No significant relationship was found between the change in cold-hardiness and seedling moisture content or seedling dry weight.

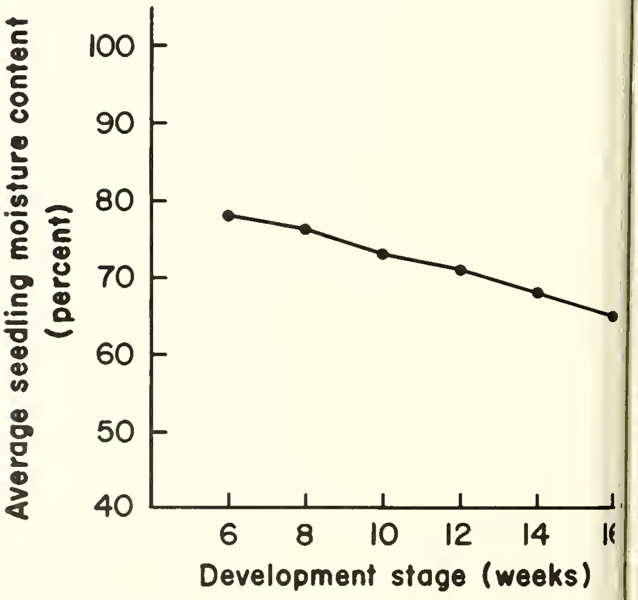


Figure 1.—Average seedling moisture content expressed as percentage for each development stage (moisture content measured after 30-day recovery period).

Soil temperatures measured in the controlled greenhouse environment were the same at depths of 1, 2, and 3 inches. The average minimum was 55°F., average maximum 72°F., and the 24-hour mean 61°F. Average soil temperatures decreased during the 8-hour cold treatments, but were not greatly different between the three treatments (fig. 3). There were no differences in soil temperatures at 1 to 3 inches in the 15°F. and 25°F. treatments. In the 5°F. treatment, however, the soil temperature at 1 inch dropped to 32°F., and approximately the upper 1/4 inch of soil froze. Soil temperatures at 2 and 3 inches averaged 34°F.

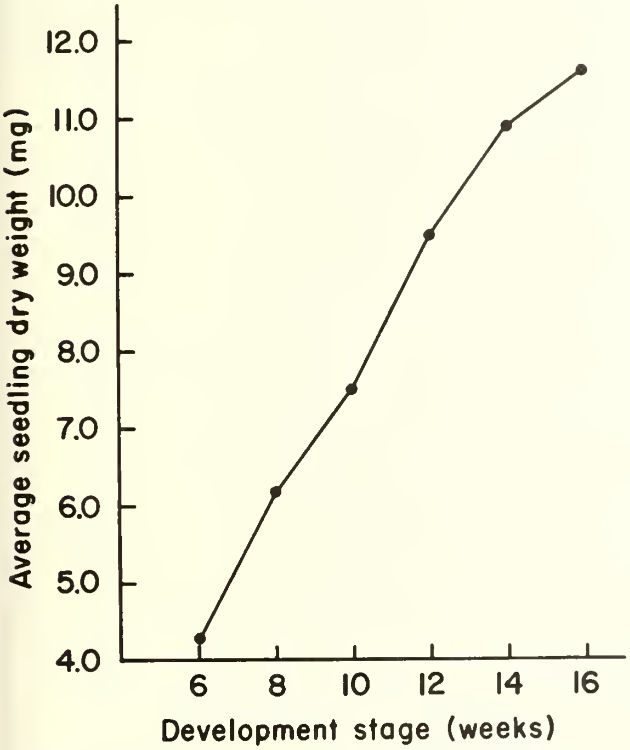


Figure 2.—Average seedling dry weight for each development stage (measured after 30-day recovery period).

Since the soil temperatures for each cold treatment were similar, the sudden lowering of air temperatures surrounding the aerial portion of the seedlings probably caused most of the damage. Cell walls most likely were ruptured by the formation of intracellular ice crystals.

When seedlings reached the 8-week stage, they were just beginning to form terminal buds. By the 10th and 12th weeks, however, the terminal buds had set and primary needles appeared mature.

Results from greenhouse studies cannot be directly extrapolated to field conditions. Seedlings in the field may develop cold-hardiness at different rates. Nevertheless, this study has verified what investigators have observed in the field: older spruce seedlings are likely to withstand a sudden drop in temperature to as low as 15°F. in late summer or early fall, whereas seedlings that germinated late in the growing season have little probability of surviving.

Literature Cited

Alexander, Robert R.
1966. Stocking of reproduction on spruce-fir clearcuts in Colorado. U.S. For. Serv. Res. Note RM-72, 8 p., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

______
1958. Silvical characteristics of Engelmann spruce. U.S. Dep. Agric., For. Serv. Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 31, 20 p., Fort Collins, Colo.

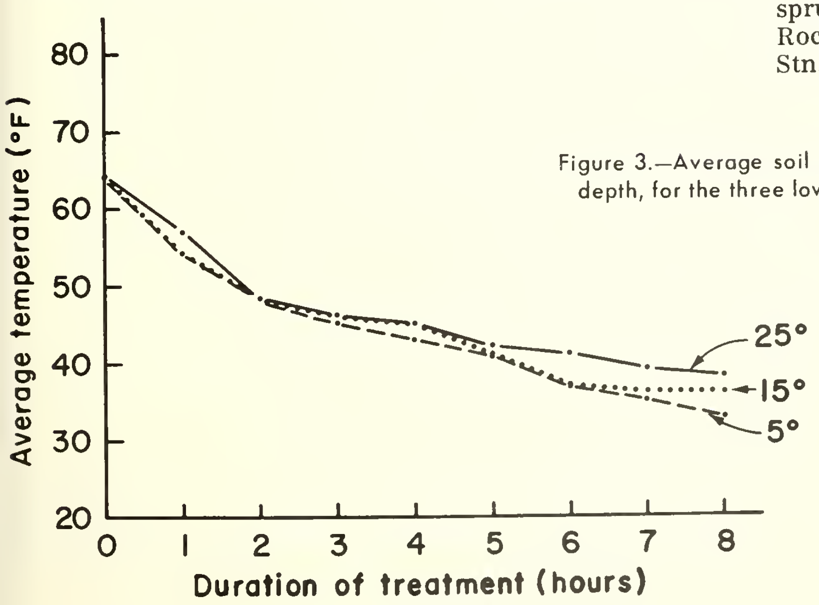


Figure 3.—Average soil temperatures, at 1 to 3 inches depth, for the three low temperatures.

Roe, Arthur L., Robert R. Alexander, and M. D. Andrews.
1970. Engelmann spruce regeneration practices in the Rocky Mountains. U.S. Dep. Agric. For. Serv. Prod. Res. Rep. 115, 32 p.

_______ and Wyman Schmidt.
1964. Factors affecting natural regeneration practices in the Intermountain Region. U.S. For. Serv. Intermt. For. and Range Exp. Stn. Mimeo Rep., 68 p., Ogden, Utah.

Ronco, Frank.
1967. Lessons from artificial regeneration studies in a cutover beetle-killed spruce stand in western Colorado. U.S. For. Serv. Res. Note RM-90, 8 p., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

____
1970. The influence of high light intensity on the survival of planted Engelmann spruce. For. Sci. 16: 331-339.

Agriculture—CSU, Ft. Collins

1973

U S D A FOREST SERVICE
RESEARCH NOTE RM-233

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Winterfat Fruits and Seeds Retain High Viability 3 Years in Cold Storage

H. W. Springfield[1]

Fruits and seeds of winterfat *(Eurotia lanata)* were stored 3 years in sealed and unsealed containers under four temperatures. Seed stored in sealed containers under refrigeration or subzero temperatures retained 93 to 99 percent viability. By contrast, seed stored in unsealed containers under room conditions retained only 46 percent viability, and under outside shed conditions, only 3 percent viability. Cold storage in sealed containers is recommended.

Keywords: Seed storage, winterfat, *Eurotia lanata*.

According to the early literature, winterfat (Eurotia lanata (Pursh) Moq.) seeds lose most of their viability within 1 or 2 years (Wilson 1931, Hilton 1941, U. S. Forest Service 1948). Recently we learned that fruits of winterfat remained more viable when stored at 38° to 42° F. than at 55° to 95° F., and that retention of viability varies with the year the fruits are collected (Springfield 1968a, 1968b).

We then undertook further studies to answer the following questions: (1) Should winterfat be stored as whole fruits or threshed seeds? (2) Should the storage containers be sealed or unsealed? (3) How does storage in an outside shed, where temperatures fluctuate widely, compare with storage in a freezer, a refrigerator, or under ordinary room conditions?

Methods

Fruits used in the study were collected November 1, 1968, from a group of plants at an experimental site 15 miles west of Corona, New Mexico. Fruits were ripe, as indicated by ease of removal from branches and the large number on the ground from natural shattering.

Soon after collection, seeds were threshed by hand from about half of the fruits. Both fruits and seeds were then air-dried for 5 weeks. Moisture contents at the start of the experiment, determined by ovendrying small samples, were: whole fruits, 10.8; threshed seeds, 8.2.

On December 7, 1968, fruits and seeds were stored in an outside shed, a room, a refrigerator, and a freezer (table 1). In each storage area, half of the fruits or seeds were stored in an open, unsealed container and the other half in a sealed container. The sealed containers were 1-quart metal cans with quarter-turn lids, fastened with masking tape. Though not absolutely airtight, they were much less subject to humidity changes than the containers without lids.

Viability was checked at yearly intervals for 3 years. At the start of each viability test, whole fruits were threshed by hand to insure comparability between fruits and seeds (about 25 percent of the fruits did not contain seeds). For each storage situation, three replications of 50 seeds were put in petri dishes filled with 100 ml vermiculite and 60 ml distilled water.

---

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

Two layers of germination blotter were put on top of the vermiculite. Seeds were placed on the blotters, which remained moist throughout the test. All germination tests were made in a refrigerator modified to provide a temperature of 56°±2° F. without light.

Seedlings were counted at 1- or 2-day intervals. Seeds were considered germinated when cotyledons and radicles together measured at least 1/2 inch and both were detached from the seedcoat.

Results and Discussion

Cold storage resulted in higher retention of viability than room or shed storage (table 1). Viability was retained at the highest level in a freezer at -4° to -10° F. Storage under refrigeration (34° to 42° F.) also generally gave higher viability. The only exception was threshed seeds stored in unsealed containers, which dropped sharply in viability between the second and third years of storage. The exact cause of this drop is not known, but some external factor, such as additional moisture, probably was responsible. In any event, whole fruits retained their viability throughout the 3 years under refrigeration, in sealed as well as unsealed containers.

Sealed storage usually gave advantages over unsealed storage, especially under the warmer storage temperatures (table 1).

Storage of winterfat seeds under room conditions generally proved unsatisfactory. Viability of threshed seeds declined appreciably after only 1 year of storage. Whole fruits, however, maintained near-maximum viability the first year. At the end of 3 years, whole fruits in sealed containers remained more viable than other fruits and seeds stored under room conditions.

Of the fruits and seeds stored in a shed outside, only threshed seeds in a sealed container retained reasonable viability. Whole fruits, especially those in an unsealed container, lost viability rapidly.

There were several inconsistencies in the responses of fruits and seeds to various storage situations. After 3 years of storage in sealed containers in a shed outside, for example, threshed seeds were 51 percent viable, but whole fruits only 11 percent viable. Under room conditions, however, fruits retained their viability better than seeds.

Table 1.--Percent viability of winterfat after 1, 2, and 3 years of storage in sealed and unsealed containers

Container and storage area	Temperature range	After 1 year		After 2 years		After 3 years		
		Fruit	Seed	Fruit	Seed	Fruit	Seed	Mean[1]
	°F.	Percent						
SEALED:								
Outside shed	-15 to 105	81.3	82.0	20.0	70.7	10.7	50.7	30.7c
Room	75 to 83	97.3	78.3	81.0	63.3	62.7	42.0	52.4c
Refrigerator	34 to 42	100.0	91.7	94.0	100.0	97.3	93.3	95.3a
Freezer	-4 to -10	100.0	100.0	97.3	98.3	98.7	96.0	97.4a
UNSEALED:								
Outside shed	-15 to 105	18.7	47.0	0.0	12.3	0.0	6.7	3.4d
Room	75 to 83	96.0	83.3	72.0	52.0	44.0	48.0	46.0c
Refrigerator	34 to 42	98.7	96.7	97.7	98.3	96.0	79.3	87.6b
Freezer	-4 to -10	97.3	100.0	100.0	96.7	100.0	96.7	98.4a

[1] Means followed by same letter do not differ significantly at .05 level.

Conclusions and Recommendations

Storage in sealed containers either at subzero temperatures (-4° to -10° F.) or under refrigeration (34° to 42° F.) is recommended for maximum retention of viability of winterfat seeds. Sealed storage is preferable to open or unsealed storage, all factors considered.

In general, winterfat can be stored satisfactorily either as whole fruit or threshed seed. Threshed seeds stored unsealed under refrigeration might show large losses of viability in 3 years, however.

Winterfat fruits — but not threshed seeds — can be stored at room temperatures for up to 1 year with practically no loss in viability; this is an important consideration from the standpoint of economics and convenience. Storage under ordinary room conditions cannot be recommended for periods exceeding 1 year, however, because losses in viability are likely.

Storage under conditions comparable to the outside shed in this experiment should be avoided.

Literature Cited

Hilton, J. W.
1941. Effects of certain microecological factors on the germinability and early development of Eurotia lanata. Northwest Sci. 15: 86-92.

Springfield, H. W.
1968a. Cold storage helps winterfat seeds retain viability. J. Range Manage. 21: 401-402.

Springfield, H. W.
1968b. Age and year of collection affect germination of winterfat seeds. U. S. For. Serv. Res. Note RM-112, 2 p. Rocky Mt. Forest and Range Exp. Stn., Fort Collins, Colo.

U. S. Forest Service.
1948. Woody plant seed manual. U.S. Dep. Agric. Misc. Publ. 654, 416 p.

Wilson, C. P.
1931. The artificial reseeding of New Mexico ranges. N. Mex. Agric. Exp. Stn. Bull. 189, 37 p.

Agriculture—CSU, Ft. Collins

U S D A FOREST SERVICE
RESEARCH NOTE RM- 234

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Computer Program for Processing Historic Fire Weather Data for the National Fire-Danger Rating System

R. William Furman[1] and Robert S. Helfman[2]

FIRDAT is a FORTRAN IV program to compute the daily components and indexes of the National Fire-Danger Rating System. FIRDAT will also compute and print the absolute, relative, and cumulative frequencies of occurrence, and print a cumulative frequency distribution for each of the components and indexes.

A description of the program and subroutine along with examples of input and output data are presented in this Note.

Keywords: Fire-Danger Rating, fire planning, fire management, data processing.

Levels for Specific Action and Manning Classes for the new National Fire-Danger Rating (NFDR) System (Deeming et al. 1972) are determined from the cumulative frequency distribution of Burning Index (BI). To obtain this distribution, the BI must be computed for all the available historic fire weather data. The computed BI's then have to be sorted into classes (or ranked) and the cumulative frequency computed. This operation normally would be quite time consuming. On a computer, however, these tasks can be accomplished accurately in a few seconds with minimum effort. Using the same approach, the effects of different land management practices or potential fire situations are easily simulated, that is, chipping versus the alternative of lopping and scattering or directional falling versus random falling, and so forth.

This report documents computer program FIRDAT constructed to perform these tasks. It is to be used in the implementation of the NFDR System, and as an aid for fire planning on the National Forests. Versions of FIRDAT are available for CDC 6400, 3300, 3100, UNIVAC 1108, and IBM System/360.[3]

Program FIRDAT

FIRDAT is the name of the program written in FORTRAN IV, which provides a fast, accurate means of computing fire behavior indexes from historic fire weather records. It will provide distributions of indexes by tabulating absolute, relative, and cumulative frequencies. A plot of the cumulative frequency distribution is also provided.

---

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

[2] *Systems Analyst, Pacific Southwest Forest and Range Experiment Station, Forest Fire Laboratory, Riverside, California.*

[3] *The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.*

Input

The "data deck" consists of three parts:

(1) **First Lead Card (see appendix I).**— This card contains information about the observing station, data input device and the output and data input options. The station information includes station name, station number, slope class, and elevation. The data input device will designate whether the ambient weather data are available on punched cards (unit 5) or magnetic tape (unit 1-4, 6-9). The output options consist of listing all the weather data with the computed indexes and components for each day; tabulating the frequencies for each of the indexes or components and plotting a graph of the cumulative frequency distribution; and punching or writing on magnetic tape the date and values of all components and indexes. The components referred to are ignition probability, rate of spread, and energy release; the indexes are Occurrence Index, Burning Index, and Fire Load Index. These options will be discussed further in the **Output** section.

There are five input data options to the program. The option chosen will depend upon the kind of data available. (The user, not the program, chooses the option.) The data combinations which determine the option to be used are tabulated in table 1. Since the number of assumptions the program makes to satisfy the data requirements increases as the number of data parameters decreases, every effort should be made to use the most comprehensive data option.

Table 1.--Data options required for specified levels of accuracy for each model--historical analysis

Data	Data options				
	I	II	III	IV	V
Station number	x	x	x	x	x
Fuel model	x	x	x	x	x
Slope class	x	x	x	x	x
Date (yr., mo., day)	x	x	x	x	x
State of weather	x	x	x	x	x
Herb. veg. condition	x	x	x	x	x
Dry-bulb temperature	x	x	x	x	x
Wet-bulb temperature	x	x	x	x	x[1]
Windspeed	x	x	x	x	x
Precip. amount	x	x	x	x	x
24-hr. max. temp.	x	x	x		
24-hr. min. temp.	x	x	x		
24-hr. max. RH	x	x			
24-hr. min. RH	x	x			
1/2-inch stick moisture	x			x	

[1] If not available, relative humidity (RH) or dewpoint may be substituted.

(2) **Second Lead Card (see appendix I).**— This card contains information about the fuel model and fire season. Included on this card are the fuel model designation, loadings in tons per acre of the 1-, 10-, and 100-Hour Timelag dead fuels and live fuels, fuel surface-area-to-volume ratios for the different fuel classes, the fuel depth, and the beginning and ending dates of the fire season. This information (except the fire season) for each fuel model is contained in table 2.

Table 2.--NFDR fuel models (1972)

Fuel model	Fuel loading				Surface area to volume				Bed depth
	1-hr load	10-hr load	100-hr load	Living load	1-hr sigma	10-hr sigma	100-hr sigma	Living sigma	
	Tons per acre				Feet^{-1}				Feet
A	1.25	0.0	0.0	0.0	3000	109	30	1500	0.75
B	5.00	4.0	2.0	2.0	2000	109	30	1500	6.00
C	1.50	1.0	0.0	0.0	2700	109	30	1500	1.00
D	1.50	2.5	2.0	0.0	1750	109	30	1500	2.50
E	1.50	1.0	0.0	0.0	2500	109	30	1500	0.30
F	1.00	0.5	0.0	2.0	1500	109	30	1500	2.00
G	3.00	2.0	5.0	0.0	1500	109	30	1500	1.25
H	1.00	1.0	1.0	0.0	2000	109	30	1500	0.40
I	4.00	5.0	10.0	0.0	1500	109	30	1500	3.50

(3) **Ambient Conditions (see appendix II).**—These data contain records of specific ambient weather conditions necessary to determine the fire-danger indexes. Only those data falling inside the fire season defined on the Second Lead Card will be used in computing the fire-danger indexes. The data format for the ambient conditions (appendix II) was designed for use with the Form WB 612-17, the 10-Day Fire Danger and Weather Record. Depending on the input device designated on the First Lead Card, the program is capable of reading the ambient conditions on either punched cards or a BCD tape of single card records. There is no limit to the number or records that can be read. If punched cards are used, a card containing 999999 in columns 1-6 must be the last card for each station. Computations for a given station will be completed and a new set of lead cards will be read when the 999999 card is encountered. If the data are on magnetic tape, a new set of lead cards will be read when a station number of greater magnitude is encountered. Therefore the data must be sorted in ascending order by station number. Fuel moisture values carry over from day to day, so the data should be arranged in ascending order by date for each station on both cards and tape. See figure 1 for an example of an input data deck.

Output

There are four parts to the output of program FIRDAT:

(1) **Daily Information List.**—This part of the output provides a line per card listing of weather parameters and fire-danger components and indexes. It is optional and may be suppressed by making the proper entry on the First Lead Card.

(2) **Frequency Tabulations.**—For any or all of the six fire-danger components and indexes, the absolute, relative, and cumulative frequencies are tabulated along with the class upper boundary. The choice of indexes to be tabulated is made on the First Lead Card (see appendix I).

(3) **Cumulative Frequency Distribution.**—A cumulative frequency curve will be printed on the computer page for the indexes designated in the output options.

(4) **Auxiliary Output of Components and Indexes.**—The program has an output feature whereby the station number, date, and the six fire components and indexes can be punched on cards or written in BCD on magnetic tape. This option is on the First Lead Card.

The auxiliary output will contain two header cards per station run plus one card per observation containing indices, arranged and formated as follows:

Header Card 1	Col.	1-6	Station Number
Header Card 2	Col.	1-6	Station Number
		7-10	Fuel Model Type
		11-30	Station Name
		31	Slope Class
		32-36	Station Elevation (feet)
Card/observation		1-6	Station Number
		7-8	Year
		9-10	Month
		11-12	Day
		13-15	Probability of Ignition
		16-18	Spread Factor
		19-21	Energy Release
		22-24	Occurrence Index
		25-27	Burning Index
		28-30	Fire Load Index

This output is arranged to be compatible with a followup program which will display the seasonal variation of the indexes graphically.

Examples of the output are found in appendix III ; a flow chart of FIRDAT is in appendix IV.

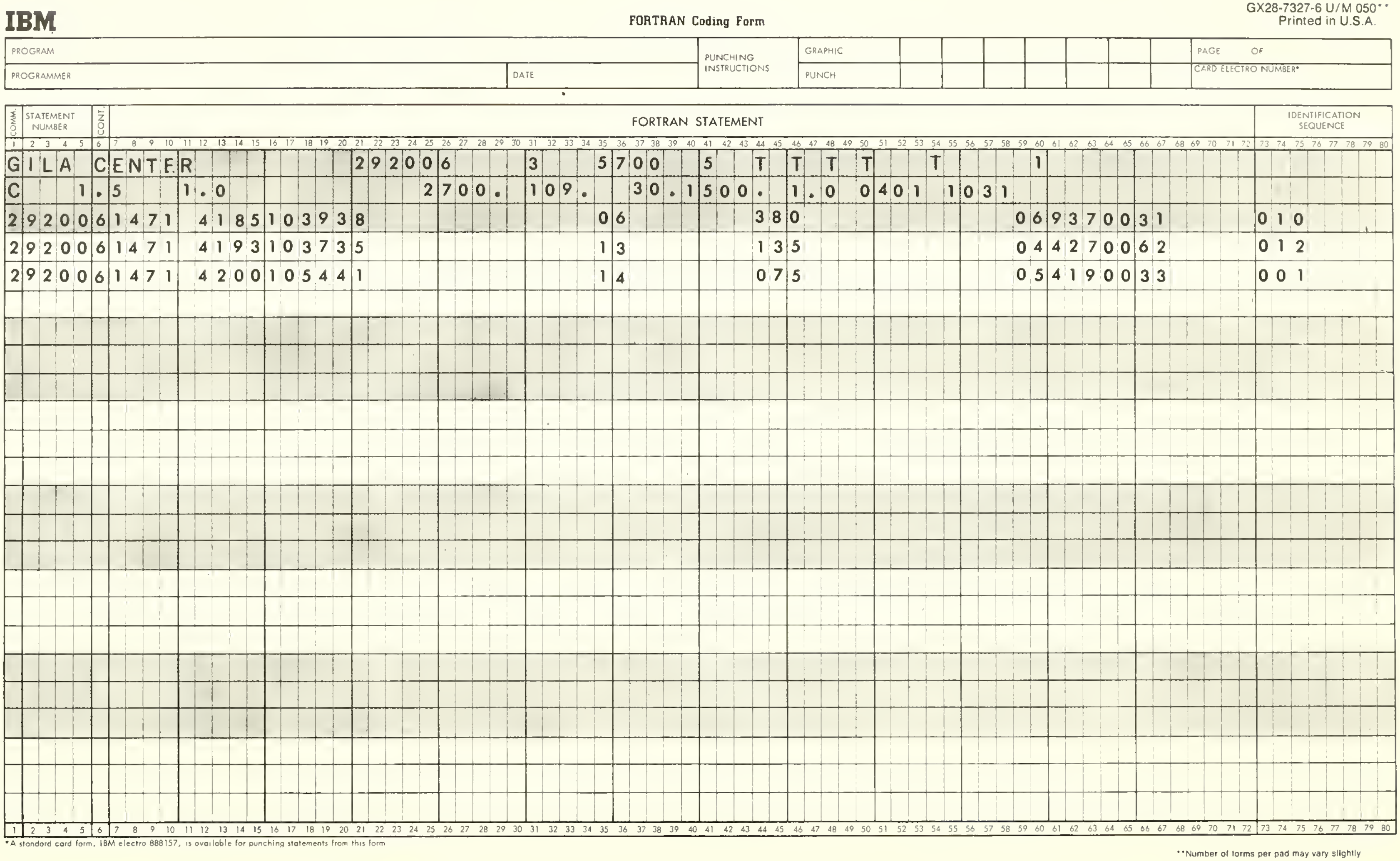
Assumptions

For many initial applications of the NFDR System, the historic data available will not include some of the parameters needed to compute the fire-danger indexes and components. Some assumptions were made to fulfill data requirements. These assumptions will depend upon the data available which, in turn, will determine which data option will be chosen by the user. The following assumptions were made for each option.

Option I.—No assumptions are made to fill missing data. All necessary data are provided.

Option II.—The 10-Hour Timelag Fuel Moisture is computed from observed temperature and humidity instead of being observed from 1/2-inch fuel moisture sticks (analog).

Option III.—In addition to the assumption in Option II, the maximum and minimum relative humidities are computed from the maximum and minimum temperatures, assuming constant specific humidity for the day.



IBM FORTRAN Coding Form GX28-7327-6 U/M 050**
Printed in U.S.A.

PROGRAM
PROGRAMMER
DATE
PUNCHING INSTRUCTIONS
GRAPHIC
PUNCH
PAGE OF
CARD ELECTRO NUMBER*

COMM. | STATEMENT NUMBER | CONT. | FORTRAN STATEMENT | IDENTIFICATION SEQUENCE

```
GILA CENTER         292006    3   5700  5  T T T T   T     1
C   1.5   1.0           2700. 109.  30.1500. 1.0 0401  1031
2920061471 4185103938             06       380            069370031     010
2920061471 4193103735             13       135            044270062     012
2920061471 4200105441             14       075            054190033     001
```

*A standard card form, IBM electro 888157, is available for punching statements from this form

**Number of forms per pad may vary slightly

Figure 1.--Example of input data deck.

Option IV.—The 100-Hour Timelag Fuel Moisture is computed from "yesterday's" 10- and 100-Hour Timelag Fuel Moisture and "today's" 10-Hour Timelag Fuel Moisture rather than from average temperature and humidity. The 10-Hour Timelag Fuel Moisture is the measured fuel moisture from the 1/2-inch fuel moisture sticks.

Option V.—This option is a combination of Options II and IV.

In addition to the assumptions made as required by the options, other assumptions are made for each observation and are independent of which option is selected. Among these are:

a. All risk values are assigned inside the program. Lightning and man-caused risk are set to 5 each for a total risk of 10.
b. If precipitation has occurred in any amount during the past 24 hours, the precipitation duration is set to 1 hour.
c. If the state of the weather indicates precipitation was occurring at the time of the observation, the fine fuel moisture and the 10-Hour Timelag Fuel Moisture (except for 1/2-inch fuel sticks) is set to 31 percent and 25 percent, respectively.
d. Living fuel moisture (woody) is set to 100 percent.

In selecting these options we felt that the five most desirable and likely combinations of data parameters were represented.

Missing Data

At several points in the program, certain data parameters are checked to determine if they have a zero value or are missing (blank). If zero or missing values are detected, that data card is usually ignored and the program proceeds to the next card. The parameters checked include:

Parameter	Value to reject	Option
Temperature	misg/u*	I-V
Relative humidity	0/misg/u	I-V
Windspeed	misg/u	I-V
Tmax - Tmin	misg/u	I-III
RHmax - RHmin	misg/u	I,II
1/2-inch stick moisture	0/misg	I,IV

*u - unrecognizable character.

Subroutines

Unless otherwise stated, all subroutines and functions are called only from the main program. Subroutines are arranged in alphabetical order, not in the order in which they are called.

Function ADJFFM

Function ADJFFM will return a value for fine fuel moisture in percent for values of 1-Hour Timelag Fuel Moisture and percent green herbaceous vegetation. This function is essentially a table look-up process. No adjustment will be made to the 1-Hour Timelag Fuel Moisture if the herbaceous vegetative condition is cured (less than 10 percent green material, appendix II).

An unrecognizable value for herbaceous condition or stage will result in a default value of 30 percent for percentage of green herbaceous material.

Subroutine C0DPRC

This routine accepts encoded over-punched numeric data, originally read in A1 format, and returns the numeric value signed plus. A missing-flag is returned ".TRUE." if the field contains any invalid code combination (legitimate codes are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 11-0, 11-1, 11-2, etc., 11-9, 12-0, 12-1, . . . 12-0, 12-1, . . . 12-9, 12-ONLY, 11-ONLY, BLANK). A blank-flag is set ".TRUE." if the field is blank, and a negative-flag is set ".TRUE." if an 11-overpunch is present (12-overpunch treated as if not present, i.e., 12-3 = 3). The returned floating point value is always signed plus. C0DPRC is called from subroutine SCAN.

Subroutine CUM

When all the data for a given station have been read, the subroutine CUM is called. Here the absolute, relative, and cumulative frequencies are computed for the desired indexes, and the number of classes is decided upon for plotting purposes. The number of classes chosen is that necessary to account for 99.5 percent of the data.

Function EQMC

This function returns a value of equilibrium moisture content for wood, given temperature

(°F) and relative humidity (%). The value is derived from regressions of the Forest Products Laboratory Tables (Simard 1968). This function is called from Subroutine M100 as well as from the main program.

Function FFMCHS

This function computes the 1-Hour Timelag Fuel Moisture (percent). Function arguments are dry bulb temperature (°F), relative humidity (%), and cloud cover (decimal).

Function GFNC

Given the packing ratio (B), volume to area ratio (S), and optimum packing ratio (B0PT), this function will deliver the maximum reaction intensity.

Function H2PCNV

This function returns approximate pressures in millibars given elevation in feet m.s.l. The function uses the same elevation ranges used in Weather Bureau psychrometric tables.

Real Function MXFNC

Given percent green and 1-Hour Timelag Fuel Moisture, this function computes and returns the extinction moisture content (%) for living herbaceous fuels.

Subroutine M100

This subroutine computes the 100-Hour Timelag Fuel Moisture (%) from Fosberg's (1972) theoretical solution. The arguments for this subroutine are 24-hour average temperature (°F), average relative humidity (%), and duration of precipitation (hrs) for the preceding 24 hours. This subroutine is used in options I-III. Function EQMC is called to deliver equilibrium moisture content.

Subroutine M100A

This subroutine estimates the 100-Hour Timelag Fuel Moisture from a stochastic model given inputs of yesterday's 10- and 100-Hour Timelag Fuel Moisture and today's 10-Hour Timelag Fuel Moisture. This subroutine is used in options IV and V where average temperature and humidity are not available.

Subroutine PL0TR

This subroutine contains the instructions to plot the cumulative frequency distribution of the index specified by the index number in the argument list. If the number of classes is less than or equal to five, or if there are fewer than 100 data points, no graph will be plotted and the appropriate error message will be printed.

Subroutine PRINTR

Class frequencies are printed in tabular form by this subroutine. The variables to be printed are in blank "C0MM0N". The arguments necessary are the number which designates which index is being handled and the number of classes to be considered.

Subroutine PSYCHR

This subroutine computes relative humidity (%) from dry bulb temperature (°A), wet bulb temperature (°A), and pressure (mb). Subroutine VAP0R is called from PSYCHR to deliver saturation vapor pressures. Wet bulb temperatures below 0° C. may be used but no correction has been made for wet bulb icing. The humidities returned will be between 1 and 100 percent inclusive.

Subroutine SCAN

This routine performs alpha-string to floating-point conversion. "-ALPHA-" is an alphanumeric array read as N-A1, "-VALUE-" is the returned real value, "-NWID-" is the number of characters of the field width, "-NDEC-" is the number of digits to be considered to be to the right of the decimal point (same conventions as FORTRAN format specifications), "-MISFLG-" is a logical set ".TRUE." for invalid code combinations or illegal sequences, "-BLKFLG-" is a logical set ".TRUE." if the field in question is entirely blank. "-0VP0S-" is an integer specifying which character of the field may be legally overpunched. For instance, for a 4 character field, if "-0VP0S-" were 3, then if an overpunch (11-PUNCH) were found in any position except the 3rd character, the error-flag would be set ".TRUE." and the field considered invalid. A "0" value for "-0VP0S-"

means that any character may be overpunched, while any negative value of "-ØVPØS-" means that no character may be overpunched. "-MINFLG-" is set ".TRUE." if the field is negative (overpunched). "-MINFLG-" is returned to permit the situation of an overpunched "0" field. CØDPRC is called from SCAN.

Subroutine SET

In subroutine SET, the arrays in which the frequencies are accumulated are initialized and the class interval is determined. This subroutine is used only once at the beginning of each station.

Subroutine SØRT

In subroutine SØRT, the index value is sorted into its proper class, and the number-in-class counters are incremented. This subroutine is accessed for every data card.

Function U20FNC

This function reduces wind measured at 20 feet aboveground to midflame height. It also restricts the maximum reduced wind to limits required by theory for the fuel bed.

Subroutine VAPØR

For a temperature (°A), this subroutine will return the saturation vapor pressure over water (mb). The operation is based on the equation from List's (1966) Smithsonian Meteorological Tables (p. 350). This subroutine is called from program FIRDAT and subroutine PSYCHR.

Literature Cited

Deeming, John E., James W. Lancaster, Michael A. Fosberg, R. William Furman, and Mark J. Schroeder.
1972. National Fire-Danger Rating System. USDA For. Serv. Res. Pap. RM-84, 165 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Fosberg, Michael A.
1972. Theory of precipitation effects on dead cylindrical fuels. For. Sci. 18: 98-108.

List, Robert J.
1966. Smithsonian meteorological tables. 527 p. Wash., D.C.: Smithson. Inst.

Simard, Albert J.
1968. The moisture content of forest fuels. I. A review of the basic concepts. For. Fire Res. Inst. Inform. Rep. FF-X-14, 46 p. Ottawa, Ont.

Appendix I: Lead card formats

Card field	Columns From	Columns To	Number of columns	Remarks
First Lead Card - Station parameters				
Station name	1	20	20	
Station number	21	26	6	
Slope class		31	1	
Elevation	34	38	5	Feet (right justify)[1]
Input device designation		41	1	1-4, 6-9 = Magnetic tape input (assign magnetic tape logical unit) 5 = Card reader input
Indexes output device designation		42	1	0 - No output 1-9 Fortran logical file no.
Ignition probability		44	1	Enter T to suppress[2]
Rate of spread		46	1	''
Energy release		48	1	''
Occurrence index		50	1	''
Burning index		52	1	''
Fire load index		54	1	''
Daily info list		56	1	''
Data option		60	1	1-5 Inclusive (see table 1)
Second Lead Card - Model name and fuel bed parameters				
Model type	1	4	4	(See table 2)
Fuel loadings				Tons per acre
1-hour timelag	5	9	5	Right justify in field[3]
10-hour timelag	10	14	5	''
100-hour timelag	15	19	5	''
Live	20	24	5	''
Area volume ratio				
1-hour timelag	25	29	5	''
10-hour timelag	30	34	5	''
100-hour timelag	35	39	5	''
Live	40	44	5	''
Bed depth	45	49	5	''
Fire season				
Beginning month	50	51	2	
Beginning day	52	58	2	
Ending month	55	56	2	
Ending day	57	58	2	

---

[1] *Integer.*

[2] *For CDC 3100 version, use 1 instead of T.*

[3] *Real number — right justify or punch decimal.*

Appendix II: Card punching and verifying instructions for the weather records

Field no.	Card field	Columns From	Columns To	Number of columns	Remarks
	Station number	1	6	6	Upper right corner
	Hour (observation time)	7	8	2	First two digits
	Year (period of time)	9	10	2	Last two digits
	Month (period of time)	11	12	2	(Convert A months to N) (Jan 01; Feb 02, etc.)
1	Day	13	14	2	
2	State of weather	15	15	1	
3	Herbaceous stage	16	16	1	(1)
4	Dry bulb temp.	17	19	3	Minus, "-" overpunch col. 19
5	Wet bulb temp.	20	21	2	Minus, "-" overpunch col. 21
7	Dew point temp.	24	25	2	Minus, "-" overpunch col. 25
8	Relative humidity	26	27	2	100%, punch zeros, "-" over 26
14	Windspeed	35	36	2	100 & over, punch zeros, - "-" over 35
	½" fuel moisture sticks	44	46	3	1 decimal place
34	Maximum temp.	59	61	3	Minus, "-" overpunch col. 61
35	Minimum temp.	62	63	2	Minus, "-" overpunch col. 63
36	Maximum humidity	64	65	2	100%, punch zeros "-" over 64
37	Minimum humidity	66	67	2	
41	24-hour amount	73	75	3	2 decimal places. Decimal blank, punch zero. Trace, punch T00

No data in field, leave blank.
Left fill all fields with zero.

Punch Operator Functions:

The field numbers on the card punch instructions correspond with the numbers printed on the WB Form 612-17.

One detail card per day of the month entry will be punched and verified.

Columns 1 through 12 can be duplicated for each form after the first day is punched.

Credits or minus figures will be punched with a "-" overpunch in the units (low order) position.

Figures which exceed two digits, 100 or more, will be punched with a "-" overpunch in the high order position.

Fields without data, leave blank.

Left fill all data fields with zeros.

---

[1] *1-cured (10 percent green material); 2-transition (30 percent green material); 3-green (50 percent green material).*

Appendix III: Output

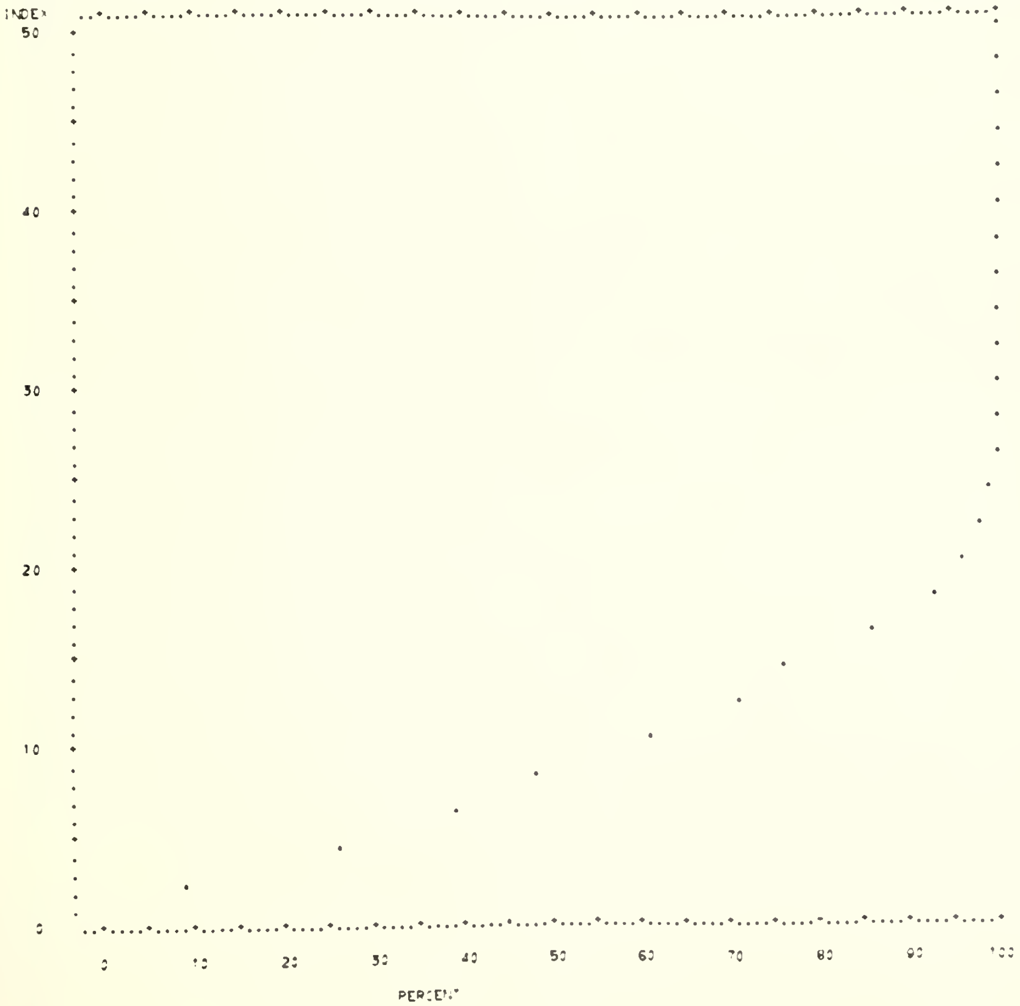
Abbreviations used on Daily Information List

SW	- state of the weather
D B TMP	- dry bulb temperature
REL HUM	- relative humidity
WD SP	- windspeed
TMP MAX	- 24-hour maximum temperature
TMP MIN	- 24-hour minimum temperature
R H MAX	- 24-hour maximum relative humidity
R H MIN	- 24-hour minimum relative humidity
PPT AMT	- 24-hour precipitation amount
PPT DUR	- precipitation duration (either 0 or 1)
L R	- Lightning Risk
M R	- Man-Caused Risk
L F	- living fuel moisture (woody vegetation condition)
PC GR	- percentage green herbaceous material
1-HR FM	- 1-hour timelag dead fuel moisture
ADJ 1-HR	- fine fuel moisture
10-HR FM	- 10-hour timelog dead fuel moisture
100-HR FM	- 100-hour timelag dead fuel moisture
IGN COM	- Ignition Component
SPD COM	- Spread Component
ENRL COM	- Energy Release Component
OCC NDX	- Occurrence Index
BUR NDX	- Burning Index

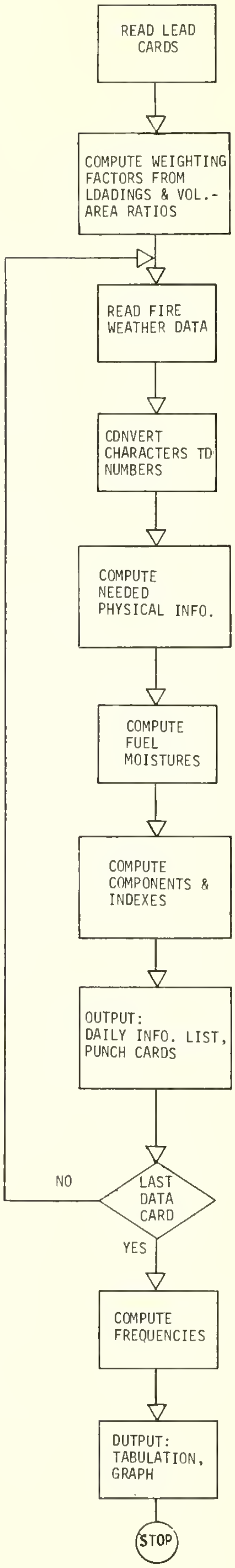
```
NATIONAL FIRE DANGER RATING SYSTEM - OPTION 1                                                            03/21/72

                 STATION - GILA CENTER              (292006)        FUEL MODEL C         SLOPE  3     ELEV.  5700

  DATE  S  D B  REL   WD  TMP  TMP  R H  R H   PPT   PPT  L  M  L  PC  1-HR   ADJ  10HR  100   IGN  SPD  ENRL   OCC   BUR
        W  TMP  HUM   SP  MAX  MIN  MAX  MIN   AMT   DUR  R  R  F  GR    FM  1-HR    FM   HR   COM  COM   COM   NDX   NDX

710418  5   39   92    6   69   37  100   31   010    0.  5  5  7  10  31.0  30.0  25.0   0.     0    0     0     0     0
710419  3   37   84   13   44   27  100   62   012    0.  5  5  7  10  19.0  19.0  13.5   0.     0    5     6     0     6
710420  0   54   32   14   54   19  100   33   001    0.  5  5  7  10   6.0   6.0   7.5   0.    46   11    20    47    14
710421  3   50   32   13   59   21  100   23   000    0.  5  5  7  10   7.0   7.0   5.0   0.    35    9    21    36    13
710422  0   58   24   14   60   28   77   23   000    0.  5  5  7  10   4.0   4.0   3.5   0.    64   14    26    66    17
710423  0   67   24   11   68   23  100   23   000    0.  5  5  7  10   4.0   4.0   2.0   0.    66    9    28    68    15
710424  0   67   20   11   70   26  100   19   000    0.  5  5  7  10   4.0   4.0   2.0   0.    66    9    28    68    15
710425  C   67   17   18   71   40   45   15   000    0.  5  5  7  10   3.0   3.0   1.5   0.    76   24    30    78    23
710426  0   59   18   18   70   43   34   12   000    0.  5  5  7  10   4.0   4.0   1.5   0.    64   21    28    66    21
710427  0   65   15   11   66   22   74   13   000    0.  5  5  7  10   3.0   3.0   1.0   0.    76   10    30    78    16
710428  0   63   19   13   68   24   88   16   000    0.  5  5  7  10   4.0   4.0   1.0   0.    65   12    29    67    17
710429 AN ERROR HAS BEEN FOUND IN THE DATA.  RECORD WAS REJECTED.
710430 AN ERROR HAS BEEN FOUND IN THE DATA.  RECORD WAS REJECTED.
710501  0   78   10    9   79   23   83   10   000    0.  5  5  7  10   2.0   2.0   1.0   0.    91    9    32    93    15
710502 AN ERROR HAS BEEN FOUND IN THE DATA.  RECORD WAS REJECTED.
710503  0   78   10   13   82   23   83    9   000    0.  5  5  7  10   2.0   2.0   3.0   0.    91   16    30    93    19
710504  0   69    8   18   86   35   29    6   000    0.  5  5  7  10   2.0   2.0   3.0   0.    89   27    30    91    24
710505  0   66   13   13   71   26   60   12   000    0.  5  5  7  10   3.0   3.0   3.0   0.    76   14    28    78    18
710506  2   62   21    9   69   32   66   18   000    0.  5  5  7  10   5.0   5.0   3.5   0.    51    6    25    52    12
710507  2   67   20   13   70   34   71   19   000    0.  5  5  7  10   5.0   5.0   4.0   0.    52   11    25    53    15
710508  1   69   16   16   73   30   73   18   000    0.  5  5  7  10   3.0   3.0   4.0   0.    77   19    27    79    20
710509  0   70   12   15   71   29   57   12   000    0.  5  5  7  10   2.0   2.0   3.5   0.    89   20    29    91    21
710510  1   70   15    6   72   27   73   14   000    0.  5  5  7  10   3.0   3.0   3.5   0.    77    4    28    79    10
710511  9   63   23   15   75   30   82   15   000    0.  5  5  7  10   5.0   5.0   4.5   0.    52   14    24    53    17
710512  3   64   38    7   65   34  100   32   016    0.  5  5  7  10   8.0   8.0  12.0   0.    32    3    15    33     7
710513  1   71   16    5   71   31   71   16   019    0.  5  5  7  10   3.0   3.0  12.5   0.    77    3    20    79     8
710514  1   76   26    7   76   36  100   16   000    0.  5  5  7  10   4.0   4.0   9.0   0.    68    4    22    70    10
710515  0   79   16   11   80   34   86   16   000    0.  5  5  7  10   3.0   3.0   6.5   0.    79   10    25    81    15
710516  0   79   13   11   82   33   76   13   000    0.  5  5  7  10   3.0   3.0   5.5   0.    79   10    26    81    15
710517  1   71   16   16   81   33   67   12   000    0.  5  5  7  10   3.0   3.0   5.0   0.    77   19    26    79    20
710518  0   63   12    7   74   38   33    9   000    0.  5  5  7  10   2.0   2.0   5.0   0.    87    6    28    89    12
710519  0   71   10    8   71   24   62   11   000    0.  5  5  7  10   2.0   2.0   4.0   0.    89    7    29    91    13
710520  0   78   10   11   78   24   77   11   000    0.  5  5  7  10   2.0   2.0   3.5   0.    91   12    29    93    17
710521  3   73   12   23   80   29   66   10   000    0.  5  5  7  10   3.0   3.0   3.5   0.    73   37    28    75    27
710522  0   70   15   16   78   29   68   11   000    0.  5  5  7  10   3.0   3.0   3.5   0.    77   20    28    79    20
710523  0   69   16   16   73   29   75   15   000    0.  5  5  7  10   3.0   3.0   3.5   0.    77   20    28    79    20
710524  0   75    7    4   75   26   46    7   000    0.  5  5  7  10   1.0   1.0   3.5   0.   100    3    31   100    10
710525  0   81   11    9   81   28   77    7   000    0.  5  5  7  10   2.0   2.0   3.0   0.    92    8    30    94    15
710526  0   80   10   11   82   32   61   10   000    0.  5  5  7  10   2.0   2.0   3.0   0.    92   12    30    94    17
710527  0   80   12   12   83   32   72   10   000    0.  5  5  7  10   2.0   2.0   3.0   0.    92   14    30    94    18
710528  1   77   14   11   82   45   46   12   000    0.  5  5  7  10   3.0   3.0   3.5   0.    79   10    28    81    15
710529  2   65   21   17   79   34   68   14   000    0.  5  5  7  10   5.0   5.0   3.5   0.    52   17    25    53    19
710530  0   69   19   12   70   31   80   19   000    0.  5  5  7  10   4.0   4.0   3.5   0.    66   11    26    68    15
710531  0   73   15   15   74   32   66   15   000    0.  5  5  7  10   3.0   3.0   4.0   0.    78   17    27    80    19
710601  0   77    9   12   77   28   57   10   000    0.  5  5  7  10   2.0   2.0   3.5   0.    91   14    29    93    18
710602  3   78    8   14   80   34   42    8   000    0.  5  5  7  10   2.0   2.0   3.5   0.    86   18    29    88    20
710603  1   76   10   18   78   31   58    8   000    0.  5  5  7  10   2.0   2.0   3.5   0.    91   27    29    93    24
710604  0   77    7   11   78   22   57    7   000    0.  5  5  7  10   1.0   1.0   3.0   0.   100   14    31   100    18
710605  0   80   10   19   82   24   84    7   000    0.  5  5  7  10   2.0   2.0   3.0   0.    92   30    30    94    26
710606  0   82    8   13   84   29   56    8   000    0.  5  5  7  10   1.0   1.0   3.0   0.   100   18    31   100    21
```

```
NATIONAL FIRE DANGER RATING SYSTEM - OPTION 1         FREQUENCY DISTRIBUTIONS FOR BURNING INDEX                          03/2

STATION - GILA CENTER        -292006  *  SLOPE CLASS 3  *  MODEL C     *  FIRE SEASON  401-1031  *  NO. PNTS.  220

                  CLASS             UPPER            NO. IN           RELATIVE          CUMULATIVE
                  NO.               BDY              CLASS            FREQ (PCT)        FREQ (PCT)

                     1                 2               19                8.6               8.6
                     2                 4               38               17.3              25.9
                     3                 6               28               12.7              38.6
                     4                 8               20                9.1              47.7
                     5                10               29               13.2              60.9
                     6                12               23               10.5              71.4
                     7                14               11                5.0              76.4
                     8                16               21                9.5              85.9
                     9                18               15                6.8              92.7
                    10                20                8                3.6              96.4
                    11                22                3                1.4              97.7
                    12                24                3                1.4              99.1
                    13                26                1                 .5              99.5
                    14                28                1                0.0             100.0
                    15                30                0                0.0             100.0
                    16                32                0                0.0             100.0
                    17                34                0                0.0             100.0
                    18                36                0                0.0             100.0
                    19                38                0                0.0             100.0
                    20                40                0                0.0             100.0
                    21                42                0                0.0             100.0
                    22                44                0                0.0             100.0
                    23                46                0                0.0             100.0
                    24                48                0                0.0             100.0
                    25                50                0                0.0             100.0
```

```
NATIONAL FIRE DANGER RATING SYSTEM - OPTION 1          CUMULATIVE FREQUENCY (PCT) - BURNING INDEX                         03/2

STATION - GILA CENTER        -292006  *  SLOPE CLASS 3  *  MODEL C     *  FIRE SEASON  401-1031  *  NO. PNTS.  220
```



Appendix IV: Flow chart for program FIRDAT



U S D A FOREST SERVICE
RESEARCH NOTE RM-235

REST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Judging Ripeness of Seeds in Black Hills Ponderosa Pine Cones

James L. Van Deusen and Lawrence D. Beagle[1]

Buoyancy of cones in water is a good indicator of cone and seed ripeness for ponderosa pine in the Black Hills. When more than half of the cones in a sample from several trees will float, cones in that vicinity should yield a satisfactory number of viable seeds. Frequent checks on specific gravity are needed from mid-August on, since ripening proceeds rapidly then.

Keywords: *Pinus ponderosa* var. *scopulorum*, seed ripeness, forest seed collecting.

Collecting cones from standing trees is a difficult and time-consuming task. There is only a brief period between times of earliest seed ripeness and the beginning of seed fall. In many years, squirrels compound the problem with their early-season cone cutting.

It is important, then, to be able to determine the earliest practical time to begin collecting cones so as to maximize the period when viable seed in sufficient quantities can be obtained. This Note presents a guide to help the manager decide when to begin his collection.

Background Information

Useful indexes of seed maturity in the pines are usually determined indirectly by some measurement of the cone. The ratio of weight to volume (specific gravity) of freshly picked cones is commonly used to estimate ripeness of the seeds contained. Maki (1940) and Fowells and Schubert (1956) related specific gravity to seed ripeness for ponderosa pine in central Idaho and the pine region of California. While specific gravity is a valid indicator of seed ripeness in the Black Hills also, the critical values used elsewhere (0.84 and 0.86) appear too low for this region.

Other methods for estimating seed ripeness or maturity — such as percent moisture content of the cones, cone color, or splitting the cone to observe degree of milkiness or hardness of seeds — all appear too variable or impractical for field use in the Black Hills.

Study Methods

Cones were collected at 1- to 3-week intervals during the ripening period in 1970 and 1971

---

[1] *Associate Silviculturist and Forestry Research Technician, respectively, located at Rapid City in cooperation with South Dakota School of Mines and Technology; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

from trees at three widely separated locations in the Black Hills National Forest. Collection areas were in the southern Hills, north-central Hills, and Bear Lodge Mountains (fig. 1).

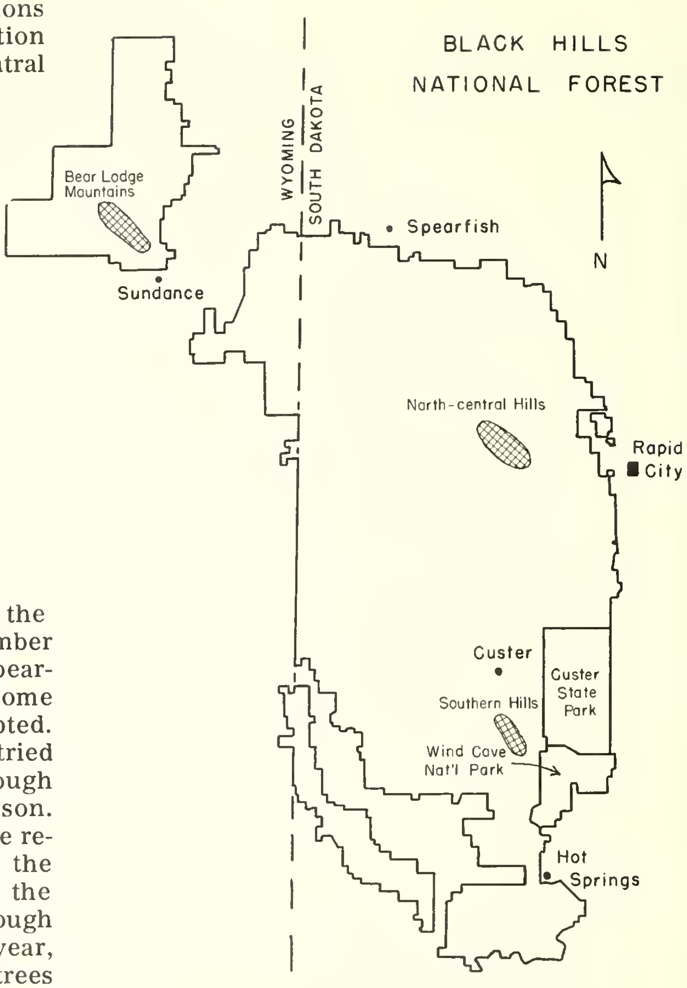


Figure 1.—Location of sampling areas for Black Hills ponderosa pine cone collections.

Sample trees.—Most were typical of the kind of trees silviculturists prefer for timber production. However, in cases where cone-bearing trees of top quality were lacking, some prolific trees of poorer form were accepted. Before cones were collected each year, we tried to select sample trees which contained enough cones to last throughout the collection season. Nevertheless, in each area a few trees were replaced by others nearby when crops on the original selections were exhausted before the season's collections were completed. Although the same three areas were sampled each year, the bulk of the cones came from different trees in the two years. Most trees sampled in 1970 produced few cones in 1971.

Collection of cones.—Size and frequency of collections were similar but not identical in the 2 years. Fifty cones (10 per tree) were collected from each area on each of three dates in 1970—450 cones in all. In 1971, 35 cones (seven per tree) were picked per area on each of six dates—or 630 cones total. All cones were picked from the upper half of tree crowns, and all were free of visible abnormalities—they would have been accepted by regular cone collectors.

Laboratory and greenhouse.—After each collection, the cones were brought quickly to the laboratory where they were weighed and their volumes determined by water displacement. Each year, 25 cones from each collection date and area were stored overwinter in individual paper bags in a heated room. Each spring seeds were extracted from open cones by shaking; unopened cones were not dissected to remove seeds.

Half of the cones collected in 1970 were ovendried to determine their moisture content at the time of collection. In 1971, moisture contents were determined for only 10 cones per collection area and data. No germination tests were made using seed from ovendried cones.

Extracted seeds were bulked by date and collection area before their germination was tested. In 1970, all seeds extracted were tested. The following year, tests were limited to 57 seeds from each area and date, except for som early-season collections which yielded fewe seeds (table 1).

Table 1.--Results of seed germination tests and some related cone characteristics for 25-cone samples of ponderosa pine in the Black Hills and Bear Lodge Mountains

	1970 COLLECTIONS						1971 COLLECTIONS					
ollection area	Date of collection	Average specific gravity	Cones with specific gravity of 1.000 or less	Cones opening overwinter in heated room	Seeds tested for germination	Germination	Date of collection	Average specific gravity	Cones with specific gravity of 1.000 or less	Cones opening overwinter in heated room	Seeds tested for germination	Germination
			- - - - - *Number*		- - - - -	*Percent*						*Percent*
ear Lodge ountains	Aug. 11	1.000	10	0	([1])	--	Aug. 3	0.986	20	1	16	0.0
	Aug. 24	.987	14	10	396	68.9	Aug. 13	1.007	4	11	279	49.8
	Sept. 9	.980	19	19	720	52.1	Aug. 23	.990	17	21	576	39.4
							Sept. 3	.958	18	25	576	32.1
							Sept. 15	.937	25	25	576	21.9
							Oct. 6	.828	25	24	576	22.7
orth- entral ills	Aug. 10	1.021	2	5	230	69.6	Aug. 4	.996	11	1	26	0.0
	Aug. 21	1.027	0	6	210	32.9	Aug. 12	1.019	3	9	252	5.6
	Sept. 8	.965	19	23	998	54.9	Aug. 25	1.017	5	14	576	34.2
							Sept. 2	.970	16	19	576	63.7
							Sept. 14	.954	18	20	576	39.9
							Oct. 5	.819	25	25	576	37.7
outhern ills	Aug. 7	1.019	2	1	44	0.0	Aug. 2	1.024	0	2	36	0.0
	Aug. 21	1.002	8	11	383	46.7	Aug. 12	1.027	0	4	([1])	--
	Sept. 8	.943	25	19	648	50.6	Aug. 25	1.027	0	7	252	20.6
							Sept. 2	1.017	1	7	240	63.8
							Sept. 14	.990	13	20	576	56.6
							Oct. 5	.823	25	25	576	54.0

[1] Too few seeds were available for germination tests.

Results and Discussion

Specific gravity of fresh cones as an index of maturity. — When 50 to 60 percent (12-15 cones) of a 25-cone sample from an area will float in water, it is probably safe to start collections in that area. By that time, most of the cones can be expected to open naturally, and yield seed with viability as good as seed collected at any later date (table 1).

One glaring and one marginal inconsistency appeared in 1971 which might have lead collectors to pick cones before they were ripe in two of the three areas. On August 3, in the Bear Lodge Mountains, 20 out of 25 cones (80 percent) would have floated in water, indicating satisfactory seed ripeness. It was not until August 23, however, that cones were ripe enough for picking in the Bear Lodge Mountains (table 1).

An overzealous collector might have started picking cones on August 4 in the north-central Hills if he had been willing to accept 11 floating cones instead of the suggested 12 to 15 in his 25-cone sample (table 1). He could have understandably reasoned that ripening would probably proceed faster than his collecting. But it was not until September 2 that the sample met the minimum specific gravity criterion for that area.

Some relatively high germination percentages were found for samples of seeds collected before average specific gravities declined to 1.000. In the north-central Hills collection of August 10, 1971 (table 1), for example, seed viability was good, but seed yield was low because only 20 percent of the cones opened.

In this study, germination did not increase steadily with progress of season as reported for white pine (Jones, Massello, and Clifford 1967) and for ponderosa pine (Maki 1940). Part of the reason for lack of a distinct ripening trend may be that, in this study, completely or partially closed cones were not dissected to extract seeds that they would not give up naturally. Thus, samples with relatively high germination percentages but small numbers of naturally opened cones may have been made up mostly of seeds that were physiologically ready to germinate, while other unopened cone scales retained seeds that were mostly immature.

Absolute values for germination of seeds in these 2 years are not as high as have been found for Black Hills ponderosa pine in some other tests. For example, seeds collected in 1967 throughout the Black Hills showed an average germination of 85 to 90 percent in standard tests at the Eastern Tree Seed Laboratory.

At least three factors, singly or in combination, may have accounted for the lower germination percentages in this study: Overwinter storage in a heated room could have affected seed viability; conditions in the greenhouse during germination tests may not have been as favorable as at the Seed Laboratory; or a variation in average viability from one seed year to another may have been a natural cause for lower germination.

On the other hand, the results of this study compare favorably with those of Bates' studies of seed production and viability in the southern Black Hills from 1912-24.[2] He found an overall

---

[2] *Unpublished data on file at Rocky Mt. For. and Range Exp. Stn., Rapid City, S. Dak.*

average germination of 49 percent for all seeds collected during the period. The best germination he observed for an annual crop was only 67 percent. The poorest for a year of high production was about 30 percent.

Results from 1970 (table 1) indicate desirability of frequent checks on cone condition. Collections from the Bear Lodge Mountains probably were made just before a critical turning point in maturation. More frequent collections would probably have identified earlier acceptable collection dates for the other areas.

Table 1 also shows a trend of cone ripening which progresses from north to south. The trend is especially noticeable in 1971 because of more frequent collections. The warmer climate in the south apparently prolongs the growing season, with consequent later maturity dates.

Percent moisture content of cones. — Maturation of pine cones and seeds involves, in part, drying of their tissues. Moisture content of cones can be used as an indication of cone and seed ripeness, but it is not readily determined in the field, at least when ovendrying is used. Figure 2 shows the general downward trend of average percent moisture of cones (including seeds) over time. We have no explanation other than biological variation to account for cones from the Bear Lodge Mountains having a higher average moisture content September 10 than August 24, 1970. A range in average moisture contents of 120 to 140 percent includes most cones that are ready for harvest. Average moisture contents for cones from the three areas were relatively close when the cones first reached harvestable condition.

Moisture content of cones at time of seed ripeness can vary greatly between species. Jones, Massello, and Clifford (1967) reported an average moisture content of 232 percent when seeds from their white pine cones first reached acceptable germination levels.

Conclusions

Specific gravity (fresh weight basis) is a usable criterion for estimating ripeness of Black Hills ponderosa pine cones and seeds. Although only three areas were sampled in each of 2 years, they covered the range of conditions likely to be encountered by Black Hills cone collectors. When 12 to 15 cones out of a 25-cone sample will float in water, the cones in that vicinity will probably yield a satisfactory quantity of viable seeds.

Inconsistencies in the relationship between specific gravity and seed ripeness early in August lead us to recommend that collectors wait until mid-August before checking cone specific gravities. In practice, cones to be float-tested should come from five or more trees in the area from which collections are to be made. Frequent checks, at no more than weekly intervals, should be made from mid-August on, since cone and seed ripening appears to progress rapidly at that time.

Literature Cited

Maki, T. E.
1940. Significance and applicability of seed maturity indices for ponderosa pine. J. For. 38: 55-60.

Fowells, H. A., and G. H. Schubert.
1956. Seed crops of forest trees in the pine region of California. U. S. Dep. Agric. Tech. Bull. 1150, 48 p.

Jones, LeRoy, James W. Massello, and Edward D. Clifford.
1967. Size and germination of white pine seed collected at weekly intervals from five trees. USDA For. Serv. Res. Note SE-74, 6 p. Southeast. For. Exp. Stn., Asheville, N. C.

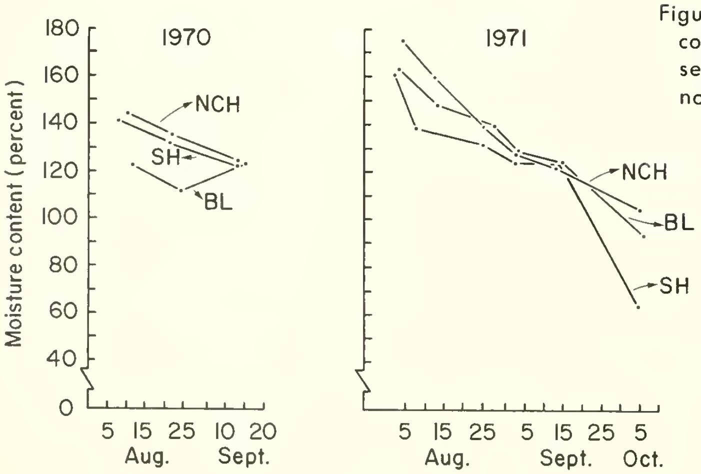


Figure 2.—Average moisture content of ponderosa pine cones collected at periodic intervals during two consecutive years from the Bear Lodge Mountains (BL), north-central Hills (NCH), and southern Hills (SH).

Agriculture—CSU, Ft. Collins

1973

U S D A FOREST SERVICE
RESEARCH NOTE RM-236

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Cliffrose and Mountainmahogany Seeds Retain Viability 6 Years in Cold Storage

H. W. Springfield[1]

Viability was highest for seeds stored at -5° to -10°F. or 36° to 44°F.

Keywords: Seed viability, *Cowania mexicana, Cercocarpus montanus.*

CLIFFROSE

Published information is meager concerning storage requirements for seeds of cliffrose (Cowania mexicana D. Don) and true mountainmahogany (Cercocarpus montanus Raf.). According to the USDA Forest Service (1948), cliffrose seeds can be stored at ordinary temperatures for at least 7 years, and one lot of mountainmahogany seeds still retained high viability after dry storage for 5 years in burlap bags in a warehouse.

To obtain further information about storage conditions for seeds of these two species, seeds were put in 1-quart metal cans with quarter-turn lids (not airtight) and stored 6 years under four conditions: in a freezer, in a refrigerator, in a heated garage, and outdoors. Facts pertaining to the seeds are:

	Cliffrose	**Mountain-mahogany**
National Forest where collected	Kaibab	Santa Fe
Date collected	June 1963	Oct. 1963
Number of seeds per pound	58,300	32,800
Date put in storage	Aug. 30, 1964	Sept. 2, 1964
Percent moisture content when put in storage	8.3	7.8
Maximum percent germination after 1 year in storage (1965)	95	89

---

[1] *Range Scientist, Rocky Mountain Forest and Range Experiment Station, located at Albuquerque, in cooperation with the University of New Mexico; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

In September 1970, 250-seed samples were taken to represent each storage condition. Seeds were stratified in moist vermiculite 30 days, then germinated for 1 month at an average temperature of 55.8°F. (range 54° to 57°F.). Seeds were considered germinated when radicles and shoots were 1 inch long.

Seeds stored at -5° to -10°F. or 36° to 44°F. for 6 years germinated significantly better than other seeds (values followed by the same letter do not differ significantly at the 0.05 level):

	Cliffrose	**Mountain-mahogany**
Storage conditions:		
-5° to -10°F. (freezer)	93.5a	84.4a
36° to 44°F. (refrigerator)	94.5a	81.6a
55° to 95°F. (heated garage)	82.0b	61.6b
-15° to 105°F. (outdoors in 30-gallon metal container)	64.5c	42.4c

Differences in retention of viability can probably be attributed to temperature differences; however, minor variations in seed moisture content may also have been important.

Retention of viability is affected by fluctuations in moisture content of the seed, especially fluctuations around the so-called "critical" moisture content, which varies with kind of seed (Barton 1961). Fluctuations in seed moisture content, although not measured, were no doubt greatest for seeds stored outdoors for 6 years. After summer rains, the combination of high humidity and high temperature could have had detrimental effects on these seeds. Since seeds lose viability rapidly under high humidity and high temperature (Mayer and Poljakoff-Mayber 1963), conditions within the freezer or refrigerator were undoubtedly more satisfactory for seed storage than those in the garage and outdoors.

TRUE MOUNTAINMAHOGANY

Literature Cited

Barton, Lela V.
1961. Seed preservation and longevity. Seed Plant Sci. Monogr. Leonard Hill (Books) Limited, London. (Interscience Publishers, Inc., N.Y.). 216 p.

Mayer, A. M., and A. Poljakoff-Mayber.
1963. The germination of seeds. 236 p. Int. Ser. Monogr. on Pure and Appl. Biol., Plant Physiol. Div. N.Y.: MacMillan Co.

U.S. Department of Agriculture. Forest Service.
1948. Woody plant seed manual. U.S. Dep. Agric. Misc. Publ. 654, 416 p.

pril 1973

U S D A FOREST SERVICE
RESEARCH NOTE RM-237

DREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Procedures for Using Yield Simulation Programs for Dwarf Mistletoe-Infested Lodgepole and Ponderosa Pine Stands

Frank G. Hawksworth and Clifford A. Myers[1]

Describes procedures for application of two recently published computer programs for yield simulation of dwarf mistletoe-infested stands: LPMIST for lodgepole pine in the central Rocky Mountains and SWYLD for ponderosa pine in the Southwest.

Oxford: 443.3:561.25:U681.3. Keywords: *Pinus contorta, Pinus ponderosa, Arceuthobium americanum, Arceuthobium vaginatum,* stand yield tables, simulation.

Procedures and computer programs for preparing yield tables in managed, dwarf mistletoe-infested stands were published recently. They apply to lodgepole pine (Pinus contorta Dougl.) in the central Rocky Mountains (LPMIST—Myers, Hawksworth, and Stewart 1971) and to ponderosa pine (Pinus ponderosa Laws.) in the Southwest (SWYLD—Myers, Hawksworth, and Lightle 1972). This Note describes certain procedures for application of the two programs. It is directed to personnel of pest detection and control programs, and to others who may not be familiar with computer programing but are interested in the use of existing, tested programs. Additional information on possible modifications of the programs, including related field work, is available elsewhere (Myers 1971).

Coefficients of the equations in the programs were computed with data from even-aged stands. Therefore, the stands to be analyzed should have an even-aged structure. In such stands, diameters of most trees will not differ greatly from average diameter of the stand, and very few of the trees will occur in the largest and smallest diameter classes. Although the range of tree diameters in an even-aged stand will increase with stand age and time since treatment, stands with a range in diameters greater than 12 inches may not be even-aged. Ages of trees in the smaller diameter classes must then be compared with ages from the main stand.

The stand must also be relatively uniform in species composition, site quality, and past treatment, to conform to the definition of the term stand. Stands of any size may be analyzed, since the yield table gives values for an average acre. Requirements of stand uniformity will usually limit stand areas to 100 to 200 acres, and they will often be much less.

Occasional trees of slightly different age class or of different species may be present in the stand being analyzed. As a practical matter, they will be included in the stand data as though they are members of the main stand. Of course, the more such trees that occur in the area, the less accurate the yield predictions may be. The amount of variation that may exist before accuracy is reduced noticeably will depend on such things as relative growth rate of the species.

Field Measurements

Data on the five following stand factors are needed for the LPMIST or SWYLD programs. The definitions of these variables given below describe the initial values obtained from field measurements, as entered by the data deck.

1. AGEO. Mean stand age at time of first thinning to be shown in the tables, based on live trees of the dominant and codominant crown classes. AGEO may be that of the first

---

[1] *Principal Plant Pathologist and Principal Mensuraonist, Rocky Mountain Forest and Range Experiment tation, with central headquarters maintained at Fort ollins, in cooperation with Colorado State University.*

computed partial cut or, with suitable program modification (Myers 1971), may be the age at time of an actual cut in a real stand.

2. DBHO. Mean d.b.h. of trees in the stand at age AGEO, based on live trees of all crown classes. DBHO should be determined to the nearest 0.1 inch. Mean d.b.h. is the diameter of the tree of mean basal area.

3. DENO. Stand density—the number of live trees per acre of all crown classes at age AGEO.

4. SITE. Site index of the stand based on mean height of dominant and codominant trees at a base age of 100 years. For lodgepole pine, determine site index with corrections for stand density as measured by the crown competition factor (CCF) (Alexander 1966). For ponderosa pine, tables published by Meyer (1938) are appropriate.

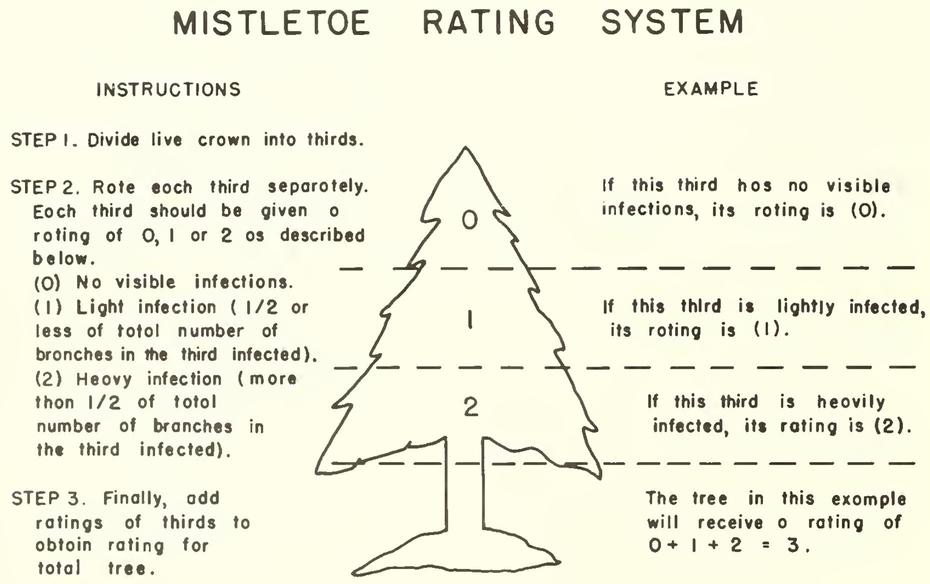
5. START. The age of the stand when dwarf mistletoe infection began. It is an overall figure indicating the mean age when infection began at various points throughout the stand. It is not merely the age when earliest infection occurred.

Shortcut methods are available for estimating START in stands under 100 years old when either the mean mistletoe rating of the stand (6-class system, fig. 1) or proportion of trees infected is known. Estimates based on average stand mistletoe ratings are believed to be most accurate and should be used whenever possible.

The length of time that dwarf mistletoe has been in a stand can be estimated from average stand mistletoe ratings from the following tabulation. For example, ponderosa pine stands with an average infection rating of 3.0 have been infected for 30 years. This period is then deducted from present stand age to determine mean stand age when infection began (START).

Stand dwarf mistletoe rating	Length of time infected Ponderosa pine	Lodgepole pine
	(Years)	
0	0	0
0.5	8	9
1.0	14	15
1.5	18	21
2.0	22	27
2.5	26	32
3.0	30	37
3.5	35	44
4.0	40	51
4.5	47	59
5.0	57	68
5.5	70	80
6.0	88	98

An alternate method of estimating length of time that dwarf mistletoe has been present in a stand is based on the proportion of trees infected. The following tabulation applies to both lodgepole pine and ponderosa pine. For example, if 75 percent of the trees in a stand are infected, the approximate time that the stand has been infected is 25 years. This period is then deducted from present stand age to estimate START.



STEP 1. Divide live crown into thirds.

STEP 2. Rate each third separately. Each third should be given a rating of 0, 1 or 2 as described below.
(0) No visible infections.
(1) Light infection (1/2 or less of total number of branches in the third infected).
(2) Heavy infection (more than 1/2 of total number of branches in the third infected).

STEP 3. Finally, add ratings of thirds to obtain rating for total tree.

If this third has no visible infections, its rating is (0).

If this third is lightly infected, its rating is (1).

If this third is heavily infected, its rating is (2).

The tree in this example will receive a rating of 0 + 1 + 2 = 3.

Figure 1.--Instructions for and example of the use of the 6-class mistletoe rating system (Hawksworth 1961)

Trees infected (Percent)	Length of time infected (Years)	Trees infected (Percent)	Length of time infected (Years)
0	0	60	19
5	4	65	20
10	7	70	22
15	9	75	25
20	10	80	28
25	11	85	32
30	12	90	36
35	13	92	39
40	14	94	42
45	15	96	46
50	16	98	52
55	17	100	70

Management Decisions

In addition to the field measurements, several management decisions must be made for the stand to be analyzed. Items 1 through 4, below, are needed for the LPMIST program; items 1 through 3 and 5 through 11 for SWYLD.

1. THIN. The growing stock level to which the stand is to be reduced in the first thinning. Growing stock levels for both ponderosa and lodgepole pines are designated by the square feet of basal area desired when average stand d.b.h. is 10 inches or more (Myers 1971). Basal area in a stand of smaller average d.b.h. is less than the designated level as shown in figure 2 and table 1. For example, if a growing stock level of 80 is desired and the stand will have an average d.b.h. after thinning of 6.0 inches, the actual basal area to be retained is 56.6 square feet. If a growing stock level of 100 is desired, (100/80) x 56.6, or 70.8 square feet will be left. Table 1 can also be used to calculate the appropriate growing stock level if it is desired to leave a certain residual basal area on the ground. For example, if it is desired to leave 71 square feet of basal area in a stand 6.0 inches in diameter, the growing stock level to be entered in the program would be 100. The computation is:

$$\text{LEVEL}/80 \times 56.6 = 71$$
$$\text{LEVEL} = 100$$

In both examples, level is divided by 80 because table 1, source of the known basal area values, is for growing stock level 80.

2. DSTY. The growing stock level to which the stand is to be reduced in subsequent thinnings. The programs will compute and print as many yield tables as desired. The first table will have as subsequent level the value of DSTY. Each following table will have a growing stock level, as defined above, 10 higher than that of the previous table computed.

3. JCYCL. The interval between intermediate thinnings. JCYCL must be in multiples of 10 years.

4. ROTA. The rotation age or age at harvest cutting, if LPMIST is used without modification. The following seven items replace ROTA for SWYLD.

5. REGN(1). Stand age at first regeneration cut. Must never be zero or blank, as this is rotation length for clearcutting.

6. VLLV(1). Percentage of previous growing stock level to be left at age REGN(1). Will be zero with clearcutting. Enter as a decimal.

7. INVL(1). New interval between cuts in effect after age REGN(1). Will be zero with clearcutting.

8. REGN(2). Stand age at which second regeneration cut, if any, will occur. Removal of seed trees or second cut of shelterwood.

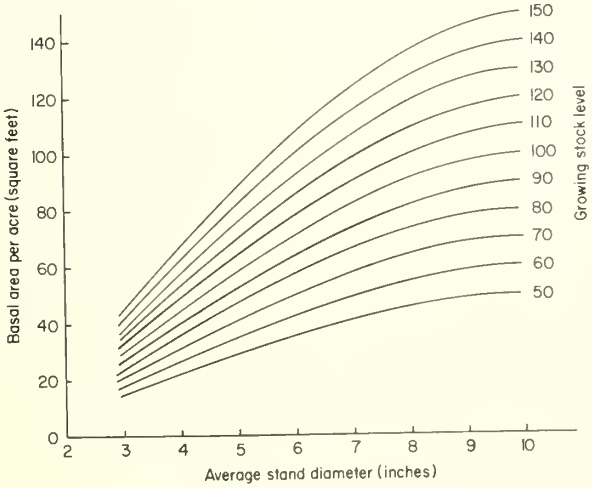


Figure 2.--Basal area after thinning in relation to average stand diameter for standard levels of growing stock.

Table 1.--Basal areas after intermediate cutting in relation to average stand diameter growing stock level 80

Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre
	Sq. ft.		Sq. ft.		Sq. ft.		Sq. ft.
2.0	12.1	4.0	35.2	6.0	56.6	8.0	72.5
2.1	13.2	4.1	36.4	6.1	57.6	8.1	73.1
2.2	14.4	4.2	37.6	6.2	58.5	8.2	73.7
2.3	15.5	4.3	38.7	6.3	59.4	8.3	74.3
2.4	16.7	4.4	39.9	6.4	60.3	8.4	74.8
2.5	17.9	4.5	41.0	6.5	61.2	8.5	75.3
2.6	19.0	4.6	42.2	6.6	62.1	8.6	75.8
2.7	20.2	4.7	43.4	6.7	62.9	8.7	76.3
2.8	21.3	4.8	44.5	6.8	63.8	8.8	76.7
2.9	22.5	4.9	45.7	6.9	64.6	8.9	77.1
3.0	23.7	5.0	46.8	7.0	65.4	9.0	77.5
3.1	24.8	5.1	47.8	7.1	66.2	9.1	77.9
3.2	26.0	5.2	48.8	7.2	67.0	9.2	78.2
3.3	27.1	5.3	49.8	7.3	67.7	9.3	78.5
3.4	28.3	5.4	50.8	7.4	68.5	9.4	78.8
3.5	29.5	5.5	51.8	7.5	69.2	9.5	79.1
3.6	30.6	5.6	52.8	7.6	69.9	9.6	79.3
3.7	31.8	5.7	53.8	7.7	70.6	9.7	79.5
3.8	32.9	5.8	54.7	7.8	71.2	9.8	79.7
3.9	34.1	5.9	55.7	7.9	71.9	9.9	79.8
						10.0+	80.0

9. VLLV(2). Percentage of previous growing stock level, including effect of VLLV(1), to be left at age REGN(2). May be zero. Enter as a decimal.
10. INVL(2). New interval between cuts in effect after age REGN(2). May be zero.
11. REGN(3). Stand age at which third regeneration cut, if any, will occur. Final cut of 3-cut shelterwood.

Literature Cited

Alexander, Robert R.
1966. Site indexes for lodgepole pine, with corrections for stand density: Instructions for field use. U. S. For. Serv. Res. Pap. RM-24, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Hawksworth, Frank G.
1961. Dwarfmistletoe of ponderosa pine in the Southwest. U. S. Dep. Agric. Tech. Bull. 1246, 112 p.

Meyer, W. H.
1938. Yield of even-aged stands of ponderosa pine, U. S. Dep. Agric. Tech. Bull. 630, 59 p.

Myers, Clifford A.
1971. Field and computer procedures for managed-stand yield tables. USDA For. Serv. Res. Pap. RM-79, 24 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Myers, Clifford A., Frank G. Hawksworth, and Paul C. Lightle.
1972. Simulating yields in southwestern ponderosa pine stands, including effects of dwarf mistletoe. USDA For. Serv. Res. Pap. RM-87, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Myers, Clifford A., Frank G. Hawksworth, and James L. Stewart.
1971. Simulating yields of managed, dwarf mistletoe-infested lodgepole pine stands. USDA For. Serv. Res. Pap. RM-72, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Agriculture—CSU, Ft. Collins

973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 238

REST SERVICE
DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Enclosed Weir for Small Streams in Snow Country

Kendall L. Johnson and Ronald D. Tabler[1]

An enclosed sharp-crested V-notch weir was designed to gage small channels under severe winter conditions at reduced costs of installation and operation. The self-contained structure consists of a multiplate pipe arch with closed ends fitted over an independent cutoff wall. The instrument shelter is mounted directly on the pipe arch over a stilling well assembly placed within the weir basin. The structure provides trouble-free winter operation. Compared to a conventional design, time of construction was reduced 50 percent and total costs by 40 percent.

Oxford: 116.3:51. Keywords: Watershed management, streamflow, measurement systems, weirs.

Sharp-crested V-notch weirs are generally used to measure small but variable flows where sediment and debris loads are not excessive. Under favorable conditions, a 2-foot-high 120° V-notch weir can be used to accurately measure flows from less than 0.1 to about 25 c.f.s. (Reinhart and Pierce 1964). When uncovered, however, such structures are difficult to operate in cold weather, particularly in areas of high snow accumulations. Additional structural features for winter operation greatly increase construction costs.

Successful winter operation of a weir requires that the stilling basin and notch be kept largely free of snow and ice. In deep snow country, the downstream channel must be kept sufficiently open to prevent back-water flooding of the notch, particularly in channels supporting little or no winter flow prior to melt. These requirements are especially difficult to meet in windswept areas where deep snowdrifts accumulate in the stream channels. In many areas above 7,000 feet on Wyoming's high plains, for example, drifts of 45 percent density up to 25 feet deep are common. Such drifts make flat-decked covers over the weirs impractical, and annual excavation of escape channels impossible.

Under the best of conditions, permanent and accurate control sections are expensive; structural modifications for protection against heavy snow loading make them even more so. This Note presents a design for a relatively inexpensive sharp-crested V-notch weir which we have operated successfully in winter on a high-elevation research site in southcentral Wyoming.

Derivation of the Design

During the first winter after construction, the control section of an uncovered weir on the research area was buried under 17 feet of snow, necessitating repeated excavation. At the time of peak accumulation, the structure was sub-

---

[1] *Research Hydrologist and Principal Hydrologist, respectively, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Research reported here was supported by the Bureau of Land Management, U.S. Department of the Interior, and conducted at Laramie, in cooperation with the University of Wyoming.*

Figure 1.—A sharp-crested weir covered by a multiplate arch. The ends of the arch were later enclosed.

jected to loading in excess of 500 pounds per square foot. The following summer, a corrugated multiplate arch (40-foot length, 28-foot span, 8-foot rise) was built over the entire weir (fig. 1). Although the arch was designed to withstand the snow load experienced the first year, its rise reduced the maximum expected snow depth at its crest to about 6 feet.

This quonset hutlike structure has allowed the streamgage trouble-free winter operation (fig. 2). It led to consideration of a unit weir—a control section installed within a multiplate pipe arch, wherein the pipe would act at once as stilling basin, apron, and cover. The approach promised important cost savings, and appeared to be particularly suitable for gaging small channels in deep snow country.

The Enclosed Weir

The enclosed weir is of a scale suitable for accurate measurement of heads up to 1.5 feet, meeting the minimum hydraulic requirements in pond depth and width (about 2.5H) specified by King (1954). Detailed information on construction is available upon request.[2] The specific dimensions may be altered to suit a particular weir site. The principal features of the unit weir are:

Figure 2.—The arch-covered weir under moderate winter conditions.

---

[2] *Address requests to Forest, Range, and Watershed Laboratory, Rocky Mountain Forest and Range Experiment Station, University of Wyoming, Box 3313, Laramie, 82071. Detailed construction plans are for the North Fork Loco Creek weir, Carbon County, Wyoming, approved April 22, 1971.*

1. **Pipe arch.**—The basic structure is a multiplate pipe arch, of 12-gage galvanized steel (30-foot length, 16-foot 7-inch span, 10-foot 1-inch rise). Pipe arches of many other nominal dimensions are readily available from commercial suppliers. The span and rise dimensions can be selected to meet the hydraulic requirements of any size weir. The pipe arch can be as long as desired; the 30 feet selected here was a normally manufactured size which allowed a stilling basin of 20 feet and a discharge apron of 10 feet. The bottom and sides of the pipe arch are slotted to fit over the cutoff wall. Figures 3 and 4 present plan and elevation views of the structure.

2. **Cutoff Wall.**—The control section, a 2-foot 120° V-notch, is mounted in a cutoff wall made of 12-gage steel sheeting, interlocking type 'B'. The portion of the wall within the pipe arch is braced by angle-iron wales, bolted to the individual plates. A 12-inch sliding gate valve, to allow periodic flushing of deposited sediment through the structure, completes the cutoff wall (fig. 5). The gate's relatively high placement was necessitated by low channel gradients where the structure has been used, and by our requirement that the notch be placed at or below the elevation of the original channel to reduce leakage.

The dimensions of the wall should be dictated by soil and geologic conditions of the weir site to minimize leakage. Because consolidated bedrock could not be reached at reasonable depth on the sites where the structure has been installed, the cutoff wall extended only 4 feet below the bottom of the pipe arch. Leakage was minimized by carefully compacting a soil-bentonite backfill around the wall. Under other conditions, and because it is independent of the pipe arch, the cutoff wall could be constructed of concrete or other suitable materials keyed into bedrock.

We recommend that the cutoff wall be placed within the pipe arch, but independent of it. Although the wall could be placed at the upstream end of the pipe arch to act as both cutoff and head wall, this would require that the control section be contained wholly within the pipe. If so placed, all joints and connections between walls and pipe arch, and the pipe arch itself upstream of the control section, would have to be watertight—a state both difficult and expensive to attain. This approach also is undesirable because the control section would be an integral part of the pipe arch; any settling or displacement of the pipe would directly affect the control section as well.

3. **Instrument Shelter.**—A stream-gage shelter, based on a standard U.S. Geological Survey plan, is mounted directly on the pipe arch. One end of the 48-inch corrugated metal pipe is cut to match the arch radius, and welded to a 'saddle' formed of an additional arch plate of the same radius. The saddle is then bolted to the arch over a hole cut to match the vertical projection of the shelter. The shelter thus becomes an integral part of the structure, providing access to the interior of the arch as well as housing all needed instruments.

4. **Stilling Well Assembly.**—An 18-inch corrugated metal pipe forms the stilling well, set within a shorter 24-inch pipe which acts as a heat sleeve. The two are joined by the inlet and drain pipes and by a metal plate welded to their bases to create a watertight, dead air space around the stilling well. If desired, a small heater may be suspended within the space and the heat sleeve covered to help prevent the stilling-well water from freezing.

The assembly is placed directly beneath the instrument shelter within the stilling basin, strapped to the pipe arch.

5. **End Covers.**—The upstream end of the structure is largely closed by the head wall. It is similar to the cutoff wall, formed of interlocking type 'B' steel sheeting, stiffened by angle-iron wales. Because its chief functions are to direct surface water into the weir and prevent erosion of backfill, the head wall is only slightly wider than the pipe arch span.

The upper portion of the upstream end, and all of the downstream end, are enclosed with 20-gage corrugated sheeting bolted to horizontal angle-iron supports secured directly to the pipe arch. Small openings are left for water entry and escape. Where necessary to exclude blowing snow, butyl rubber flaps can be fastened over the openings. Once the snowpack has covered the structure, the flap can be opened from the inside, well before the onset of snowmelt.

6. **Escape Pipe.**—In a drifting snow environment, streams with low gradients, particularly intermittent channels, may require piping to maintain an adequate escape channel for peak snowmelt flows. Corrugated aluminum piping, for ease of installation, is laid in the channel downstream, with its upper end placed inside the structure on the apron floor. The diameter of the pipe should be dictated by the expected volumes of flow, and its length by the gradient of the downstream channel.

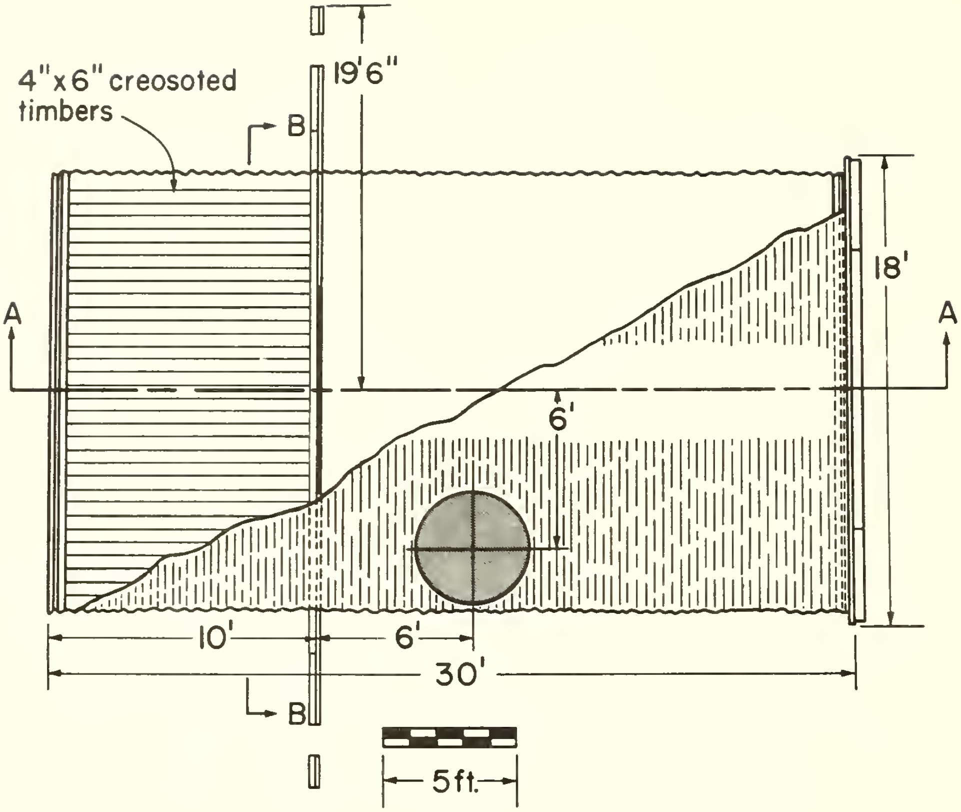


Figure 3.— Plan view of the enclosed weir.

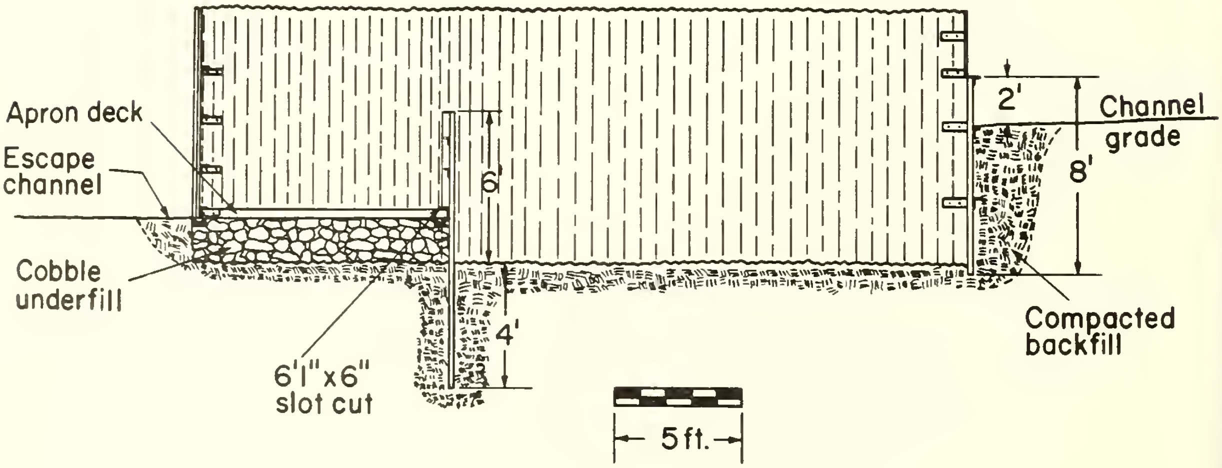


Figure 4.—Section A-A: elevation view at centerline of the enclosed weir.

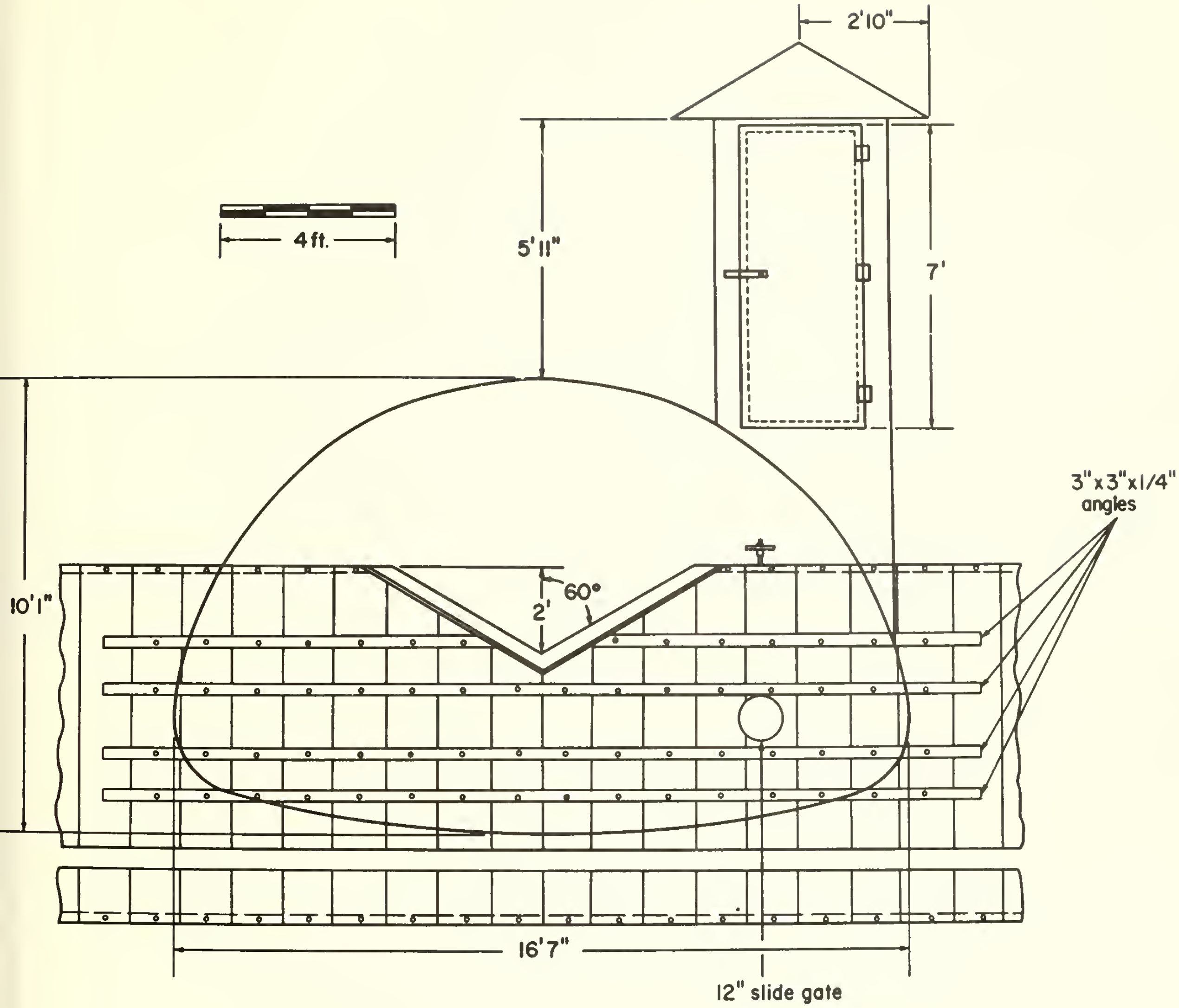


Figure 5.—Section B-B: view at cutoff wall of the enclosed weir.

Installation

We have installed two enclosed weirs by different construction techniques. One weir was completely assembled and fitted in a machine shop, partially disassembled, and transported to the weir site as five modular units: cutoff wall, head wall, apron portion of the pipe arch including its end cover, instrument shelter, and stilling well assembly. Actual installation of the weir largely involved reassembly of the modular units. This procedure requires heavy machinery to lift the several units into place.

The second weir was assembled and fitted at the weir site. The instrument shelter and stilling well assembly were transported to the weir site as modular units. All angle-iron wales were cut to length and drilled, and all support brackets and braces were prefabricated. The entire weir, aside from the two modular units, was built in place. Equipment necessary to construct the enclosed weir by either method of installation include a motor grader, backhoe, bulldozer or front-end loader, dump truck, air compressor, field welder, and torch.

Construction begins with excavation of the cutoff wall trench and pipe-arch bed. The cutoff wall is either lifted into the trench as a complete unit or constructed in place, braced into position, and backfilled with a bentonite-soil mixture. Next the pipe-arch bed is shaped into a rough approximation of the structure's lower curve. In the modular form of construction, the entire apron section of the pipe arch is then lifted into place against the cutoff wall. The lower half of the pond section is bolted together and laid into place as a unit, and the remaining plates are installed to close the arch. Alternatively, the pipe arch can be erected in place, by conventional multiplate construction techniques. With either method of construction, the preassembled head wall, instrument shelter, and stilling well assembly can be lifted into place and secured. Placement of the end covers and butyl rubber flaps close the structure against snow. Only the final construction details remain to complete the weir (figs. 6 and 7).

The enclosed weir can be installed quickly by either technique. Modular assembly of the

Figure 6.—A nearly completed enclosed weir showing the instrument-shelter mounting and cutoff wall placement.

weir, including transportation of components to the weir site, required about 20 man-days by a crew of one to three men. Time spent in assembly and shop fitting of the structure was included in the purchase contract for materials. Inclusion of this labor would make the total number of man-days spent in construction much higher.

The field-assembled structure required approximately 60 man-days by a crew of one to four men. For comparison, construction of a conventional weir of about the same overall size required approximately 155 man-days. The conventional weir consisted of a concrete cutoff wall, treated-timber apron, headwall, stilling basin (with no floor), a detached stilling well and instrument shelter, and a multiplate-arch cover. The economy in construction time with the enclosed weir not only reduces cost, but could be important in areas with a short construction season between late spring snowmelt and early fall accumulation.

Cost of Construction

The total cost, exclusive of instruments, for installation (modular assembly) of the first enclosed weir in early 1970 was $16,850. This amount included excavation of 250 feet of escape channel, construction of a 500-foot access road, and final dressing of the site.

The costs of field assembly of the enclosed weir provide a more direct comparison with the costs of conventional weir construction. The weir was constructed in 1971 by the Medicine Bow National Forest construction crew, for a total cost of $11,530. This amount does not include money spent for an access road or excavation of the escape channel — the two most variable factors in total costs. Excluding the same variables, costs for a conventional weir (including an estimated figure for an arch cover) were approximately $14,875 in 1968. Applying a 10 percent annual rise in construction costs, the adjusted 1971 price would have been roughly $19,800.

Figure 7.—Interior view of the enclosed weir looking downstream.

Applications

The enclosed weir was designed to gage small channels under severe winter conditions where sediment and debris loads are not excessive. The structures have protected the control section and the instruments for 2 years, and have allowed ready winter access to the streamgage for periodic servicing (fig. 8). Once the arch becomes snow covered, the stilling basin and notch stay ice-free. The escape pipe eliminates backwater effects, and minimizes excavation of the downstream channel. In addition, the pipe arch provides a convenient means for installing radiant heaters to prevent ice formation, where this might be necessary, and for housing sediment samplers and other instruments used in associated data collection.

The enclosed weir offers important economies in both time and cost of construction. Time of construction can be reduced by 50 percent or more, and the total costs may be as much as 40 percent less. In locations where snow loading is not a problem, the enclosed weir, with escape pipe and end covers deleted, would offer even stronger cost reductions. Where weirs can be used, the design may have ready application to low-elevation grassland situations as well.

With excavation of snow reduced to a minimum, the design provides savings in operational costs which are hard to quantify but are substantial. The enclosed weir facilitates routine servicing of the stream gage, and provides a reliable, continuous record of streamflow.

Literature Cited

King, H. W.
1954. Handbook of hydraulics. Fourth ed. Sect. 4, p. 1-67. McGraw-Hill Book Co., N.Y.
Reinhart, K. G., and R. S. Pierce.
1964. Stream-gaging stations for research on small watersheds. U.S. Dep. Agric. Agric. Handb. 268, 37 p.

Figure 8.—The enclosed weir under typical winter conditions.

973

U S D A FOREST SERVICE
RESEARCH NOTE RM - 239

OREST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Soil-Topographic Site Index for Engelmann Spruce on Granitic Soils in Northern Colorado and Southern Wyoming[1]

John A. Sprackling[2]

Site index of Engelmann spruce can be estimated from soil depth to the C horizon and elevation. Predictions should be confined to potential spruce-fir sites on granitic soils in northern Colorado and southern Wyoming.

Oxford: 541:113.4. Keywords: *Picea engelmannii*, site index, topography (site).

Site indexes based on heights and ages of dominant and codominant trees are commonly used to express the productive capacity of forest land. Frequently, however, the conventional height-age relationship cannot be used to estimate site quality because either the area has been deforested by fire or logging, or the trees present are too young or otherwise unsuitable for measurement. In those situations, an alternative method of evaluating site productivity is necessary.

One alternative is to base site classification on environmental factors related to site index (Coile 1938). A productivity rating based on the permanent features of soil and topography can be used on any site, regardless of the presence, absence, or condition of the vegetation.

The objective of this study was to develop a prediction equation based on soil and topographic factors that can be used to estimate the site index of Engelmann spruce (Picea engelmannii Parry) growing on granitic soils in southern Wyoming and northern Colorado. The following factors were selected for investigation: (1) aspect, (2) slope percent, (3) slope position, (4) elevation, (5) soil depth to the C horizon, and (6) texture of the B horizon. These were selected because they were found to be most often correlated with site index in similar studies of other species in the Rocky Mountains (Mogren and Dolph 1972, Myers and Van Deusen 1960).

Methods

During the summer of 1971, 129 1/5-acre plots were established in even-aged, natural stands dominated by Engelmann spruce and subalpine fir (Abies lasiocarpa (Hook.) Nutt.) on National Forest land in northern Colorado and southern Wyoming (fig. 1). Plots were confined to stands that met the following criteria:

1. Even-aged (not more than 25 years' spread in the age of dominant trees).
2. Average age of dominants from 60 to 300 years.
3. Topography and stand conditions uniform on and adjacent to each plot.
4. Soils derived from granitic rock.

---

[1] *Based on a thesis submitted to the Graduate Faculty of Colorado State University in partial fulfillment for the requirements for the degree of Doctor of Philosophy.*

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

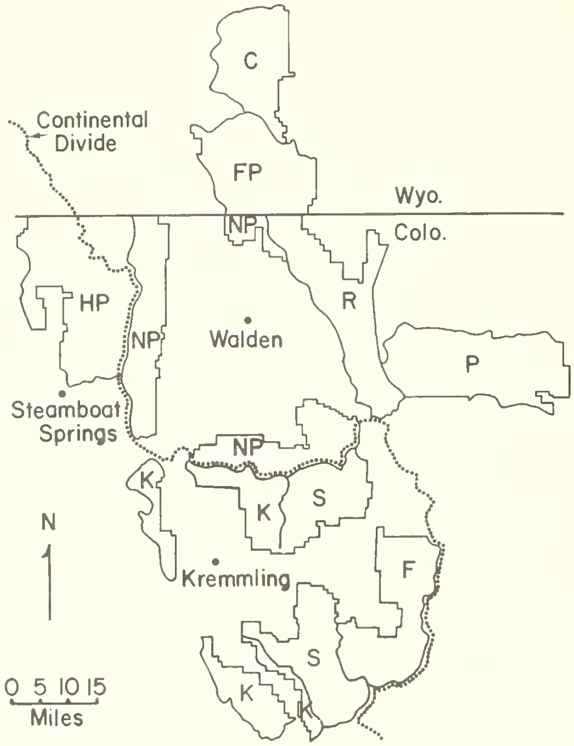


Figure 1.—Study areas were located on nine Ranger Districts of four National Forests in northern Colorado and southern Wyoming, as follows:

Arapaho National Forest, Colorado
  F — Fraser District
  K — Kremmling District
  S — Sulphur District
Roosevelt National Forest, Colorado
  P — Poudre District
  R — Redfeather District
Routt National Forest, Colorado
  HP — Hahns Peak District
  NP — North Park District
Medicine Bow National Forest, Wyoming
  C — Centennial District
  FP — Foxpark District

Plots were not randomly selected, but were chosen so that most or all possible combinations of site index, aspect, slope percent, and elevation were included.

On each plot, six to eight trees were selected for site determination. Only trees that met the following criteria were selected:

1. Dominants or appeared-to-have-been dominants throughout their lives.
2. No evidence of past suppression, or damage from fire, insects, or diseases that may have affected height growth.
3. Sound enough for ring counts.

Heights and ages were measured in the conventional manner. The aspect of each plot was measured with a compass and expressed as the sine of the azimuth clockwise from southeast plus one (Gaiser 1951). Slope percent was measured with an Abney level and expressed as a decimal. Slope position was the paced distance from the bottom of the slope up to the plot center divided by total slope distance, expressed as a decimal. Elevation was measured with an altimeter. A soil pit was dug at the center of each plot and soil depth to the C horizon measured in inches. Soil samples were obtained from the B horizon for textural analysis.

The relationships between site index and the soil and topographic factors were examined in a stepwise multiple regression. Site index at base age 100 years was determined for each plot from height-age curves developed by Alexander (1967). Site index was plotted over each independent variable, and nonlinear relationships were converted to linear form. Independent variables not related to site index were discarded. The remaining variables were tested for significance by analysis of variance.

Results

Two variables can be used to estimate the site index of Engelmann spruce on granitic soils in northern Colorado and southern Wyoming. The equation is:

$$Y = -106.63509 + 62.46021\,(X_1) + 809.39618\,(X_2) \qquad [1]$$

where:
Y = site index in feet;

X_1 = logarithm of soil depth in inches to the top of the C horizon;

X_2 = 1000/elevation in feet.

The multiple correlation coefficient (R) is 0.804, with 65 percent of the variation in site index accounted for. The standard error of estimate at the means of the independent variables is ± 9.00 feet.

Five other independent variables — (1) percent clay in the B horizon, (2) percent sand in the B horizon, (3) sine of the aspect from southeast plus 1, (4) slope position, and (5) slope percent—were also significant, but made no real contribution to the amount of total variation accounted for (Sprackling 1972).

Figure 2 and table 1 were developed from equation 1 to permit rapid estimates of site index in the field. These data are applicable to spruce-fir sites within the study area where granitic soils vary from 7 to 53 inches to the top of the C horizon and elevations are between 8,600 and 11,200 feet.

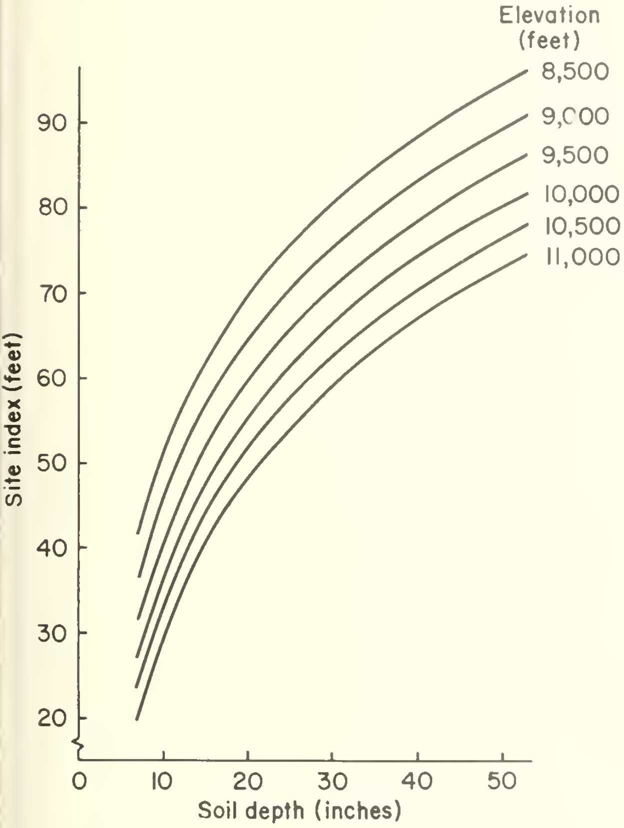


Figure 2.—Site index for Engelmann spruce on granitic soils in northern Colorado and southern Wyoming in relation to soil depth and elevation.

Discussion and Conclusions

Relative Importance of Factors

Soil depth to the top of the C horizon was the most important factor in determining site index in the study area. It accounted for 52 percent of the total variation in site index. This concurs with similar studies in the Rocky Mountains by Myers and Van Deusen (1960) who studied ponderosa pine (Pinus ponderosa Laws.), and Mogren and Dolph (1972) who studied lodgepole pine (Pinus contorta Dougl.).

As soil depth increased, the amount of water available to trees increased. The rate at which height growth increased with increasing soil depth was not constant, however. The rate of increase declined as soils became deeper, but did not reach the point where growth leveled off. The real value of soil depth as an indicator of site productivity lies in the fact that it is an integrator of those climatic factors that most affect height growth in trees: precipitation and temperature.

Elevation accounted for 13 percent of the total variation in site index. As elevation increases, height growth decreases because of lower temperatures and shorter growing seasons despite the increase in precipitation. However, stands of spruce with surprisingly good height growth were observed at 11,000 feet above sea level. The soils on these sites were very deep, and as a result height growth was good despite the short growing season at high elevations. If soil depth remained constant with increasing elevation, then height growth decreased along the environmental gradient because of a shorter growing season. But any change in soil depth was most important in affecting height growth, and offset any changes in temperature which occurred with elevational changes.

Sources of Unexplained Variation

All of the soils in the study area had developed largely from granitic rock, but the percentage of granite varied. Other parent materials found in the study area in combination with granite include slate, gneiss, schist, sandstone, dolomite, pumice, and conglomerate. Differences in soils throughout the study area, due to different combinations of parent materials, are thought to be the greatest single source of unexplained variation in site index.

The precipitation pattern was not uniform with respect to elevation throughout the study area. More precipitation fell west of the Continental Divide than east of it at the same elevation. Had the study area been located entirely east of the Continental Divide, some of the unexplained variation may have been eliminated.

A study of this type assumes that environmental factors are solely responsible for the different growth rates of trees. The inherited growth rates of individual Engelmann spruces may be different, however, and contribute to the unexplained variation.

Table 1.--Site index for Engelmann spruce on granitic soils in northern Colorado and southern Wyoming in relation to soil depth and elevation

Soil depth to C horizon (inches)	Elevation (thousands of feet)													
	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.8	11.0	11.2
7	40	38	36	34	32	30	29	27	26	24	23	21	20	18
9	47	45	43	41	39	37	36	34	32	31	29	28	27	25
11	53	50	48	46	45	43	41	39	38	36	35	33	32	31
13	57	55	53	51	49	47	46	44	42	41	39	38	37	35
15	61	59	57	55	53	51	49	48	46	45	43	42	40	39
17	64	62	60	58	56	55	53	51	50	48	47	45	44	42
19	67	65	63	61	59	58	56	54	53	51	50	48	47	46
21	70	68	66	64	62	60	59	57	55	54	52	51	50	48
23	73	70	68	66	65	63	61	59	58	56	55	53	52	51
25	75	73	71	69	67	65	63	62	60	59	57	56	54	53
27	77	75	73	71	69	67	65	64	62	61	59	58	56	55
29	79	77	75	73	71	69	67	66	64	63	61	60	58	57
31	81	78	76	74	73	71	69	67	66	64	63	61	60	59
33	82	80	78	76	74	73	71	69	68	66	65	63	62	60
35	84	82	80	78	76	74	72	71	69	68	66	65	63	62
37	85	83	81	79	77	76	74	72	71	69	68	66	65	64
39	87	85	83	81	79	77	75	74	72	71	69	68	66	65
41	88	86	84	82	80	78	77	75	73	72	70	69	68	66
43	90	87	85	83	81	80	78	76	75	73	72	70	69	68
45	91	89	87	85	83	81	79	78	76	74	73	72	70	69
47	92	90	88	86	84	82	80	79	77	76	74	73	71	70
49	93	91	89	87	85	83	82	80	78	77	75	74	73	71
51	94	92	90	88	86	84	83	81	79	78	76	75	74	72
53	95	93	91	89	87	85	84	82	80	79	77	76	75	73

Literature Cited

Alexander, Robert R.
1967. Site indexes for Engelmann spruce in the central Rocky Mountains. U. S. For. Serv. Res. Pap. RM-32, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Coile, T. S.
1938. Forest classification: Classification of forest sites with special reference to ground vegetation. J. For. 36:1062-1066.

Gaiser, R. N.
1951. Relationship between topography, soil characteristics, and site index of white oak in southwestern Ohio. U.S. For. Serv., Cent. States For. Exp. Stn., Tech. Pap. 121, 12 p.

Mogren, E. W., and K. P. Dolph.
1972. Prediction of site index of lodgepole pine from selected environmental factors. For. Sci. 18:314-316.

Myers, Clifford A., and James L. Van Deusen.
1960. Site index of ponderosa pine in the Black Hills from soil and topography. J. For. 58:548-555.

Sprackling, John A.
1972. Soil-topographic site index for Engelmann spruce. Ph.D. Thesis, 60 p. Colo. State Univ., Fort Collins.

1973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 240

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Sagebrush Control with Herbicide Has Little Effect on Elk Calving Behavior

A. Lorin Ward[1]

Elk did not change their calving behavior or feeding habits on a site where 96.7 percent of the big sagebrush *(Artemisia tridentata)* cover had been killed with 2 pounds acid equivalent of 2,4-D herbicide.

Oxford: 156.2:268.44. Keywords: Wildlife habitat management, herbicides (range), *Cervus canadensis, Artemisia tridentata.*

Elk (Cervus canadensis) have their calves on big sagebrush (Artemisia tridentata) sites on some ranges (Altmann 1952, Anderson 1954, Eustace 1967, King 1964, Madson 1966). It has also been reported that calving takes place in other vegetation types such as grasslands, willows, aspen, and conifers (Altmann 1952, Mackie 1970, Madson 1966, Picton 1960, Preble 1911). Many of the big sagebrush areas are heavily grazed by elk during winter and spring, and by cattle during the summer. To increase food supplies and improve range conditions for livestock, range managers often seek to kill the sagebrush on these areas. The question of how sagebrush control may affect elk calving behavior has not been answered.

Sagebrush control, an accepted range-improvement practice for many years, has been successful on 5 to 6 million acres throughout the West and in the past 30 years (Pechanec et al 1965). The USDA Forest Service and USDI Bureau of Land Management sprayed about 155,000 acres of sagebrush on lands under their administration in Wyoming from 1952 through 1964 (Kearl and Brannan 1967).

Wilbert (1963) concluded from animal sightings and pellet-group counts that sprayed sagebrush plots were more attractive to elk than unsprayed plots on the Gros Ventre elk spring range in Teton County, Wyoming. How calving might have been affected by sagebrush control was not mentioned.

The study reported here was conducted in the Dry Fork drainage of the Little Bighorn River on the Bighorn National Forest in Wyoming, from 1968-71. The objective was to determine whether sagebrush control with herbicide on relatively small areas would affect established elk calving behavior. The study area had a southwest aspect; vegetation was a mixture of forbs, grasses, and big sagebrush. Elevation of the area is 7,300 feet. Elk activity on the area was observed from the west side of Dry Fork in Bull Elk Park (fig. 1).

Figure 1.—
Study area on Dry Fork, Bighorn National Forest, Wyoming, looking toward sagebrush-control areas (dotted lines) with southwest aspect.

---

[1] *Principal Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins, in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at Laramie, in cooperation with the University of Wyoming.*

The Dry Fork flows northwest between Bull Elk Park and the study site. Elk move to this area in the spring during the calving season from the Kern's winter elk pasture on the east side of the Big Horn Mountains. The date the elk are able to get there and how long they stay depends upon the amount of snow and the weather. As the vegetation in the higher country develops, the elk move on to the west. Only a few elk are seen in this area during the summer. The main herds pass through this area in the fall on their way to the winter pasture.

Methods

Two areas, one 85 acres and another 45 acres, were sprayed by helicopter with 2 pounds acid equivalent per acre of 2,4-D herbicide after the elk calving season (mid-June) in 1969. Only the more gentle slopes and areas away from trees were sprayed. Considerable acreage of sagebrush type remained between and around the sprayed areas.

The calving sites were observed from a remote vantage point with telescopes and cameras for 2 years before spraying and 2 years after spraying.

The total number of hours that adult elk, elk calves, and mule deer were on the study area was obtained each year for the sprayed and nonsprayed areas.[2] The first pretreatment observation period (1968) began May 31, and continued until July 7. Observations the second pretreatment year (1969) covered a 10-day period from May 29 to June 8. Posttreatment data covered the period June 10 to 15, 1970, and June 3 to 11, 1971. A very heavy snowpack and a late spring in 1970 delayed elk reaching Dry Fork.

Locations of adult elk and elk calves and their grazing patterns were observed and plotted twice daily on aerial photographs. First observations began at daylight and continued for about 3 hours; the second period began at 6 p.m. At the beginning of each observation period all animals that could be seen were recorded. Their travels were followed and any new animals were added as they appeared. In many cases, elk calves could not be seen until they got to their feet when their mothers approached. The area was observed periodically during the middle of the day to record any elk activities and continued until dark. Occasionally observations were interrupted by poor visibility.

Vegetation composition was estimated before and after spraying by the step-point method (Evans and Love 1957). These data provided an estimate of the kill of big sagebrush and forbs on the treated sites.

At least 20 fresh elk fecal droppings were collected on the study area every year soon after observation data were taken. Droppings were examined by microtechniques described by Ward (1970) to identify graminoids, forbs, sagebrush, and other browse eaten by elk.

Results

Spraying significantly changed vegetation composition (percent hits):

	1969 (before spraying)	1970 (after spraying)
Graminoids	46.5	64.1
Forbs	44.2	25.6
Live shrubs		
Sagebrush	8.3	0.5
Other browse	1.0	1.1
Sagebrush cover	33.5	1.1
Dead shrubs		
Sagebrush	0.0	8.7
Other browse	0.0	0.0
Sagebrush cover	0.0	32.4

The herbicide killed 94.7 percent of the sagebrush plants, which reduced sagebrush cover 96.7 percent. After spraying, hits on graminoids increased 17.6 percent, and decreased on forbs 20.6 percent.

Food Habits

Fecal droppings at this time of the year are very soft, high in moisture content, and rapidly dispersed. The samples collected in 1970 and 1971 reflect little change in the percentage of graminoids in the diet from the pretreatment period (table 1). Although forbs in the vegeta-

Table 1.--Food habits of elk as determined by fecal analysis

Year[1]	Scats	Graminoids	Forbs	Sagebrush	Other browse
	Number	- - - - -	-*Percent*-	- - - -	
1968	26	43.4	46.0	0.9	9.7
1969	20	33.0	46.0	1.0	20.0
1970	29	40.9	51.5	0.9	6.7
1971	25	34.4	56.9	0.0	8.7
Averages		37.9	50.0	0.7	11.3

[1] Area sprayed with 2,4-D in June 1969.

---

[2] *Observation data from Bull Elk Park were collected in 1968 by USDA Forest Service employees Bob Joslin, Dale Morris, and the author. In 1969, 1970, and 1971, Marvin Hawley, Bob Williams, and Mac Black of the Wyoming Game and Fish Commission worked with the author to collect the data.*

tion complex decreased from 44 percent before spraying to 26 percent after, the percentage of forbs identified in the feces increased an average of 8 percent following spraying. Sagebrush made up only a small percentage of the elk diet at this time of the year.

Elk Calves

The calves spent an average of 3.4 and 5.5 hours on the spray area before and after treatment, respectively (table 2), which was not significantly different at any reasonable level. During feeding periods in 1968, calves were on the area to be sprayed twice as many hours as the adjacent area. Three very young calves spent 2 entire days on one spray site, which accounted for 21 of the 48 hours of feeding period observations. In the other years calves spent about equal time on the sprayed and adjacent sagebrush areas during the feeding periods. Standing dead sagebrush had no apparent adverse effects on the use of the area by elk calves. The more hours per feeding period in 1970 was due to heavy snow cover.

During the middle of the day, older calves spent considerably more time both before and after spraying in sagebrush areas with scattered conifer and aspen trees. The calves usually accompanied their mothers into the shaded areas to ruminate, especially on warm days. However, calves less than 3 days old usually bedded down on the warm, exposed slopes during the day, apart from their mothers.

Adult Elk

The number of adult elk fluctuated considerably among years (66 to 38, table 2). Snow cover and plant development had the most influence on number of elk seen. The early seasonal development in 1969 and 1971 allowed elk to move across Dry Fork and west to the higher country. More elk were seen in Bull Elk Park these 2 years.

Our observations showed that elk graze at a slow walk. In the course of one feeding period they moved indiscriminantly over the entire study area without preference for timber or open sagebrush cover. We could not detect that their grazing habits were altered by the spray treatments. The animals did spend more time feeding where forage was most abundant and on the more gentle slopes.

The average hours of adult elk use per feeding period between sprayed and unsprayed areas in years of similar plant development and weather conditions were about the same. The late plant development in 1968 and 1970 would account for the higher average hours of elk use per feeding period on the lower areas near the spray site. Since there was considerably more acreage of unsprayed sagebrush control area within our view, it was natural that more hours of elk use were recorded on the unsprayed area, both before and after treatment. An analysis of variance showed no significant (F = 1.066 at 95 percent level) difference in grazing hours of use due to effects of spraying sagebrush. The

Table 2.--Recorded adult and calf elk presence and use on treated area and on adjacent sagebrush area during feeding periods, 5:30-8:30 a.m., and 6:00-9:00 p.m.

lk presence by treatment and year	Feeding periods	Animals sighted	Total time on area--		Time per feeding period on area--		Observed time on area--	
			Treated	Sagebrush	Treated	Sagebrush	Treated	Sagebrush
	Number- -		*Hours*		*Hours*		*Percent*	
ALVES ON AREA--								
efore spraying:								
1968	10	6	48	24	4.8	2.4	67	33
1969	19	6	42	44	2.2	2.3	49	51
fter spraying:								
1970	9	10	60	66	6.7	7.3	48	52
1971	16	9	62	66	3.8	4.2	48	52
DULTS ON AREA--								
efore spraying:								
1968	10	66	331	476	33.1	47.6	41	59
1969	19	46	273	664	14.4	34.9	29	71
fter spraying:								
1970	9	51	350	492	38.9	54.7	30	58
1971	16	38	302	703	18.9	43.9	30	70

averages of feeding for adult elk were 23.5 and 29.6 hours before and after spraying, respectively.

Adult elk spent about 2 hours feeding at each of the two feeding periods during daylight. The rest of the time was spent resting, ruminating, and playing. Since only about one-fourth of their time is spent feeding during daylight on open slopes, we found more pellet groups or fecal pies in or near the trees. Other studies (Boeker and Reynolds 1966, Pearson 1968, Reynolds 1969, Skovlin et al. 1968), have also shown fecal pellets more numerous near trees. Density and location of fecal droppings appear to be a poor index to elk feeding activity.

Other Animals

Mule deer observed on the study area for the 4 years showed about the same feeding pattern before and after sagebrush spraying. They did not travel much while feeding, and remained closer to tree cover. Deer and elk were often seen feeding within a few feet of each other.

Black bears and coyotes were also seen on the study area. Elk showed more concern over the presence of coyotes than bears. In three cases cow elk with calves moved when coyotes were seen near. When black bears passed through the study area, the elk kept track of their location, but did not move out of the bear's way or show aggression. On one occasion a black bear passed within 30 feet of five grazing bull elk.

Summary

Elk did not change their calving behavior or grazing activity patterns on a site where 96.7 percent of the big sagebrush cover was killed with 2,4-D herbicide. Analysis of fecal samples from the study site showed no large changes due to spraying in grass-forb ratios consumed. Feeding elk showed no indication they preferred to stay close to timber. Hence, it appeared that sagebrush control, if confined to limited and scattered areas, had no detrimental impact on elk during the calving period.

Literature Cited

Altmann, Margaret.
1952. Social behavior of elk (Cervus canadensis Nelsoni) in the Jackson Hole area of Wyoming. Behavior 4(2):116-143.

Anderson, Chester.
1954. Jackson Hole's elk herd. Wyo. Wildl. 18(4):26-34.

Boeker, E. L., and Hudson G. Reynolds.
1966. Deer and elk habitat improvement studies in southern New Mexico. Ariz.-N. Mex. Sect. Wildl. Soc. Proc. 5:29-35.

Eustace, Charles D.
1967. Food habits, range use and relationships between elk and livestock in the Gravelly Mountains, Montana, M.S. Thesis, 55 p. Mont. State Coll., Bozeman.

Evans, R. A., and R. M. Love.
1957. The step-point method of sampling—a practical tool in range research. J. Range Manage. 10:208-212.

Kearl, G. W., and M. Brannan.
1967. Economics of mechanical control of sagebrush in Wyoming. Wyo. Agric. Exp. Stn. Sci. Monogr. 5, 35 p.

King. Calvin L.
1964. Inventory and evaluation of sagebrush spray sites. Job Completion Rep. Wyo. Game and Fish Comm. Big Game Surv. W-27-R-16, 209 p.

Mackie, Richard J.
1970. Range ecology, and relations of mule deer, elk and cattle in the Missouri River Breaks. Wildl. Monogr. 20, 79 p.

Madson, John.
1966. The elk. 125 p. Winchester-Western Press, Olin Mathieson Chem. Corp., East Alton, Ill.

Pearson, Henry A.
1968. Thinning, clearcutting, and reseeding affect deer and elk use of ponderosa pine forests in Arizona. USDA For. Serv. Res. Note RM-119, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pechanec, J. F., A. P. Plummer, J. H. Robertson, and A. C. Hull, Jr.
1965. Sagebrush control on rangelands. U.S. Dep. Agric. Agric. Handb. 277, 40 p.

Picton, Harold D.
1960. Migration patterns of the Sun River elkherd, Montana. J. Wildl. Manage. 24:279-290.

Preble, Edward A.
1911. Report on condition of elk in Jackson Hole, Wyoming in 1911. U.S. Biol. Surv. Bull. 40, 23 p.

Reynolds, Hudson G.
1969. Aspen grove use by deer, elk, and cattl in southwestern coniferous forests. USDA For. Serv. Res. Note RM-138, 4 p. Rocky Mt For. and Range Exp. Stn., Fort Collins, Colo

Skovlin, Jon M., P. J. Edgerton, and R. W. Harris
1968. The influence of cattle management o deer and elk. N. Am. Wildl. and Nat. Resour. Conf. Trans. 33:169-181.

Ward, A. Lorin.
1970. Stomach content and fecal analysis Methods of forage identification. p. 146-158 In Range and wildlife habitat evaluation— research symposium. U.S. Dep. Agric. Misc Publ. 1147, 220 p.

Wilbert, Don E.
1963. Some effects of chemical sagebrus control on elk distribution. J. Range Manag 16:74-78.

Agriculture—CSU, Ft. Collins

973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 241

REST SERVICE
. DEPARTMENT OF AGRICULTURE

Y MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Engelmann Spruce Seedling Roots Reach Depth of 3 to 4 Inches Their First Season

Daniel L. Noble[1]

First-year Engelmann spruce seedlings have an average rooting depth of 3.4 inches, 11 branch roots, and a total root length of 5 inches. Seedlings were field-grown on scarified shaded seedbeds in the central Rocky Mountains, Colorado.

Oxford: 181.36:232.324. Keywords: Root development, seedling survival, *Picea engelmannii*.

The rate of root growth of Engelmann pruce seedlings (Picea engelmannii Parry) is mportant for survival, especially during the irst growing season. Deeper root penetration ill increase the probability of seedlings suriving drought, frost-heaving, and erosion.

Roe et al. (1970) reported rooting depth of nly 1.5 inches for spruce seedlings in western ontana. Smith (1955) found that spruce seedngs grown under field conditions in British olumbia had short roots which averaged 1.7 nches in length with an average of 6.5 side oots. Jones (1971) listed vertical root penetraion for Engelmann spruce seedlings of 2.7 ches in eastern Arizona.

None of the reports relate root growth to ge, although seedlings were probably less than months old. Consequently, those estimates of rst-season root penetration may underestimate rowth.

This study was conducted to provide estiates of: (1) rooting depth — main root in its nextended position following washing, (fig.); (2) number and length of unextended branch oots; and (3) total root length — rooting depth plus branch roots — for 3-month-old field-grown spruce seedlings in the central Rocky Mountains.

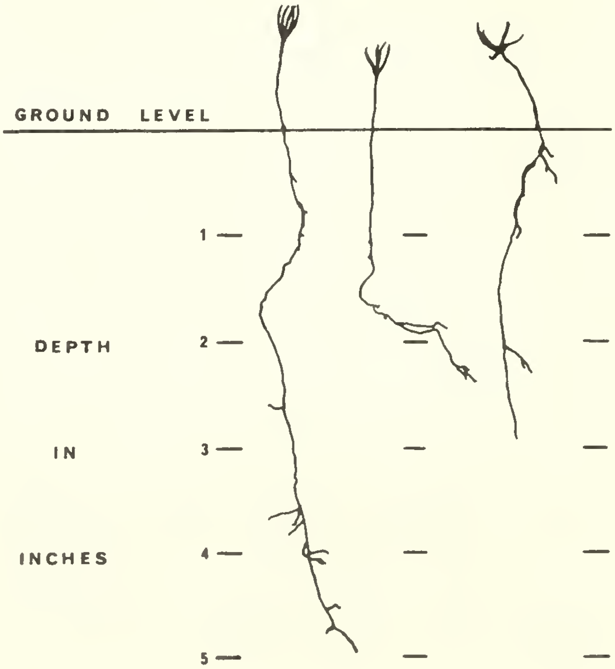


Figure 1.—Rooting depths of 3-month-old Engelmann spruce seedlings.

---

[1] *Forestry Research Technician, Rocky Mountain orest and Range Experiment Station, with central headuarters maintained at Fort Collins, in cooperation with olorado State University.*

Study Area Description

Seedlings were grown on the Fraser Experimental Forest, Colorado, in a 15-year-old spruce-fir clearcut on a gentle north-facing slope at an elevation of 10,600 feet. The dominant understory is whortleberry (Vaccinium myrtillus L. and V. scoparium Leiberg).

The climate of the area is typical of the subalpine zone of the west slope of the Front Range. Temperatures range from -30° to +90°F., and precipitation from 18 to 34 inches annually. A climatological summary of the experimental area has been provided by Haeffner (1971).

Temperatures and precipitation during the summer are important to this study. Average temperatures for an 8-year period (1965-72) were: maximum 63°F., minimum 38°F., and mean 50.5°F. Average precipitation was 7.6 inches with a range from 5.6 to 11.4 inches. Temperatures and precipitation are from the Fool Creek Windtower Station, approximately 300 yards from the study area, and with less than 100 feet difference in elevation.

The soil is a gravelly, sandy-loam Podzol of the Darling Series, developed in place under a spruce-fir stand from coarse-textured material weathered from mixed gneisses and schists (Retzer 1962). The average combined depth of A and B horizons is 12 to 16 inches. Laboratory analysis of the soil showed approximately 56, 34, and 10 percent sand, silt, and clay, respectively. Moisture contents at tensions of 1/3 and 15 bars were approximately 18 and 9 percent (Noble 1972).

Methods and Materials

Temperatures and precipitation were recorded on the study area during 3 summers (1970 through 1972) using a standard Weather Bureau shelter with a recording hygrothermograph and dial maximum-minimum thermometer. A standard 8-inch rain gage exposed without funnel or tube was weighed to measure precipitation.

Slash was removed and the area hand raked before further treatment. In late September of each year, 200 seeds (local seed source with 65 percent laboratory germination) were sown on the surface of two 1/4-mil-acre plots scarified to mineral soil and provided with about 50 percent overhead shade. The wooden shade frames were made from 1- by 2-inch fir strips held 8 inches above the ground by a 3/8-inch metal frame (fig. 2). Shade frame slats were oriented in a north-south direction so that throughout the day seedlings were alternately exposed to periods of shade and sunlight.

Seedlings that germinated in the last week of June or first week of July were measured

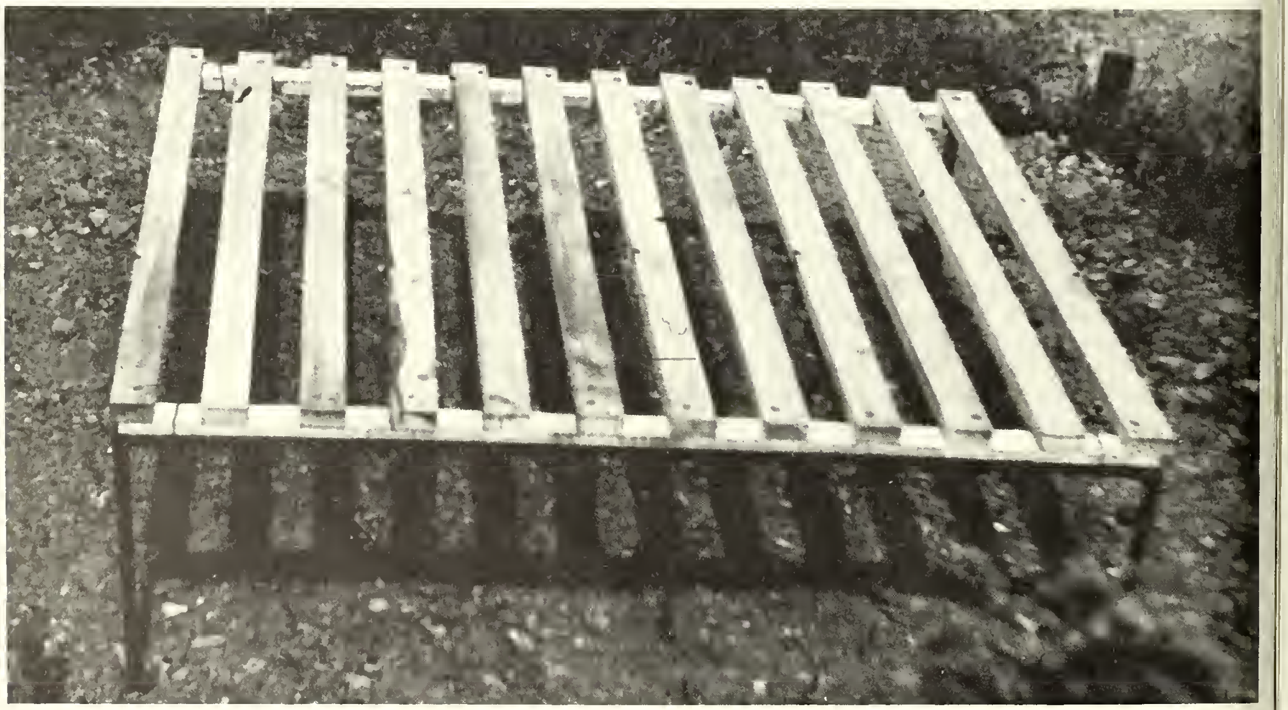


Figure 2.—Scarified and shaded seedbed.

when they reached 15 weeks (±1) of age. Seedlings were carefully lifted with a shovel and trowel, and the soil was washed from the roots in a water-filled barrel. Rooting depth and length of branch roots were measured to the nearest 0.1 inch.

Analysis of variance showed that differences in rooting depth, number of branch roots, and total root length between years were not significant. Therefore, the three samples (years) were combined to calculate means, ranges, and standard errors.

Results

Temperatures averaged close to normal with little difference between years. For the 3 growing seasons average temperatures were: maximum 63.1°F., minimum 38.6°F., and mean 50.9°F. Precipitation averaged about 1 inch below normal.

Fifteen seedlings survived to be measured in 1970, 16 in 1971, and 15 in 1972. The average root depth was 3.36 inches with a range from 2.0 to 5.3 inches, and the standard error for the mean was 0.10. Number of branch roots ranged from 2 to 37 and averaged 10.7, with a standard error of 1.02. Total root length averaged 4.98 inches, ranging from 2.4 to 9.0 inches. The standard error was 0.21.

Conclusions

Under field conditions, 15-week-old spruce seedlings do not develop a vigorous root system. Rooting depth is about 3.4 inches; branch roots are few in number, and range in length from 0.1 to 0.7 inch.

The failure of spruce to develop a deeper root system in the field is a major factor contributing to mortality on both mineral soil and undisturbed areas. Under severe drought conditions, first-summer root growth is not adequate to keep up with the rate at which the seedbed dries out. Furthermore, first-year seedlings are readily killed when weather conditions are conducive to frost-heaving.

Literature Cited

Haeffner, Arden D.
1971. Daily temperatures and precipitation for subalpine forest, central Colorado. USDA For. Serv. Res. Pap. RM-80, 48 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Jones, John R.
1971. Mixed conifer seedling growth in eastern Arizona. USDA For. Serv. Res. Pap. RM-77, 19 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Noble, Daniel L.
1972. Effects of soil type and watering on germination, survival, and growth of Engelmann spruce: A greenhouse study. USDA For. Serv. Res. Note RM-216, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Retzer, J. L.
1962. Soil survey of Fraser alpine area, Colorado. U.S. Dep. Agric. For. Serv. and Soil Conserv. Serv., in cooperation with Colo. Agric. Exp. Stn., Soil Surv. Ser. 1956, No. 20, 47 p.

Roe, Arthur L., Robert R. Alexander, and Milton D. Andrews.
1970. Engelmann spruce regeneration practices in the Rocky Mountains. U.S. Dep. Agric. Prod. Res. Rep. 115, 32 p.

Smith, J. H. G.
1955. Some factors affecting reproduction of Engelmann spruce and fir. Dep. Lands and For., Brit. Columbia For. Serv. Tech. Publ. 43, 43 p.

Agriculture—CSU, Ft. Collins

973

U S D A FOREST SERVICE
RESEARCH NOTE RM-242

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Herbicides Ineffective in Controlling Southwestern Dwarf Mistletoe

Paul C. Lightle[1] **and Eslie H. Lampi**[2]

The oil-soluble amine and butoxyethanol ester of 2,4,5-trichlorophenoxy butyric acid (4-(2,4,5-TB)) in concentrations of 0.5, 1.5, and 3.0 percent were used in a trial to control southwestern dwarf mistletoe. Both were ineffective in reducing the infection levels of the parasite in ponderosa pine trees in northern New Mexico.

Oxford: 441—414.12:443.3. Keywords: Herbicides, *Pinus ponderosa*, *Arceuthobium vaginatum* subsp. *cryptopodum*.

The National Park Service and the USDA Forest Service in Arizona and New Mexico are concerned about high infection rates of dwarf mistletoe (Arceuthobium vaginatum subsp. cryptopodum (Engelm.) Hawks. and Weins) in ponderosa pine (Pinus ponderosa Laws.) in heavy use areas, such as those around Park Headquarters, picnic areas, and in scenic roadside strips (Lightle and Hawksworth 1973). For many years the only available methods for controlling dwarf mistletoe have been silvicultural. While these methods are applicable to forest stands in general, there is a growing need for a control method to save individual high-value trees. A chemical that would eliminate the parasite from the tree, without undue damage to the host, would be desirable.

Quick (1964) evaluated experimental herbicides to control dwarf mistletoe in some conifer species in California. His most promising chemical was the isooctyl ester (IOE) of 2,4,5-trichlorophenoxy butyric acid (4-(2,4,5-TB)), followed by the butoxyethanol ester (BOEE) and the oil-soluble amine (OSA) formulations. He reported these materials to be effective over a rather broad range of concentrations (0.2 to 1.5 percent acid equivalent) when applied directly to the dwarf mistletoe infections and the surrounding bark. A cooperative test of some of these promising materials was installed at Bandelier National Monument, New Mexico, in 1965. The purpose of this Note is to report the results of that test.

Methods and Materials

The BOEE and the OSA formulations of 2,4,5-TB were used in three concentrations (0.5, 1.5, and 3.0 percent acid equivalent) in a number 2 stove oil carrier. (The IOE formulation was not available from the manufacturer when this test was made.) These, together with the carrier alone and no treatment, gave a total of eight treatments.

Six hundred and three ponderosa pine trees were tagged, and their diameters at breast height (d.b.h.), and total heights measured. The smallest tree treated in each case was less than 6 feet high. Each tree was rated for dwarf mistletoe according to the 6-point system

---

[1] *Principal Plant Pathologist, Rocky Mountain Forest and Range Experiment Station, located at Albuquerque in cooperation with the University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Resource Management Specialist, Southwestern Region, National Park Service, U.S. Department of the Interior, Santa Fe, New Mexico.*

(Hawksworth 1961, p. 77). In addition, the numbers of branch and bole infections were recorded.

The trees used in each treatment were essentially equivalent (table 1). Average d.b.h. varied from 2.6 to 3.1 inches. With the exception of the trees that received no treatment, the proportion of infected trees was nearly equal, and ranged from 89.7 to 93.5 percent. The average dwarf mistletoe rating for the trees in each treatment also was similar and varied from 2.7 to 3.2.

Treatments were randomly assigned so that approximately the same number of trees was included in each treatment, except for the "no treatment" category. Chemicals were applied as a spray from small, pressure-type garden sprayers. They were sprayed directly on the dwarf mistletoe shoots, and on the bark of the host approximately 12 inches beyond signs of infection, until the solution dripped or ran off. The bark was thoroughly wetted, and the branch or bole was treated completely around the circumference. Trees to be treated that had infections higher than could be reached from the ground were sprayed from ladders. All treatments were applied during the first week in October 1965.

Trees were examined 1, 2, and 6½ years after treatment. The following rating system, similar to Quick's 5-step scale, was used to rate both damage to the host and effectiveness against the parasite:

	Treatment-effectiveness scale	
	Quick	**Lightle**
Tree or infection —		
Dead	5	5
Looks dead	4	4
Seriously affected	3	3
Affected, but not seriously so	2	2
Very slightly affected	-	1
Not affected	1	0

Results and Discussion

Damage to uninfected trees from the sprayed chemicals was very slight (all were rated one). Damage to infected trees varied considerably from tree to tree but in general was negligible (1.3 to 1.7). Apparent effectiveness of the materials decreased with time after treatment so that after 6 years very little effect from the treatment could be recognized (table 2). The average dwarf mistletoe rating for the trees in each treatment varied only slightly after 6 years (table 2). No major difference among the various treatments was apparent.

An analysis of trees that died during the test period showed some correlation with dwarf mistletoe severity, as might be expected, but little with treatment (table 3). Fifteen percent of the trees that died had no dwarf mistletoe and received no treatment. The cause of their

Table 1.--Comparison of pretreatment data (1965) for areas to be treated to control dwarf mistletoe at Bandelier National Monument

Planned treatment	Total trees (603)	Diameter at breast height		Trees infected	Dwarf mistletoe rating (6-class)[1]
		Average	Largest tree		
	Number	*Inches*		*Percent*	
None (check)	173	3.1	15.4	11.6	2.7
Oil-soluble amine					
0.5 percent	66	3.0	9.1	90.9	3.1
1.5 percent	61	2.6	8.6	90.2	2.7
3.0 percent	57	2.9	7.3	93.0	3.0
Butoxyethanol ester					
0.5 percent	59	2.9	11.9	91.5	3.1
1.5 percent	62	2.8	9.2	93.5	3.0
3.0 percent	58	2.9	8.7	89.7	3.0
Carrier (stove oil)	57	2.8	8.3	91.2	3.2

[1] Based on 6-class rating system developed by Hawksworth (1961, p. 77); includes uninfected trees.

Table 2.--Effectiveness of chemicals against dwarf mistletoe and average infection rating of trees in the control test at Bandelier National Monument

Treatment	Original dwarf mistletoe rating (6-class)[1]	Treatment effectiveness (5-class)[2]			Average dwarf mistletoe rating (6-class)[1]	
		1st year	2nd year	6th year	End of study	6-year change
None (check)	2.7				2.2	-0.5
Oil-soluble amine						
0.5 percent	3.1	4.1	2.3	2.0	3.1	0
1.5 percent	2.7	4.2	2.1	1.8	2.6	-0.1
3.0 percent	3.0	4.0	1.7	2.0	3.5	+0.5
Butoxyethanol ester						
0.5 percent	3.1	4.3	2.0	2.0	3.4	+0.3
1.5 percent	3.0	4.1	1.9	1.9	3.4	+0.4
3.0 percent	3.0	4.3	2.1	2.1	2.7	-0.3
Carrier (stove oil)	3.2	4.2	2.1	1.9	3.2	0

[1] Based on 6-class rating system developed by Hawksworth (1961, p. 77); includes uninfected trees.

[2] Based on 5-class treatment-effectiveness scale on page 2.

deaths was not determined. However, since two-thirds of them were less than 1 inch d.b.h., including three that were less than 6 feet tall, suppression was the probable cause of death.

Literature Cited

Hawksworth, F. G.
1961. Dwarfmistletoe of ponderosa pine in the Southwest. U.S. Dep. Agric. Tech. Bull. 1246, 112 p.

Lightle, Paul C., and Frank G. Hawksworth.
1973. Control of dwarf mistletoe in a heavily used ponderosa pine recreation forest: Grand Canyon, Arizona. USDA For. Serv. Res. Pap. RM-106, 22 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Quick, Clarence R.
1964. Experimental herbicidal control of dwarfmistletoe on some California conifers. U.S. For. Serv. Res. Note PSW-47, 9 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Table 3.--Numbers of trees that died (100) during 6 years in Bandelier National Monument chemical control test

Treatment	Tree mortality in relation to original dwarf mistletoe rating							Total
	0	1	2	3	4	5	6	
				Number				
None (check)	15	0	0	1	1	0	0	17
Oil-soluble amine								
0.5 percent	0	0	1	3	2	1	9	16
1.5 percent	0	0	0	2	0	1	5	8
3.0 percent	0	1	0	2	0	0	4	7
Butoxyethanol ester								
0.5 percent	1	0	1	1	0	0	8	11
1.5 percent	0	2	1	2	0	0	6	11
3.0 percent	1	3	0	1	1	0	9	14
Carrier (stove oil)	0	1	1	3	1	1	9	16
Total	17	7	4	15	5	3	49	100

Agriculture—CSU, Ft. Collins

973

U S D A FOREST SERVICE
RESEARCH NOTE RM-243

REST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Revegetating Devastated Sites in New Mexico with Western Wheatgrass Transplants[1]

Earl F. Aldon, O. D. Knipe, and George Garcia[2]

Western wheatgrass (*Agropyron smithii* Rydb.) survived well and produced daughter plants from rhizomes during the first year when good seeds were grown to 3-month-old transplants, then transferred to sandy or clay loam sites at elevations of around 7,500 feet.

Oxford: 181.3:232.324. Keywords: Plant propagation, transplanting, soil stabilization, *Agropyron smithii*.

Eroding alluvial bottom lands and new road cuts are common sights in the Southwest. Land managers responsible for restoring productivity or reducing erosion on these sites are faced with a difficult problem. The steep slopes and poor soils of road cuts often make direct seeding impossible. Narrow arroyo bottoms and U-shaped sidewalls preclude the use of seeding equipment on some alluvial sites.

Shrub transplants can be used successfully for restoration work in the Southwest (Aldon 1970a). Eighty percent survival was attained after the second growing season with fourwing saltbush (Atriplex canescens) when specific guides were followed (Aldon 1970b, 1972). Little work has been done previously with grass transplants, however.

Grass establishment with transplants, if successful, offers quick cover and rapid spread; hence good soil protection on steep slopes. Two areas having steep slopes and no vegetation were available on the Gila and Cibola National Forests in New Mexico where methods of establishing grass transplants could be tested.

Planting Materials and Procedures

Seedlings of western wheatgrass (Agropyron smithii) were grown outdoors in Albuquerque. Good garden soil was used in 4-inch by 4-inch by 4-inch asphalt honeycomb planting bands. Four seeds were sown in each cell in April when temperatures were optimum (Knipe 1972). Seeds had been treated with a fungicide, and showed high germination potential in independent tests (Knipe 1972). Bands were watered daily until seeds germinated, and were then saturated as needed.

Approximately 2,000 3-month-old seedlings were transplanted at each of two sites in New Mexico. The Snow Lake site is a road cut slope on a newly built road in the pine type of the Gila National Forest near Snow Lake Dam (fig. 1), at an elevation of 8,000 feet. Soils are derived from sandstones of the Gila conglomerate formation. The Continental Divide site is an arroyo bottom near the Continental Divide

---

[1] *The assistance of the watershed personnel of the Gila and Cibola National Forest is gratefully acknowledged.*

[2] *Principal Hydrologist, Plant Ecologist, and Forestry Research Technician, Rocky Mountain Forest and Range Experiment Station, located at Albuquerque in cooperation with the University of New Mexico. Knipe is now located at Tempe, Arizona, in cooperation with the Arizona State University. Station's central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

Figure 1.--

Snow Lake road cut site on Gila National Forest:

Before planting;

Immediately after planting;

1 year after planting.

in the pinyon-juniper type on the Cibola National Forest near Thoreau, at an elevation of about 7,400 feet. Annual precipitation is between 11 and 14 inches. Soil is of the Prewitt clay loam series (Williams 1967). Precipitation was recorded at both sites. The Divide site was fenced to prevent grazing.

Seedlings were planted after summer rains began, when laboratory determinations showed that soil moisture stress was less than 1 atmosphere. Four-inch plant bands containing one or more seedlings were planted in holes dug at 2-foot intervals with a posthole digger. Bands were planted flush with the ground surface, and the holes were backfilled and tamped.

Plant survival and evidence of daughter plants from rhizomes were sampled after the first and second growing seasons at the Continental Divide site and after the first growing season and in June of the next year at the Snow Lake site. Twenty random plants were checked in five randomly selected rows in each of four replications.

Results

Survival of western wheatgrass transplants averaged 96.5 ± 0.5 percent after the first growing season (October 1971) at Snow Lake, 86.5 ± 1.9 percent at Continental Divide. Mortality and losses from erosion dropped survival to 86 ± 6.5 percent at Snow Lake in June 1972, and to 82.5 ± 2.5 percent at Continental Divide in October 1972. Daughter plants from rhizomes were visible from 64 percent of the sampled plants after the second growing season. This figure may not be entirely accurate because without excavation it is not possible, in some instances, to determine from which parent plant the shoot arises (fig. 1).

Soil moisture at the time of planting averaged 5 percent on the sandy road cut (Snow Lake) and 14.2 percent on the clay loam alluvial bottom (Continental Divide). In both cases this represented a value of less than 1 atm. moisture tension. Precipitation was about normal at both sites, although long-term averages are not available for the road cut site.

Recommendations

Western wheatgrass transplants can be successfully planted on sandy sites (road cuts in the ponderosa pine type) and clay loam sites (alluvial bottom lands in the pinyon-juniper type) at elevations around 7,500 feet if the following steps are followed:

1. Grow transplants in 4-inch by 4-inch by 4-inch asphalt honeycomb planting bands in good garden soil.
2. Plant tested seed (germination percentages of 95+ should be obtained by your own tests) in bands when outdoor temperatures are optimum (between 55° and 75°C). Keep moist until germination; after that saturate as needed. Thin to one plant per band.
3. Plant transplants in the field at 2-foot spacing when 3 months old. Prevent drying when transporting seedlings to the field and when planting.
4. Plant individual plant bands at ground level when soil moisture at 4 inches is less than 1 atm. tension. Tamp soil firmly around bands.
5. Plant when probabilites for precipitation of a half inch or more are greatest.
6. Soils on the proposed planting sites should be checked to see if they differ widely from the soils used here. If so, small test plantings should be tried first.

Literature Cited

Aldon, Earl F.
1970a. Fourwing saltbush can be field planted successfully. USDA For. Serv. Res. Note RM-173, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Aldon, Earl F.
1970b. Growing fourwing saltbush transplants for field planting. USDA For. Serv. Res. Note RM-166, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Aldon, Earl F.
1972. Critical soil moisture levels for field planting fourwing saltbush. J. Range Manage. 25:311-312.

Knipe, O. D.
1972. Western wheatgrass germination as related to temperature, light, and moisture. J. Range Manage. 26:68-69.

Williams, John A.
1967. Soil survey, Zuni Mountain area, New Mexico. 86 p., 24 maps. U.S. Dep. Agric., For. Serv. and Soil Conserv. Serv. Gov. Print. Off., Wash. D.C.

Agriculture—CSU, Ft. Collins

USDA FOREST SERVICE
RESEARCH NOTE RM- 244

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Bark Beetle Emergence Cages Modified for Use as Pit Traps

J. M. Schmid,[1] J. C. Mitchell,[1] and M. H. Schroeder[2]

Bark beetle emergence cages collect numerous ground dwelling insects when modified for use as pit traps.

Oxford: 453:413.1. Keywords: Insect traps.

In 1967 Germain and Wygant[3] designed a collecting device consisting of a cylindrical screen cage over a funnel to capture emerging bark beetles. In use, an infested bolt is placed within the screen cylinder and emerging Dendroctonus beetles and other insects eventually fall into a jar attached to the funnel spout. These cages have been used extensively in laboratory rearings and work well with either naturally or artificially infested bolts.

We recently modified these cages for use as pit traps. The leg stands and screening were separated from the funnel and stored. A rectangular piece of sheet metal was soldered to form a cylinder slightly larger than the outside diameter of the upper portion of the funnel, so that the funnel fitted snugly into the cylinder and its lip rested on the edge of the cylinder. At the collection site, the sheet metal cylinder and funnel were placed in a hole dug just wide enough to accommodate the cylinder and deep enough to have the lip of the funnel level with the ground (fig. 1). Loose soil was backfilled

Figure 1.—Pit trap in collecting position.

---

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

[2] Bureau of Sport Fisheries and Wildlife, Denver Wildlife Research Center, Denver, Colorado.

[3] Germain, C. J., and N. D. Wygant. 1967. A cylindrical screen cage for rearing bark beetles. U. S. For. Serv. Res. Note RM-87, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

around the cylinder and leveled to the top of the funnel. Any soil falling into the cylinder during backfilling was removed to allow room for the jar at the bottom of the funnel.

A standard canning jar — half-filled with alcohol — was attached to the funnel (fig. 2) which was then inserted in the cylinder. The metal bolts which normally support beetle-infested bolts were left in place to serve as handles for removing the funnel from the cylinder. The collecting jars can be changed rapidly, and evaporation of alcohol is negligible. If the emergence cages are needed for bark beetle studies, the funnels can easily be reassembled with the other parts. Since the emergence cages are not extensively used in spring and early summer for bark beetle rearings, the funnel portion can serve in both capacities.

People who do not have access to a Germain-Wygant cage can easily and inexpensively construct their own trap. The parts can be purchased and assembled for approximately $5 (10-inch diameter funnel = $3, sheet metal, bolts, and jar = $1, soldering = $1) if a 10-inch diameter funnel is used and labor is not included. Funnel size is optional, although smaller funnels may be less effective because their smaller necks may clog or prevent the larger insects, spiders, or small mammals from falling into the jar.

Adult insects collected during the 1972 field season included specimens of Carabidae, Cantharidae, Cerambycidae, Cicindelidae, Coccinellidae, Curculionidae, Elateridae, Scarabaeidae, Silphidae, Staphylinidae, and Tenebrionidae. Also collected were adults of the families Acrididae, Gryllidae, Lygaeidae, Asilidae, Calliphoridae, Muscidae, Tabanidae, Tachinidae, Apidae, Chrysididae, Formicidae, Ichneumonidae, and Mutillidae. Although adults were most numerous, larvae of some groups were also taken.

Most of the insects probably fell into the traps. Exceptions seem to be the ichneumonids and asilids which were probably overcome by alcohol fumes while searching the neck of the funnel for prey or oviposition sites. Other Diptera may have suffered a similar fate.

In addition to insects, the traps also collected numerous arachnid families including: Clubionidae, Dictynidae, Gnaphosidae, Hahniidae, Linyphiidae, Lycosidae, Micryphantidae, Salticidae, Theridiidae, and Thomisidae.

Throughout the trapping period, several species of small mammals, both young and old, were found in the traps. These were believed to have fallen in accidently while foraging. Species trapped included: masked shrew (Sorex cinereus Kerr), vagrant shrew (Sorex vagrans Baird), Richardson ground squirrel (Citellus richardsoni (Sabine)), northern pocket gopher (Thomomys talpoides (Richardson)), Wyoming pocket mouse (Perognathus fasciatus Maximilian), deer mouse (Peromyscus maniculatus (Wagner)), grasshopper mouse (Onychomys laucogaster (Maximilian)), mountain vole (Microtus montanus (Peale)), longtailed vole (Microtus longicaudus (Merriam)), and sagebrush vole (Lagurus curtatus (Cope)).

Figure 2.—Pit trap ready for insertion into the cylinder.

U S D A FOREST SERVICE
RESEARCH NOTE RM- 245

REST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Revegetating Coal Mine Spoils in New Mexico: *A Laboratory Study*

Earl F. Aldon and H. W. Springfield[1]

Emergence and early growth of mountain rye and fourwing saltbush were studied in untreated 3-year-old mine spoils, and in spoils to which organic matter or fertilizer had been added under greenhouse conditions. Emergence and growth were satisfactory from untreated spoils; adding amendments had no effect on seedling emergence or early growth.

Oxford: 114.449.8:114.54. Keywords: Mine spoils, rehabilitation, *Secale montanum, Atriplex canescens*.

With the passage of the New Mexico Coal Surfacemining Act in 1972, much interest has been generated in finding ways to establish vegetation cover on coal mine spoils. The Rocky Mountain Forest and Range Experiment Station has recently entered into cooperative research with several coal mine companies in New Mexico to develop methods of rehabilitating strip-mined areas. Because of widespread interest, these studies are reported even though they are preliminary in scope. More sophisticated work is planned, based on results of the studies reported here.

The problems evaluated were: Will selected plants grow under optimum temperature and moisture on these mine spoils? If not, what is limiting growth? Will the addition of organic matter make a difference to plant growth? Which, of several organic soil amendments, might help? What moisture retention might be expected from selected spoil material?

Methods

The 3-year-old spoil material used was taken from the McKinley Mine of Pittsburg and Midway Coal Company, located near Gallup, New Mexico, at an elevation of 6,600-6,800 feet and annual precipitation of 11-15 inches. Characteristics of the spoil material were as follows: Texture — clay loam; pH — nearly neutral; conductivity — shows slight salinity; sodium absorption ratio — shows alkalinity (sodium) in moderate degree to very low; organic matter high due to coal particles.

Moisture drying curves for the spoil materials were prepared from data obtained with a pressure membrane apparatus. Three spoil samples were used at each tension level: Saturation, 0.3 bar, and 15 bars.

Mountain rye (Secale montanum) and fourwing saltbush (Atriplex canescens) were used as test plants in 2.5- by 2.5- by 2-inch pots holding 0.30 pound of spoil material per pot. These species offered promise for growth and survival because previous work on nearby areas showed they were adapted to the climatic conditions of the mine site. Plants were grown in a growth chamber programed for 8 hours at 75°F with light and 16 hours at 65°F in darkness. Distilled water was used throughout,

---

[1] *Principal Hydrologist and Range Scientist, respectively, Rocky Mountain Forest and Range Experiment Station, located at Albuquerque, in cooperation with the University of New Mexico; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

and all pots were kept at field capacity. This required watering at 2-day intervals. Two separate studies were conducted for 5 weeks.

Study A

A randomized block design was used with three replications of each of the following treatments:

1. Amendments added — none.
2. Manure added at a rate of 10 tons per acre.
3. Bark (ponderosa pine) added at a rate of 10 tons per acre.
4. Straw added at a rate of 2 tons per acre.
5. Sawdust added at a rate of 10 tons per acre.

These amendments were mixed into the spoil material. Twenty seeds of mountain rye and 10 seeds of fourwing saltbush were added to each pot. Seedlings were counted at 3- to 5-day intervals, and height measured to the nearest 1/2 inch at 5 weeks.

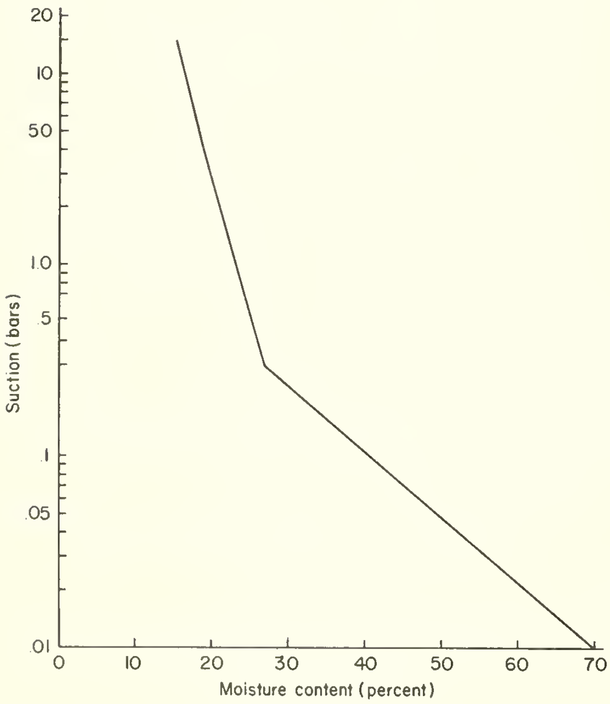


Figure 1.—Drying curve for average of three samples of spoil material from McKinley Mine, near Gallup, New Mexico.

Study B

A randomized block design with three replications of each of the following treatments was used:

1. No fertilizer.
2. Fertilizer (10-5-5) added at a rate of 800 pounds per acre.
3. Fertilizer (10-5-5) added at a rate of 1,600 pounds per acre.

Ten seeds of mountain rye were added to each of three pots, and 10 seeds of fourwing saltbush were used in each of three additional pots. Measurements were taken as in study A.

Results

Moisture-holding capacity of the spoils material is relatively high (fig. 1). At 0.3 bar tension, which approximates field capacity, the three samples averaged nearly 27 percent moisture, whereas at 15 bars, which approximates the wilting point, the samples contained about 15 percent moisture.

Both mountain rye and fourwing saltbush emerged and grew satisfactorily from untreated spoil material. In both studies, seedlings of both species began emerging within 3 to 4 days after seeding. Most seedlings had emerged by the 7th day. Maximum emergence, however, was not attained until the 21st day due to delayed germination of a few seeds.

Adding organic matter to the spoil materia did not significantly improve emergence or early growth of mountain rye or fourwing saltbush seedlings (table 1). Five weeks after seeding maximum emergence of mountain rye averaged about 43 percent and seedling height about 10 inches. Straw appeared to depress emergence and height of the grass slightly, but this effec was not significant.

Fourwing saltbush showed a trend toward better emergence and taller seedlings where organic matter was incorporated in the spoi material (fig. 2), but none of the difference were statistically significant due to relatively large variability among replications.

Fertilizer applied at the time of seeding di not significantly improve emergence or earl growth of mountain rye or fourwing saltbus (table 1). The higher rate of fertilizer, in fac tended to inhibit emergence of mountain ry seedlings for some unexplained reason. Sligh trends were shown toward taller seedlings o both species with fertilization.

Figure 2.—Comparative growth of seedlings in treated and untreated spoils materials from McKinley Mine:

Study A—
Spoils treatments (left to right), none, manure, bark, straw, sawdust.
Mountain rye and fourwing saltbush.

Study B—
Spoils treatments (left to right), no fertilizer, 800 pounds per acre, 1,600 pounds per acre.

Mountain rye,

Fourwing saltbush.

Table 1.--Effects of amendments on emergence and early growth of mountain rye and fourwing saltbush seedlings from mining spoils

Study and amendment	Rate per acre	Mountain rye		Fourwing saltbush	
		Maximum emergence	Average height[1]	Maximum emergence	Average height[1]
		Percent	*Inches*	*Percent*	*Inches*
STUDY A (Organic matter)					
None		44	9.2	50	2.1
Manure	10 tons	48	10.5	70	2.2
Bark (ponderosa pine)	10 tons	48	10.0	60	2.2
Straw	2 tons	34	9.1	73	2.2
Sawdust	10 tons	40	10.3	83	2.2
STUDY B (Fertilizer, NPK)					
None		67	6.8	90	2.1
10-5-5	800 pounds	60	7.9	83	2.2
10-5-5	1,600 pounds	33	7.6	87	2.3

[1] Study A, 5 weeks after seeding; Study B, 3 weeks after seeding.

Future Work

These studies point up areas for future work. Some leads to be tested are:

1. Find ways to improve moisture penetration into the spoils. Watering was sometimes difficult due to surface crusting and cracking, and could be a major problem under field conditions.
2. Repeat experiments with better detectability in order to determine whether the addition of organic matter does in fact improve emergence of seedlings.
3. Test other plant species that may be useful as forage and ground cover for protection from soil erosion.
4. Test plants grown on spoil material under moisture stress, a situation that might more typify field conditions.
5. Determine effects of fertilization on long-term growth of plants in spoil materials.

Agriculture—CSU, Ft. Collins

gust 1973

U S D A FOREST SERVICE
RESEARCH NOTE RM-246

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Pressure Bomb Measurements Indicate Water Availability in a Southwestern Riparian Community

C. J. Campbell[1]

In spring and summer, soil moisture availability is the most important environmental variable affecting plant moisture stress. The Scholander pressure-bomb technique detected differences in plant moisture stress between and among species, thereby delineating areas of high or low potential evapotranspiration within a riparian zone.

Oxford: 181.31:116.13. Keywords: Plant-water relations, riparian vegetation.

Composition of riparian communities in the outhwest is determined primarily by geography, minimum and maximum temperatures, il moisture conditions, and flood disturbances. o a lesser extent, composition is affected by mpetition between and within species for ght, water, and nutrients (Campbell and Green 68). Specific microclimatic conditions within ost of these communities are not known.

In 1970 and 1971, the microclimate of a parian community was studied in detail at ycamore Creek, near Sunflower, Arizona levation 3,400 feet). The objectives of the udy were to determine (1) ecological and ant-water relationships of a relatively stable parian community, and (2) environmental ctors which most consistently affect the plant oisture stress of plants within this community.

Study Area and Methods

The study area consisted of a 1-acre plot with a mixed stand composed of sycamore *(Platanus wrightii)*, cottonwood *(Populus fremontii)*, ash *(Fraxinus pennsylvanica)*, and walnut *(Juglans major)*, dominant because of their relative crown height over subordinate Utah juniper *(Juniperus osteosperma)*, mesquite *(Prosopis juliflora)*, desert willow *(Chilopsis linearis)*, and hackberry *(Celtis reticulata)*. In addition, Arizona white oak *(Quercus arizonica)*, shrub live oak *(Q. turbinella)*, catclaw mimosa *(Mimosa biuncifera)*, skunkbush sumac *(Rhus trilobata)*, poison ivy *(R. radicans)*, catclaw acacia *(Acacia greggii)*, and prickly pear cactus *(Opuntia engelmannii)*, are widely scattered throughout the plot. Sycamore, mesquite, and juniper immediately surrounded a ground-water well with a water table at generally less than 10 feet depth. The roots of all three plants were assumed to penetrate to the capillary fringe at about 6 feet below the ground surface.

The alluvial soil at the well site was 28 feet deep. The hackberry monitored was located some 120 feet from the well near the base of a mountain, and was believed to be growing in parent material and obtaining moisture solely

[1] *Botanist, Rocky Mountain Forest and nge Experiment Station, located at the ation's Research Work Unit at Tempe, in operation with Arizona State University. ation's central headquarters is maintained Fort Collins, in cooperation with Colorado ate University.*

from local precipitation. Consequently, the sycamore, mesquite, and juniper monitored were expected to react simultaneously to moisture stress or atmospheric changes, while hackberry was expected to show the effect of drought conditions preceding the summer rains.

Soil temperature at the 20-inch depth, and air temperature at 3, 6, and 18 feet from a centrally located steel tower, were measured with thermocouples at bihourly intervals during 24-hour periods. Crown temperatures of each of the four species were measured at two-thirds the individual tree height. Sap temperature was measured 0.5 inch beneath the outer bark on the north side of the trunk at a 3-foot height. Vapor pressure deficit was calculated from temperatures taken at 3 feet. Net radiation was determined at 18 feet on the tower, and direct solar radiation at 8 feet in a natural clearing 125 feet from the tower. An estimated 95 percent of direct radiation was recorded; 5 percent of potential was lost because of shadows cast by adjacent canyon hillsides.

Plant moisture stress (PMS) was determined at bihourly intervals during daylight hours and occasionally at night with a pressure bomb (Scholander et al. 1964, 1965; Campbell and Pase 1972). The pressure bomb data formed the dependent variables in later analyses. Windspeed and other temperature values were not included in the analyses because they apparently did not change PMS. Windspeed was never less than 0.3 foot per second for any 4-hour period nor greater than 7.2 feet per second. Higher windspeeds always preceded summer convectional storms, but they did not appear to materially influence PMS. Precipitation always reduced PMS, probably because atmospheric stress declined as a result of change in vapor pressure deficit during the rain rather than because of the additional soil moisture.

Results and Discussion

We found that PMS of all four species reacted differently but usually consistently to atmospheric changes. Hackberry, as expected, showed the effects of apparent limited soil water. Juniper at this site has a wide tolerance for light, soil moisture, and soil types. It is found scattered on adjacent chaparral slopes, and is the dominant understory plant beneath the taller sycamore, ash, and walnut. Juniper showed more drought stress than expected, apparently because of a high transpiration-root absorption ratio.

Depth to water table at the well ranged between 9 and 11 feet from March to October. Diurnal fluctuations began the latter part of March and peaked at 0.09 foot in June. Diurnal and seasonal water-table fluctuation followed the cyclic course of evapotranspiration: slight diurnal fluctuations in the spring, with progressively larger fluctuations during high radiation loads in the summer. Cloudy and cooler days in the fall steadily reduced the diurnal fluctuations until they ceased between October and March.

Radiation loads increased progressively between spring and summer, and tended to taper off during the monsoon season in July August, and early September. PMS followed this trend and usually was correlated with radiation intensity. Because of other environmental influences, however, PMS could not be accurately predicted from radiation values alone

Average bihourly bomb values for the entire growing season showed hackberry with a mean PMS of 24.2 bars, consistently higher than eithe mesquite, juniper, or sycamore, with 16.7, 16.4 and 15.6 bars, respectively. Differences in PMS between hackberry and the other species wer greater at 0600, 0800, and 1000 hours than a 1200, 1400, 1600, and 1800 hours. Averaged bom values for the morning period were 23.3 bar for hackberry and 13.2 bars for the othe species. Afternoon PMS averaged 24.8 bars fo hackberry and 20.1 for the others.

PMS values among sycamore, mesquite juniper, and hackberry were similar durin winter dormancy. In the spring, however, leave developed at different times and rates, causin PMS to vary. In May and June, PMS of th three species growing over a shallow wate table, where both soil moisture and root aer tion were favorable, tended to be close correlated. PMS of hackberry was much highe In July and August, when leaf maturation wa similar between all species, PMS differenc were less pronounced. Cloud cover reduce radiation which likely helped to reduce PMS all four species. By September and Octobe PMS of hackberry, growing without the aid a shallow water table, was highly correlat with that of sycamore, mesquite, and junip either because of reduced radiation duri partially cloudy days or extra soil moistu from precipitation.

At night, during May, June, and July, PMS among the four species was either high negatively correlated or nonsignificant. t night, in August, September, and October, PMS among all species was highly correlated.

Radiation and vapor pressure deficit peaked at about 1400 hours, when PMS values were expected to vary greatly among species (table 1). Temperatures within the canopy of all species rose gradually from dawn until 1400 hours and declined thereafter. During the morning, temperature within the canopy of hackberry was not significantly greater than in sycamore, but sycamore, mesquite, and juniper crowns were warmer than hackberry during afternoon hours which may account for their greater rise in PMS. Apparently, the closed canopy formed by sycamore, mesquite, and juniper allows less incoming radiation to be reflected than at the open and exposed hackberry site. Similar observations in mesquite versus openings between stands were observed by Tromble and Simanton (1969).

Apparently, lack of soil water near hackberry caused PMS divergence from the other species sampled. The relationship between water availability in plants and root resistance, soil salts, low water conductivity in unsaturated soil, and stomatal and cuticular transpiration is very complex; PMS serves only as an index to these interrelated factors. Differences in PMS were greater among species in spring and summer before rains began (table 1). Also, from May through August, hackberry did not recover from high daytime stresses as quickly as the other three species. By September and October, 1800-hour values were nearly identical for the three species, but were still comparatively high for hackberry.

In 1972, bomb data from six additional mesquite trees near the study site varied widely. Some plants obviously tapped the ground water and others probably depended upon local precipitation. Because these plants were widely spaced from the ground-water well, soil moisture availability was not known. Although PMS values among the mesquites were obviously different, there were no visually apparent physiological differences. It appears that site location and availability of capillary water may have as much or more effect on PMS (and, consequently, on evapotranspiration rates) as actual species selection.

Table 1.--Summary of plant moisture stress, direct radiation, and vapor pressure deficit data on Sycamore Creek, central Arizona, 1971

Seasons and hours	Plant moisture stress				Vapor pressure deficit	Direct radiation
	Sycamore	Mesquite	Juniper	Hackberry		
	Bars				*inHg*	*ly/min*
SPRING (May-June)						
0600	7.7	9.6	10.4	23.9	0.30	0.0
1000	17.3	16.6	18.3	25.9	.78	.37
1400	16.4	19.9	22.6	28.4	.91	1.25
1800	11.6	13.3	12.5	31.0	.78	.53
SUMMER (July-Aug.)						
0600	4.5	11.0	19.0	22.6	.23	0.0
1000	13.0	24.6	20.0	40.4	.54	.26
1400	21.9	32.0	27.0	33.5	.85	1.12
1800	7.9	8.8	18.7	24.1	.48	.50
FALL (Sept.-Oct.)						
0600	3.1	5.9	6.6	5.7	.13	0.0
1000	23.3	25.0	18.6	27.2	.49	.45
1400	25.5	29.4	22.6	29.0	.72	.83
1800	7.2	9.2	11.6	23.5	.54	.30

Implications

From bomb data we can determine **which** plants are under **how much** stress. This stress occurs because of atmospheric conditions, water quality or availability, or inherent morphological and physiological characteristics of the particular species. But in general, water availability is the variable most likely to change from site to site. Because stresses change with seasons, single readings do not portray a clear picture. A seasonal series of bomb readings, however, indicates which plants are under drought stress. Thus the bomb technique can serve as a useful survey tool to determine relative availability of water to individual plants or species. With this information a map can be drawn on each stream sector depicting those areas of the flood plain where plants have additional soil moisture available. Such a map would indicate areas of highest potential water loss within the riparian zone.

Our measurements and analyses of the riparian microclimate did not reveal plant-soil-water conditions accurately enough to reliably predict plant moisture stress (PMS). PMS of plants utilizing shallow ground water usually responds similarly to changing radiation and vapor pressure deficit. PMS of hackberry, however, with an apparent soil moisture deficit, was seldom correlated with either radiation or vapor pressure deficit. Neither air, leaf, or crown temperatures, nor windspeed could be used to predict PMS reliably.

Literature Cited

Campbell, C. J., and Win Green.
1968. Perpetual succession of stream-channel vegetation in a semiarid region. J. Ariz. Acad. Sci. 5(2):86-98.

Campbell, C. J., and Charles P. Pase.
1972. Pressure bomb measures changes in moisture stress of birchleaf mountain-mahogany after partial crown removal. USDA For. Serv. Res. Note RM-221, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Scholander, P. F., H. T. Hammel, E. A. Hemmingsen, and E. D. Bradstreet.
1964. Hydrostatic pressure and osmotic potential in leaves of mangroves and some other plants. Natl. Acad. Sci. Proc. 52:119-125.

Scholander, P. F., H. T. Hammel, E. D. Bradstreet, and E. A. Hemmingsen.
1965. Sap pressure in vascular plants. Science 148:339-346.

Tromble, J. M., and J. R. Simanton.
1969. Net radiation in a riparian mesquite community. Water Resour. Res. 5:1139-1141.

Agriculture—CSU, Ft. Collins

ember 1973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 247

REST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Snowmelt Lysimeters Perform Well in Cold Temperatures in Central Colorado

Robert W. Schultz[1]

Comparison between lysimeter and snow-tube measurements of melt rates indicated that the lysimeters provided reliable measurements of snowmelt. The lysimeter frame did not noticeably affect the thermal regime of the snow within the lysimeter.

Oxford: 111.784:116.12. Keywords: Lysimeters (snowmelt), snow.

Reliable measurements of daily snowmelt can provide information for forecasting residual volume and streamflow, for development and testing of snowmelt models, and about the effects of various forest environments on the snowmelt process. A snowmelt lysimeter recently designed by Haupt (1969a, 1969b) is capable of measuring this parameter.[2] His lysimeters have been used extensively at Priest River Experimental Forest in northern Idaho where relatively mild winter temperatures prevail (Haupt 1972). Before they could be used in snowmelt studies in the central Rocky Mountains, we needed to know how these lysimeters would perform under severe cold temperature conditions — such as those found at Fraser Experimental Forest, Colorado.

Lysimeter Design

Haupt's lysimeter measures melt percolate as it emerges from the base of the pack. Melt water is allowed to drain through the pack, where it is funneled into a tank, and measured volumetrically with a water-level recorder.

The lysimeters used in this study are almost identical to Haupt's. A few minor modifications were made to reduce costs and to make the lysimeters more portable.

The lysimeters consist of a trough assembly (fig. 1), and a catchment tank with a water-level recorder (fig. 2). These two units are connected with a plastic drain hose buried at a sufficient depth to prevent freezing.

A trough is 58 by 43 by 25 centimeters (cm), with an outlet drain at its base. For insulation and filtering, a layer of litter is supported in the bottom of the trough by a wire mesh screen reinforced by steel bars. The barrier support frame is attached to the corners of the trough and supports a white, opaque polyethylene barrier which is pulled up the frame at intervals during the snow accumulation period. At the beginning of the melt season, the barrier support frame is removed, which leaves an isolated, undisturbed column of snow within the polyethylene barrier.

---

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

[2] *The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.*

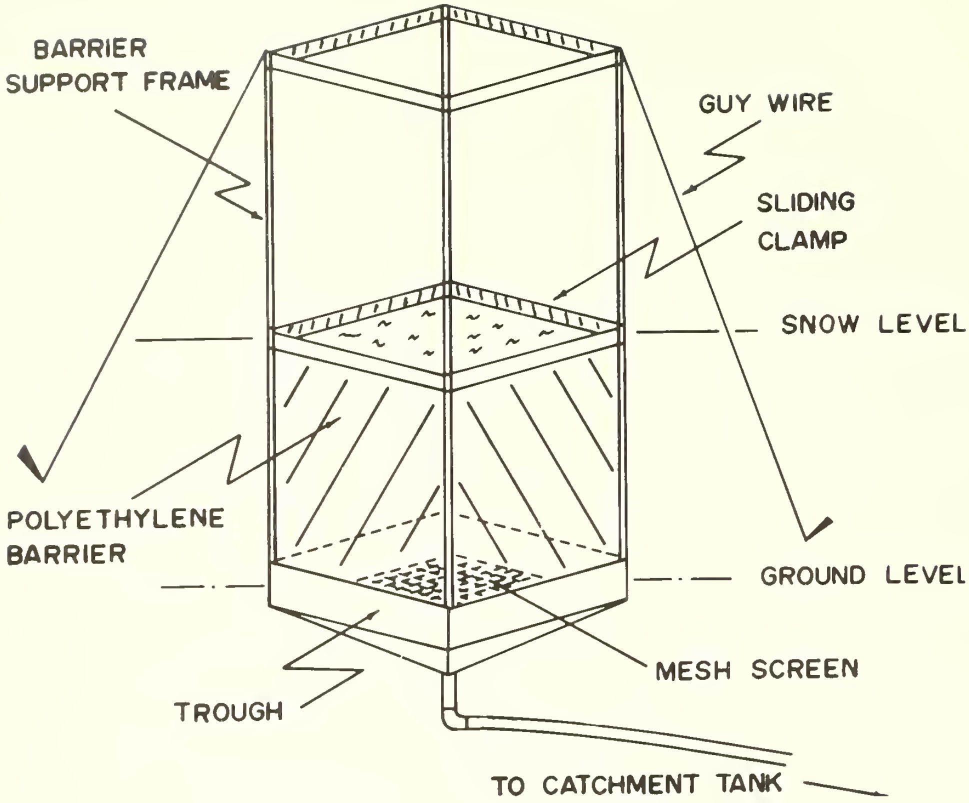


Figure 1.--Barrier support frame of snowmelt lysimeter.

Melt water drains by gravity into the catchment tank. The tank consists of a 55-gallon drum with a 25 by 25-cm entryway centered at the top. A water level recorder is supported over the entryway and covered with a small instrument shelter. Operation of these lysimeters is described in detail by Haupt (1969a, 1969b).

The cost of the materials for each lysimeter, less the water level recorder, was just under $100.

Description of Study Site

The study was conducted on West St. Louis Creek watershed, a small drainage basin on the Fraser Experimental Forest. The site was in the upper reaches of the watershed at an elevation of 3,140 meters (m) on a south-facing slope (22 percent average gradient) beneath a fairly uniform subalpine forest.

Climate

The climate at Fraser Experimental Forest is characterized by long, cold winters, and short, cool summers. The average yearly temperature for 12 years of record was 0.5° C. The mean monthly temperature was -10.0° C for January and 12.6° C for July (Haeffner 1971).

Precipitation at the Experimental Forest is mainly in the form of snow. Snow cover usually becomes permanent by late fall and remains until May or June. Throughout the winter, the pack remains well below freezing and does not begin to melt until late March or April. At an elevation of 3,200 m, Leaf (1969) found that the peak snow accumulation for an average year amounts to about 37 cm of water. During the melt season, an additional 13 cm of precipitation, generally in the form of snow, is added to the snowpack, increasing the average yearly melt to 50 cm.

Vegetation

An even-aged stand of lodgepole pine formed the upper stratum of the stand. Engelmann spruce and subalpine fir, shade-tolerant species, formed an uneven-aged, multi-leveled canopy beneath the lodgepole pine. The dominant trees on the study site averaged 14 m,

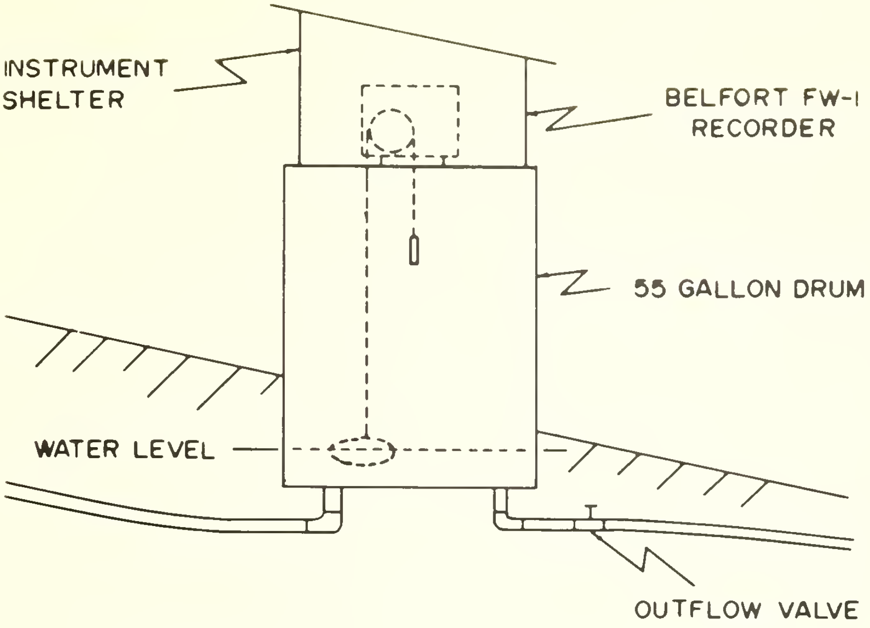


Figure 2.--Catchment tank of snowmelt lysimeter.

ranging from 11 to 21 m, and had moderately developed crowns. Crown closure, as measured by the vertical crown projection method, was approximately 53 percent. Basal area averaged 49 m^2 per hectare (ha) with a density of 850 stems/ha. Average diameter at breast height (d.b.h.) was 29 cm for the lodgepole pine and 14 cm for the Engelmann spruce and subalpine fir. Understory vegetation was composed almost entirely of a dense mat of grouse whortleberry.

Data Collection

Four snowmelt lysimeters were situated at the study site about 40 m apart and spaced along the same contour. Each was under forest canopy representative of the area. To avoid point locations which would be influenced by abnormal melting conditions, lysimeters were placed at least 2 m from the nearest tree bole or fallen tree. Lysimeters were not located in local depressions or small drainages where cold air drainage might influence melt rates.

Data collection began on March 24 and continued through June 23, 1971. Precipitation and snow water equivalents were measured at weekly intervals beginning March 31, while snow temperature profiles were recorded through April 8. Snowmelt was recorded continuously throughout this period by the lysimeters.

Lysimeter Melt

To obtain daily snowmelt rates for each lysimeter, the data were first analyzed to determine if melt water was delayed enroute through the pack. Outflow at 3-hour intervals was obtained from the water-level charts. Melt water had usually drained completely by 0600 hours (h) the following day (fig. 3). Melt water outflow from 0600 to 0600 gave the quantity of daily melt, and no corrections for delayed routing through the pack were necessary. Anderson (1968) and Leaf (1966) also found that, for a snowpack less than 1.5 m in depth, the free water in the pack drains almost completely by the following morning.

Cumulative daily melt values reveal that snow in lysimeter 2 melted more rapidly than

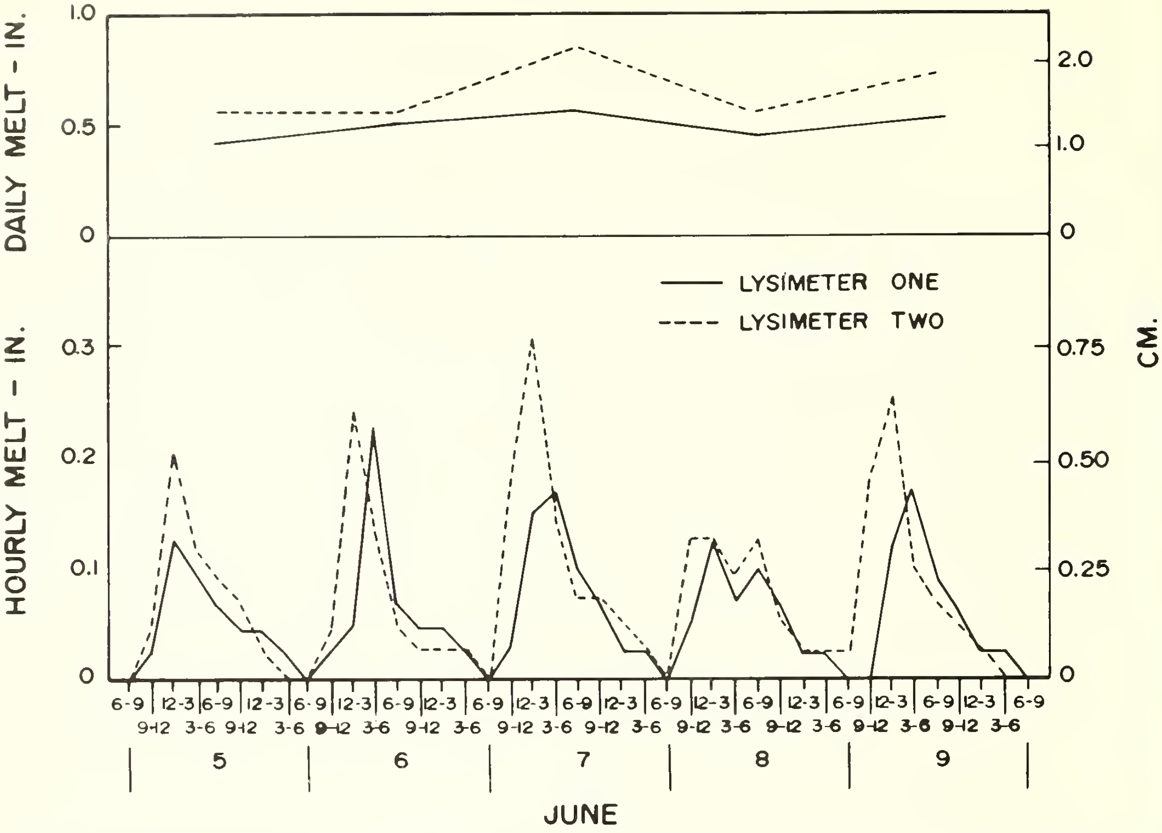


Figure 3.--Average hourly snowmelt by 3-hour intervals for lysimeters 1 and 2. Snow depth during this period averaged 100 centimeters. Snow density averaged 0.45 gm/cm^3.

in lysimeters 1, 3, and 4 (fig. 4), perhaps because the canopy to the south of lysimeter 2 was more open than that to the south of the other lysimeters.

Lysimeter Performance

There is a question about the effects of the polyethylene barrier on the thermal regime of the snowpack during accumulation and melt. Although the polyethylene barrier is an obstruction to horizontal water and heat transport, intercepts shortwave energy in the upper portion (25 cm) of the snowpack, and absorbs sensible heat and longwave radiation at the surface of the pack, the integrated result on the energy exchange within the isolated snow column is not known.

To learn more about this effect, snow temperature was measured to the nearest 0.1° C at the end of the accumulation season to assess the effect of the polyethylene barrier on the vertical temperature profile within each snow column. The temperature probe consisted of a thermistor unit mounted on a pole 1.5 cm in diameter (Swanson 1967). Vertical temperature profiles were obtained within each lysimete snow column and at three sample points outside. Measurements were taken on March 2 at lysimeters 1 and 3 and on March 30 at lysimeters 2 and 4. Because only one temperatur profile was taken within each snow column i order to minimize disturbance to the snow withi the plastic barrier, a statistical analysis wa not possible. Instead, a simple rational approach was taken.

Variation between the snow temperatur profiles inside and outside of a lysimeter sno column was greatest at lysimeter 1 (fig. 5) The mean of the three temperature profile adjacent to each snow column and the temperature profile within each snow column ar illustrated in figures 6 and 7. At any give depth, snow temperatures within and adjacen to the snow columns differed only slightly.

There also was little difference in the col content between the mean outside snowpac

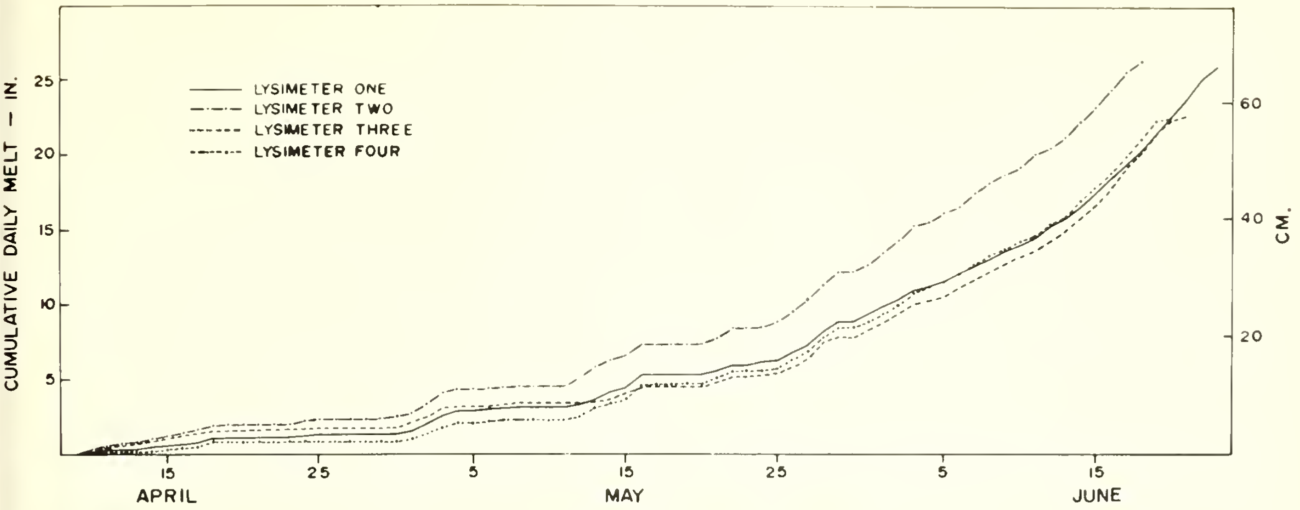


Figure 4.--Cumulative daily snowmelt at each lysimeter.

temperatures and the lysimeter temperatures. On March 24, the difference in cold content was 8 calories for lysimeter 1 and 5 calories for lysimeter 3, while on March 30, the difference was 8 calories for lysimeter 2 and 0 for lysimeter 4. The effect of the barrier on the time when the pack within the snow column became isothermal was negligible.

To test the ability of the lysimeters to measure melt rates at a point, five snow sample points were located within 3 m of each lysimeter. At these points, snow water equivalents were measured with a Federal snow sampler at weekly intervals throughout the melt season. Weekly precipitation was also recorded at each lysimeter. Average weekly snowmelt calculated from the precipitation data and water equivalent readings was then compared with the weekly melt from each lysimeter.

Average weekly differences and correlation coefficients were calculated to explain the weekly variation between the snow tube measurements and lysimeter readings at each lysimeter site:

Lysimeter	Average weekly difference (cm)	Correlation coefficient
1	+1.30	0.97
2	+ .90	.97
3	+1.60	.96
4	+1.30	.95

Weekly melt rates estimated from the snow-tube measurements were generally higher than those obtained from the lysimeters.

The main reasons for the difference are probably related to (1) the accuracy of the Federal snow sampler, which measures to the nearest 3 cm (Weiss and Wilson 1958), and (2) difficulties in obtaining an accurate series of readings with the snow sampler when air temperature is below 0° C and snow contains free water which freezes to the inside of the snow tube. This freezing occurred on April 27 and May 18, and may have affected melt rates computed from data taken on those dates. The lysimeter measurements are evidently the more accurate of the two.

A second check on lysimeter melt rate was based on the assumption that, on an area with a relatively uniform forest cover at the same aspect, slope, and elevation, quantities of daily melt from any two given points should be proportional from day to day.

Daily melt ratios were computed for each lysimeter. These ratios equaled daily melt over the total melt. For this comparison, total melt was the cumulated daily lysimeter melt to the time when the first lysimeter became bare.

The cumulative ratios with time were very similar between lysimeters (fig. 8). An analysis of variance was made on the daily lysimeter ratios in order to obtain a measure of the variation of the lysimeter ratios within each day. The computed mean variance of melt rates in percent within each day was small, equaling 0.11 percent, which indicated the lysimeters were furnishing good measures of daily snowmelt.

Haupt (1969a, 1969b) reports that the polyethylene barrier generally causes abnormal surface melt at the borders of the snow column.

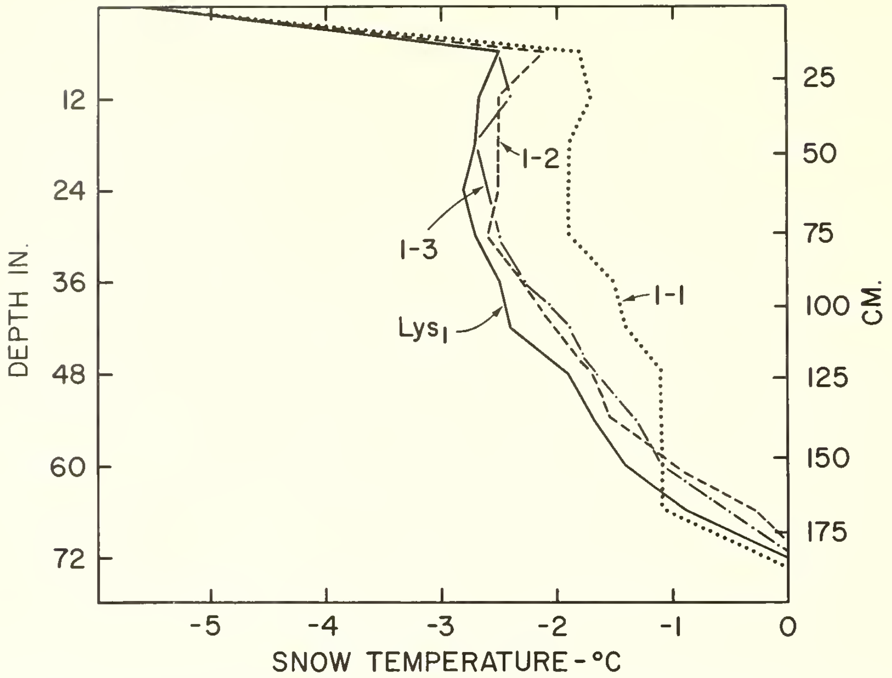


Figure 5.--Snow temperature profiles with depth at lysimeter 1 on March 24, 1971. Profile Lys_1 represents temperature profile measured within polyethylene barrier. Profiles 1-1, 1-2, and 1-3 represent temperature profiles measured adjacent to polyethylene barrier.

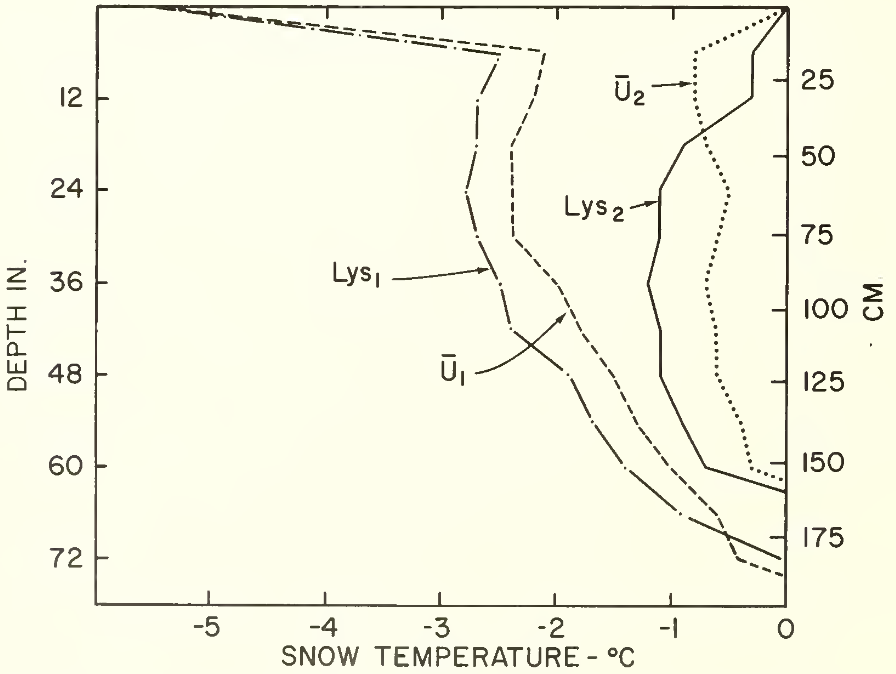


Figure 6.--Snow temperature profiles with depth. Temperature profiles for lysimeters 1 and 2 were measured on March 24, 1971, and March 30, 1971, respectively. Profiles Lys_1 and Lys_2 represent temperature profiles measured within each polyethylene barrier. Profiles $\overline{U}_1$ and $\overline{U}_2$ represent the average temperature profile of the three sample points adjacent to each polyethylene barrier.

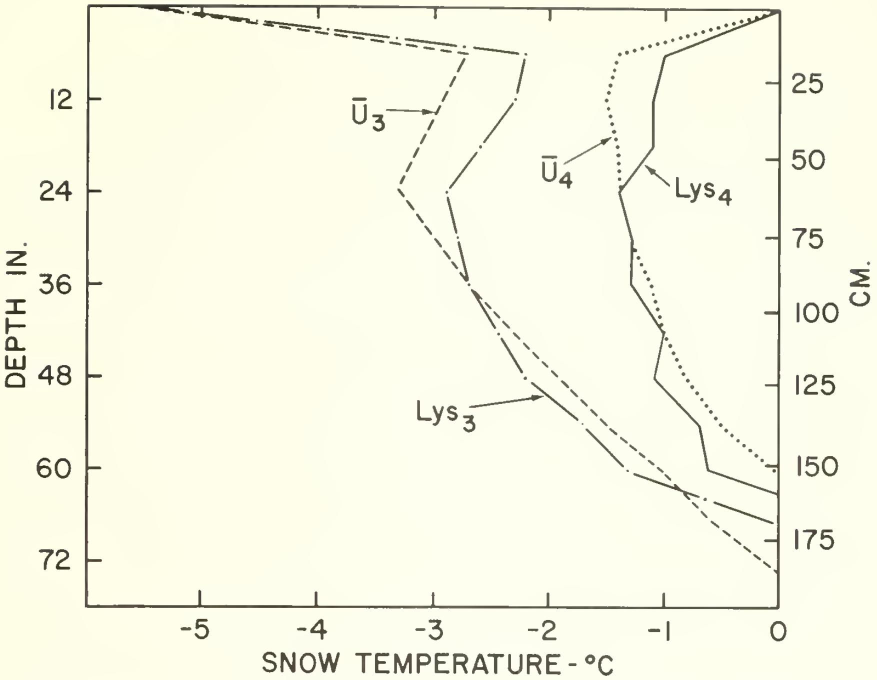


Figure 7.--Snow temperature profiles with depth. Temperature profiles for lysimeters 3 and 4 were measured on March 24, and March 30, 1971, respectively. Profiles Lys_3 and Lys_4 represent temperature profiles measured within each polyethylene barrier. Profiles $\bar{U}_3$ and $\bar{U}_4$ represent the average temperature profile of the three sample points adjacent to each polyethylene barrier.

The effect is greatest in the openings and decreases with increasing forest cover. Some abnormal surface melt did occur at the borders of the four snow columns, but the effect was small.

A source of error in the melt measurements was the change in surface area of the snow columns, which were assumed to equal 0.250 m^2 throughout the melt season. However, on June 9, the surface area of snow columns 1 through 4 was 0.226, 0.250, 0.239, and 0.226 m^2, respectively. The decrease in surface area, which ranged from 0 to 10 percent, probably originated during the accumulation period when a snow shovel was used to cut down along the barrier support frame to the polyethylene barrier so that the barrier could be raised. Although temperatures were low throughout the melt season, the melt percolate did not freeze within the drainpipe. The snow was of sufficient depth to prevent excessive heat loss from the ground and the catchment tank during this period.

Summary and Conclusions

The lysimeters are well suited to the severe temperature conditions at Fraser Experimental Forest. Throughout much of the Forest, melt and rain-on-snow events rarely occur before April. During that accumulation period, melt measurements need not be made, and the lysimeters must be visited only to raise the polyethylene barrier after each 30 to 40 cm of snow accumulation.

Obtaining accurate estimates of daily melt is simplified because melt rarely occurs during the night. Since melt during the day usually drains from the pack by 0600 the following morning, it is not necessary to correct for melt water retained within the pack to obtain a measure of daily melt.

At other locations in the central Rocky Mountains, particularly those with shallow or intermittent snowpacks, some modifications in design may be required to make the lysimeters operational.

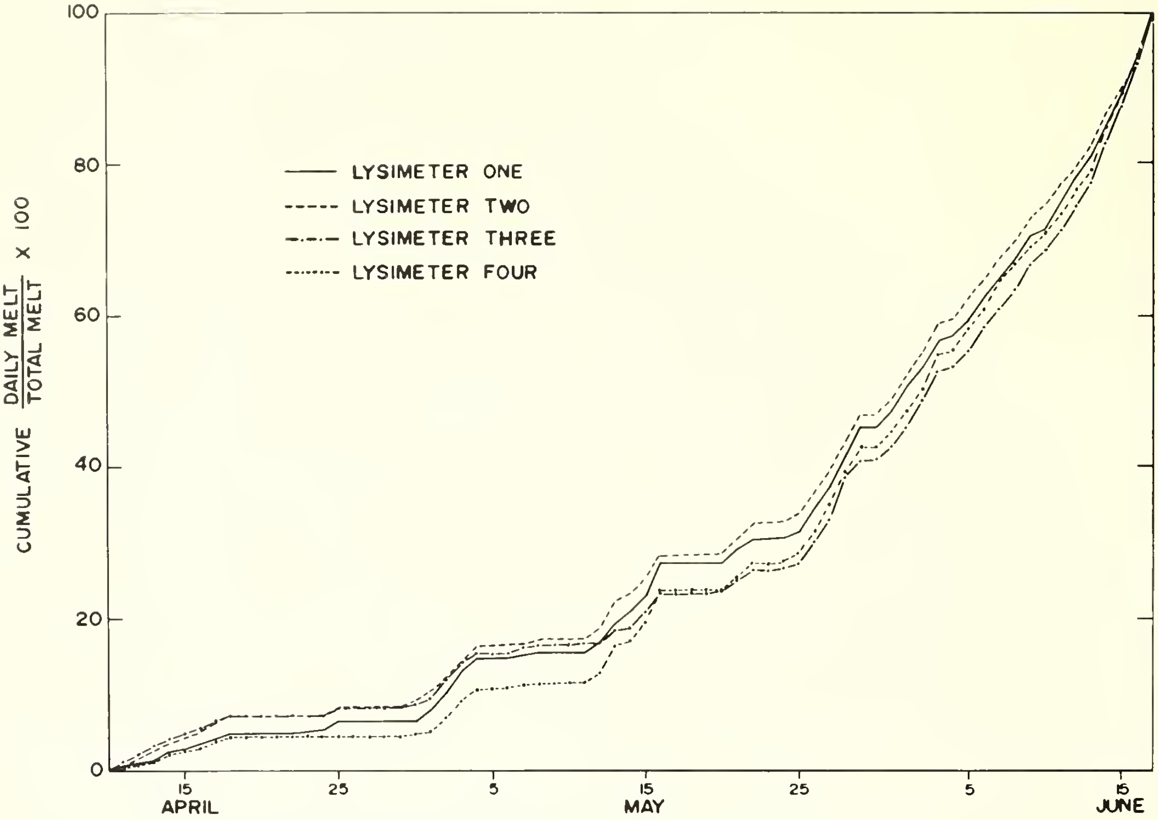


Figure 8.--Cumulative daily lysimeter ratios with time.

Literature Cited

Anderson, E. A.
1968. Development and testing of snowpack energy balance equations. Water Resour. Res. 4:19-37.

Haeffner, Arden D.
1971. Daily temperatures and precipitation for subalpine forest, central Colorado. USDA For. Serv. Res. Pap. RM-80, 48 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Haupt, H. F.
1969a. A simple snowmelt lysimeter. Water Resour. Res. 5:714-718.

Haupt, H. F.
1969b. A 2-year evaluation of the snowmelt lysimeter. West. Snow Conf. [Salt Lake City, Utah] Proc. 37:97-101.

Haupt, H. F.
1972. The release of water from forest snowpacks during winter. USDA For. Serv. Res. Pap. INT-114, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Leaf, C. F.
1966. Free water content of snowpack in subalpine areas. West. Snow Conf. [Seattle, Wash.] Proc. 34:17-24.

Leaf, C. F.
1969. Snowpack depletion and runoff in Colorado. Ph.D. Thesis, 154 p. Colo. State Univ., Fort Collins, Colo.

Swanson, R. H.
1967. A low-cost instrument to measure temperature or resistance accurately. U.S. For. Serv. Res. Note RM-80, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Weiss, L. L., and W. T. Wilson.
1958. Snow-melt degree-day ratios determined from Snow-Lab data. Am. Geophys. Union Trans. 39:681-688.

Agriculture—CSU, Ft. Collins

ptember 1973

U S D A FOREST SERVICE
RESEARCH NOTE RM-248

EST SERVICE
DEPARTMENT OF AGRICULTURE

Y MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Seventeen-Year Sediment Production from a Semiarid Watershed in the Southwest[1]

Earl F. Aldon and George Garcia[2]

Average annual rate of sediment production declined 71 percent in the period 1967-71 compared with the period 1956-66 on a 471-acre watershed on the Rio Puerco drainage in New Mexico. This decline was a result of an increase in plant size and litter production on the alluvial flood plain.

Oxford: 116.6:385.3. Keywords: Erosion control, sediment.

In spite of the recent concern with other environmental contaminants of water, sediment remains the number one contributor to water pollution (Robinson 1971, Grant 1971). Significant amounts of sediment are present in most waterways most of the time. The damaging effects on downstream values are well known. Of current interest is the attachment of heavy metals and pesticides from industrial, agricultural, and urban sources to sediment particles. We need to understand sediment deposition rates if we are to know the ultimate resting place for these pollutants. Information on the deposition rates and amounts of sediment is scarce for many areas in the Southwest. In addition, information is lacking on what management practices may favorably alter these rates.

The objective of this study was to determine the long-term effects of management practices on plant changes and sediment yields from a semiarid watershed in the Rio Puerco drainage of New Mexico.

Study Site and Methods

The San Luis watersheds on the Rio Puerco drainage are located 58 miles northwest of Albuquerque, New Mexico, in the transition zone between woodland and semidesert grassland. The area is comprised of mesas or uplands, steep rocky breaks, and alluvial grasslands.

The study watershed, watershed II, encompasses 471 acres (0.74 square mile). The headwaters originate on the mesas that break off into steep, rocky slopes. These slopes give way to rolling foothills that merge with the alluvial bottoms. A layer of Mesa Verde sandstone overlies Mancos shale. The sandstone breaks and underlying shales form the parent soil material, the texture of which varies from sandy loams to silty clays. A study of the soil characteristics reveals no serious soil problems in terms of salinity or fertility (Campbell 1968).

In 1952, a reservoir with a capacity of about 13 acre-feet was constructed on the alluvium to

---

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

[2] *Principal Hydrologist and Forestry Research Technician, respectively, Rocky Mountain Forest and Range Experiment Station, located at Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

measure runoff and sediment. Flow is ephemeral and the reservoir dries out seasonally. In 1956 the reservoir was cleaned and a survey consisting of five cross sections was made. These cross sections were resurveyed in 1967 and 1972. The changes in volume were used as a measure of sediment. No adjustment was made for sediment that might have passed through an outlet pipe or through the spillway (at time of overflow). These amounts are considered to be only a small percentage of the total (Aldon 1964).

Pits were randomly located in the reservoir during the resurveys, and volume weight samples were taken at 0.5-foot intervals throughout the 4.5-foot depth of the pits. Brass cylinders (137.4 cc volume) were used to obtain core samples for volume weight determinations.

Volume and volume-weight measurements were converted to sediment rates in tons per acre and tons per square mile per year.

Precipitation, runoff, ground cover, and forage production measurements have been described previously (Aldon 1964, Hickey and Garcia 1964). Ground cover was measured by the 3/4-inch loop-frequency method on 25 clusters of three 100-foot transects randomly distributed over the watershed.

Management on the area throughout the study consisted of summer-deferred grazing with 55 percent utilization of alkali sacaton (Sporobolus airoides (Torr.) Torr.) (Aldon 1966). Forage production was measured each fall by the weight-estimate and double-sampling technique, and stocking rates were adjusted to achieve the utilization standard desired (Aldon and Garcia 1971).

In 1963 all areas having slopes less than 5 percent were ripped to retard surface runoff. This treatment effectively reduced runoff, but the change was short lived (Aldon 1966). Ripping caused a favorable shift in forage production from galleta (Hilaria jamesii (Torr.) Benth.) to alkali sacaton — a pattern that has persisted for 10 years (Aldon and Garcia 1972).

Results

The average annual rate of sediment production declined 71 percent in the period 1967-71 compared with the period 1956-66, even though averages of runoff and precipitation from 1967 to 1972 were about the same or slightly higher than in the period of higher sediment production (table 1).

Table 1.--Precipitation, runoff, perennial grass production, loop frequency hits, and sediment production from San Luis watershed II, 1956-72

Year	Precipitation		Surface runoff	Grass production (air-dry)	Loop frequency hits				Sediment		
	Annual (Nov. 1-Oct. 31)	Growing season (May 1-Nov. 1)			Perennial grass	Rock	Litter	Bare soil	Cumulative volume in reservoir	Average annual rate	
	Inches		*Acre-ft*	*Lbs/acre*	- - - *Number* - - - -				*Ft*^{3}	*Tons/m*^{2}*/yr*	*Tons/acre/yr*
1956	6.21	2.20	10.04	73.3					0	0	0
1957	12.05	8.16	88.62	103.0							
1958	12.72	6.44	17.20	237.8	3.08	6.02	5.33	77.93			
1959	10.72	6.84	24.28	195.4							
1960	11.48	5.42	14.19	167.4							
1961	10.60	9.59	44.83	250.0	8.43	8.50	14.65	63.72			
1962	6.25	2.32	2.92	332.0							
1963	9.42	3.94	0.00	282.9							
1964	9.00	6.57	18.28	497.7	10.03	10.49	7.01	71.01			
1965	12.81	9.02	0.00	429.4							
1966	8.62	6.05	4.67	525.0							
1967	10.33	9.08	38.13	522.3					112,184	493	.77
1968	10.11	5.60	.13	561.8							
1969	14.84	11.57	39.44	721.0	9.51	13.63	16.72	58.74			
1970	8.50	5.92	3.94	653.0							
1971	10.03	7.14	27.25	509.0	9.69	13.47	17.22	58.93			
1972									17,758	141	.22
Average											
1956-66	9.99	6.05	20.46								
1967-71	10.76	7.86	21.78								

Sediment declined as a result of increased plant size and litter production on the alluvial flood plain above the reservoir (fig. 1). As sediment-laden flash floodwaters hit the alluvial fan, they were slowed down by plants and litter long enough to allow sediment to settle out above the reservoir.

The increase in plants is reflected in two ways. Perennial grass production has steadily increased from 73 pounds per acre in 1956 to a high of 721 pounds in 1969. Annual grass production varies with precipitation, but the steady yearly increase is obvious. These production figures suggest that individual perennial plants are increasing in size. Secondly, ground-cover data show a decrease in bare-soil hits from 78 to 58 and an increase in litter from 5 to 17. Perennial grass hits went from a low of 3 to a high of 10 hits. Francis et al. (1972) note that loop frequency estimates presence or absence of plants and shows a bias in favor of plants and underrates soil surface factors (litter and bare soil). The doubling of hits on grass and litter and the reduction on bare soil between 1956 and 1972 may indicate increases in the number of plants. The sediment reduction can be attributed to reduction in floodwater velocities by increases in plant size, and possibly an increase in plant numbers, and the resultant increase in litter production.

Figure 1.--
The alluvial floodplain:

In 1956, plants were scarce and sediment was abundant;

In 1969, conditions were reversed.

Literature Cited

Aldon, Earl F.
1964. Ground-cover changes in relation to runoff and erosion in west-central New Mexico. U.S. For. Serv. Res. Note RM-34, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Aldon, Earl F.
1966. Deferred grazing and soil ripping improves forage on New Mexico's Rio Puerco drainage. N.M. Stockman 31(11):44-46.

Aldon, Earl F., and George Garcia.
1971. Stocking rangelands on the Rio Puerco in New Mexico. J. Range Manage. 24:344-345.

Aldon, Earl F., and George Garcia.
1972. Vegetation changes as a result of soil ripping on the Rio Puerco in New Mexico. J. Range Manage. 25:381-383.

Campbell, R. E.
1968. Production capabilities of some upper Rio Puerco soils of New Mexico. U.S. For. Serv. Res. Note RM-108, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Francis, Richard E., Richard S. Driscoll, and Jack N. Reppert.
1972. Loop-frequency as related to plant cover, herbage production, and plant density. USDA For. Serv. Res. Pap. RM-94, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Grant, K. E.
1971. Sediment: Everybody's pollution problem. p. 23-28. **In** 33d Nat. Farm Ins. Chamber of Commerce Proc., Des Moines, Iowa.

Hickey, Wayne C., Jr., and George Garcia.
1964. Changes in perennial grass cover following conversions from yearlong to summer-deferred grazing in west-central New Mexico. U.S. For. Serv. Res. Note RM-33, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Robinson, A. R.
1971. A primer on agricultural pollution: Sediment. J. Soil Water Conserv. 26:61-62.

Agriculture—CSU, Ft. Collins

vember 1973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 249

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Literature Review of Timber-Harvesting Effects on Stream Temperatures:

Research Needs for the Southwest

David R. Patton[1]

Water temperature affects fish by changing their metabolic rate, changing oxygen content of water, influencing hatching and development time, and influencing migration. Creating a more open forest in the water-producing zone can change water temperature in shallow, low-volume streams. Research is needed on how timber harvesting affects water temperature to produce guidelines to meet Federal Water Pollution Control standards for cold-water fish.

Oxford: 157:116.1. Keywords: Water temperature, timber harvesting, fish habitat.

Projected increases in timber demands from outhwestern forests mean timber management nust become more intensive. Precise estimates f amount of timber to be cut are probably not o important — in terms of influences on stream emperatures and fish populations — as how and here the timber is cut. The current trend is oward open stands which would allow more adiation to reach the forest floor.

Because of the location of timbered lands ith respect to high precipitation and runoff, ny change in structure of the forest will affect ater quantity. Perhaps more important, howver, is that it will affect water quality, espeially temperature.

Over 2,000 miles of perennial streams could e affected by logging on National Forests in e Southwest:

Miles of Perennial Streams

Arizona		New Mexico	
Apache	242	Carson	425
Coconino	191	Cibola	33
Coronado	39	Gila	366
Kaibab	11	Lincoln	23
Prescott	59	Santa Fe	578
Sitgreaves	40		
Tonto	311		
	893		1425

Of this total, about 80 percent is a cold-water fishery resource in the spruce-fir and ponderosa pine zones. The importance of temperature to this limited cold-water fishery in a hot, dry climate needs to be considered in more detail.

Importance of Water Temperature to Fish

Water temperature is probably the most important factor affecting the physiology of fish. The range of temperature under which different fish live is very great, but for most species the

---

[1] *Wildlife Biologist, Rocky Mountain Forest and Range xperiment Station, located at Tempe, in cooperation ith Arizona State University; Station's central headuarters maintained at Fort Collins, in cooperation with olorado State University.*

comfort range is limited to a change of 12° to 15° F (Norman 1951). Since fish are poikilothermic they cannot regulate body temperature. In general, vital processes are accelerated by warm temperatures and decelerated by cold temperatures. Rapid cooling and warming can by lethal, especially to delicate cold-water species such as trout (Lagler et al. 1962). Acclimation to temperature can also be important. Chinook *(Oncorhynchus tschawytscha)* and coho salmon *(Oncorhynchus kisutch)* fry raised in 69° F water die when temperatures reach 75° F (Brett 1956). The optimum range for sockeye salmon *(Oncorhynchus nerka)* fry has been found to be 53° to 62° F (Donaldson and Foster 1940). Ideal water temperature for cold-water fish is between 50° and 65° F; generally they cannot tolerate temperatures over 75° F (Trippensee 1953). Warm-water fish are less specialized and can live in a wider temperature range.

Temperature affects fish by changing their metabolic rate, changing oxygen content of water, influencing hatching and development, and affecting migration. Metabolic rate rises with body temperature, which in turn determines nutritional requirements (Lagler et al. 1962). Brown (1957) found that brown trout *(Salmo trutta)* grew best between 45° and 48° F. Appetite was high at 50° F, as were maintenance requirements. Below 45° F the maintenance requirements were low but so was appetite. For most species the development time from fertilization to hatching decreases as temperature increases; in brook trout *(Salvelinus fontinalis)* it takes 165 days at 37° F but decreases to 32 days at 54° F (Hayes 1949). Pritchard (1944) found that high temperatures shorten and low temperatures lengthen the incubation period of pink salmon *(Oncorhynchus gorbuscha)* eggs.

Water temperature during the summer months has been cited as the most important limiting factor on the survival of trout (Needham 1938). Limiting temperatures for brook trout, brown trout, and rainbow trout *(Salmo gairdneri)* are 75°, 81°, and 83° F. This will vary with other factors, such as pH, oxygen, and carbon dioxide.

Temperature has also been found to influence fish distribution. Sockeye salmon come to the surface of a lake when temperature rises from 39° to 41° F (Foerster 1936). White (1939) reported that a salmon smolt descent from a brook in Nova Scotia was related to a rise in temperature. Vertical distribution of fish in lakes has been shown to be related to temperatures. Cisco *(Coregonus artedi)* migrate to deepwater in spring and spend the summer in the cool thermocline (Fry 1937). Trout in two lakes in Nova Scotia were found at a particular temperature rather than a specific depth (Hayes 1946).

The ability of water to hold oxygen increases as the temperature decreases. At 32° F water can hold 14.6 parts per million (p/m) of oxygen but at 75° F can hold only 8.5 p/m at saturation (Welch 1948). Cold-water fish need a minimum of 4 to 5 p/m to survive over long periods.

Another consideration is the effect of temperature upon bacteria, algae, phytoplankton and zooplankton. Organisms such as these usually follow van't Hoff's rule of increasing activity and production as temperature increase (Sawyer 1960). An increase in organisms wil cause an increase in oxygen consumption, which lowers the amount available to fish. This is als true where organic material is decomposing.

Effects of Logging on Stream Temperature

Research on the effects of logging on wate temperature generally has been limited to th Pacific Northwest and eastern United States. A literature review failed to find any results from research in the Southwest. To understand th importance of the results reported, it i necessary to review briefly the heat exchang process.

Change in water temperature depends o how much heat is received and the volume o water being heated. The energy producing th heat comes from solar radiation. Heat may b lost or gained by evaporation, condensation conduction, or convection. These processes in fluence stream temperature only to a ver limited extent as compared to direct radiation Brown (1967) found solar radiation alon forested streams was 0.3 to 0.4 langley pe minute, but open stretches received 1.1 to 1 langleys per minute. Small streams with lo summer flows and a large surface area in rel tion to volume react more quickly t microclimate changes than do large rivers. It i then, the amount of sunlight that reaches th forest floor to warm the soil or directly he the runoff from tributaries and main channe that changes the water temperature.

Studies in Oregon by Brown and Krygi (1967) show that clearcutting increased the dai stream temperature by 14° F in August, whi an uncut watershed showed no stream temperature change in average monthly maximum. Th streams studied were small, about 4 to 8 fe wide and 6 to 8 inches deep in summe Summer water flows were less than 1 cubic fe per second. Such streams in Oregon are us for spawning and rearing by salmon.

Clearcutting on the Fernow Forest in West Virginia increased maximum stream temperatures in summer and decreased the winter minimum (Eschner and Larmoyeux 1963). The average maximum stream temperature increase on the clearcut area was 8° F, but temperatures over 75° F were observed several times. Eschner and Larmoyeux concluded that these temperatures over 75° F would probably eliminate brook trout in the stream.

In North Carolina, six forest cuttings were evaluated for effects on stream temperature (Swift and Messer 1971). All six showed an increase in summer maximums after cutting, with an increase of 1° to 12° F depending on type of cut. On one watershed, 8 years after the cut, stream temperature was 2° F less in the summer than the control. This decrease was attributed to dense shading effect from 8-year-old regrowth.

From research in the Douglas-fir region it appears that logging near the stream channel has the most effect in raising water temperature (Levno and Rothacher 1967). In Connecticut a survey revealed an increase of 10° F along a half-mile section where all brush was removed (Titcomb 1926).

Meeham et al. (1969) in Alaska studied the effects of clearcutting on salmon habitat. They noted a significant increase in average monthly stream temperatures. The maximum increase was 9° F during July and August. Green (1950) reported temperatures of a nonforested stream in the Southeast to be 13° F higher than an adjacent forested stream.

Stream temperatures increased significantly in two experimental watersheds in Oregon when floods removed the riparian vegetation in a partially cut watershed (Levno and Rothacher 1967). Mean monthly temperatures increased 7° to 12° F from April to August. Monthly maximum averages increased by 4° F in the second watershed after a clearcut.

The amount of stream temperature increase after any vegetation removal will depend on the amount removed and how it is distributed. Brown (1967), in studying energy budgets, found a decrease of 8° F when a stream passed through 700 feet of undisturbed canopy. Cormack (1949) and Green (1950) have shown the same relation in their work, principally that shaded streams are cooler.

These studies all indicate that removal of vegetation from a watershed will increase stream temperature. The increase can be either detrimental or beneficial, depending on which margin the stream is operating. For a stream that is cooler than optimum, a slight increase in temperature could increase productivity. In such cases logging would be beneficial. Streams with temperatures on the high side in July and August could become "trout-less" with an increase of only a few degrees.

In the Southwest where January surface temperatures are from 50° to 68° F and July surface temperatures are from 68° to 86° F, logging along streambanks and heavy cutting within a watershed could be detrimental to trout in shallow, low-volume streams. Although there is no evidence from either Arizona or New Mexico, research from the Northwest and East adequately demonstrated the relationship. However, results are all from areas with a much cooler climate than the Southwest. If clearcutting in a cool region such as Oregon raises the daily water temperature by 14° F, what would the effect be in a warmer climate?

The only way to protect trout environment in timber harvest areas is to maintain a vegetative cover along the streambanks. The amount to leave is not a precise figure and will depend on topographic shading, height of streamside vegetation, and width and volume of the stream. Cormack (1949) recommended cover strips of 60 to 100 feet along both banks to keep temperature down and to preserve esthetic values.

The effect of clearcutting on stream temperature can be predicted by using a technique developed by Brown (1970). In areas where clearcutting is being considered, knowing the approximate temperature changes resulting from the cut will provide the evidence needed to maintain a residual strip adjacent to the stream.

Research Needs

Research on the effects of logging on stream temperature should be a high priority in Arizona and New Mexico. Data are needed so that streams in harvested forests will meet standards set by the Federal Water Pollution Control Administration for optimum temperatures for cold-water fish (USDI 1970). These standards are:

Resident trout waters: winter, 42° to 58° F;
summer, 42° to 68° F.
Spawning areas: resident and anadromous,
45° to 55° F.
Rearing areas: resident and anadromous,
50° to 60° F.

Research should include the following:

1. Identification of perennial streams with temperatures that are marginal on the high side in prospective areas of timber harvest.
2. Studies on the effect of timber harvesting on water temperature in the ponderosa

pine, mixed conifer, and spruce-fir zones to include different intensities of cut as well as different cutting patterns.

3. Determination of temperature ranges of rare and endangered fish that exist in the Southwest.

4. Studies to determine the importance of riparian vegetation in maintenance of the aquatic habitat.

Literature Cited

Brett, J. R.
1956. Some principles in the thermal requirements of fishes. Q. Rev. Biol. 31:75-81.

Brown, G. W., III.
1967. Temperature prediction using energy budget techniques on small mountain streams. Ph.D. Thesis. 120 p. Oreg. State Univ., Corvallis.

Brown, G. W., III.
1970. Predicting the effect of clearcutting on stream temperature. J. Soil Water Conserv. 25:11-13.

Brown, G. W., III, and J. T. Krygier.
1967. Changing water temperatures in small mountain streams. J. Soil Water Conserv. 22:242-244.

Brown, Margaret Elizabeth.
1957. Experimental studies on growth. p. 361-400. **In** The physiology of fishes. Vol. I. Acad. Press, N. Y.

Cormack, R. G. H.
1949. A study of trout streamside cover in logged over and undisturbed virgin spruce woods. Can. J. Res. 27:78-95.

Donaldson, L. R., and F. J. Foster.
1940. Experimental study of the effect of various water temperatures on the growth, food utilization, and mortality rates of fingerling sockeye salmon. Am. Fish. Soc. Trans. 70:339-346.

Eschner, A. R., and Jack Larmoyeux.
1963. Logging and trout: Four experimental forest practices and their effect on water quality. Prog. Fish Cult. 25:59-67.

Foerster, R. E.
1936. The relation of temperature to the seaward migration of young sockeye salmon *(Oncorhyncus nerka)*. J. Biol. Board, Can. 3:421-438.

Fry, F. E., Jr.
1937. The summer migration of the cisco *(Leucichthys artedi)* in Lake Nipissing, Ontario. Univ. Toronto Studies, Biol. Ser. 44:1-91.

Green, Geoffrey, E.
1950. Land use and trout streams. J. Soil Water Conserv. 5:125-126.

Hayes, F. R.
1946. Inland fisheries investigations. Nova Scotia Dep. Ind. Rep. 1946:34-44.

Hayes, F. R.
1949. The growth, general chemistry, and temperature relations of salmanoid eggs. Q. Rev. Biol. 24:281-308.

Lagler, Karl F., John E. Bardoch, and Robert R. Miller.
1962. Ichthyology. 545 p. Univ. Mich., Ann Arbor.

Levno, A., and J. Rothacher.
1967. Increases in maximum stream temperature after logging old growth Douglas-fir watersheds. U.S. For. Serv. Res. Note PNW-65, 12 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Meeham, W. R., W. A. Farr, D. M. Bishop, and J. H. Patric.
1969. Some effects of clearcutting on salmon habitat of two southeast Alaska streams. USDA For. Serv. Res. Pap. PNW-82, 45 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Needham, Paul R.
1938. Trout streams: Conditions that determine their productivity and suggestions for stream and lake management. 233 p. Comstock Publ. Co., N. Y.

Norman, J. R.
1951. A history of fishes. 464 p. Ernest Benn Ltd., London.

Pritchard, A. L.
1944. Physical characteristics and behavior of pink salmon at McClinton Creek. J. Fish Res. Board, Can. 6:217-227.

Sawyer, Clair N.
1960. Chemistry for sanitary engineers. 367 p. McGraw Hill Book Co., N. Y.

Swift, Lloyd W., Jr., and James B. Messer.
1971. Forest cuttings raise temperatures of small streams in the southern Appalachians. J. Soil Water Conserv. 26:111-116.

Titcomb, J. W.
1926. Forests in relation to fresh water fishes. Am. Fish. Soc. Trans. 56:122-129.

Trippensee, Reuben E.
1953. Wildlife management. Vol. II, 572 p. McGraw Hill Book Co., N. Y.

U. S. Department of the Interior.
1970. Industrial waste guide on logging practices. 44 p. Fed. Water Pollut. Control Adm. Northwest Reg., Portland.

Welch, Paul S.
1948. Limnological methods. 381 p. McGraw Hill Book Co., N. Y.

White, H. C.
1939. Factors influencing descent of Atlantic salmon smolts. J. Fish Res. Board, Can. 4:323-326.

Agriculture—CSU, Ft. Collins

ovember 1973

U S D A FOREST SERVICE
RESEARCH NOTE RM-250

REST SERVICE
. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Emergence Cage for Soil-Pupating *Rhyacionia* spp.

Daniel T. Jennings[1]

Describes materials, construction, and installation of an inexpensive cage successfully used to determine adult emergence periods for the southwestern pine tip moth, *Rhyacionia neomexicana* (Dyar). The cage can be used to trap other soil-pupating *Rhyacionia* spp.

Oxford: 114.68 — 145.7. Keywords: Insect emergence, *Rhyacionia* spp.

The southwestern pine tip moth overwinters s pupae in cocoons attached to root collars of onderosa pines. Cocoons are constructed about inch below the surface of the soil, and often orm a ring around the base of the tree (fig. 1). 'or life history studies and timing of control easures directed at the adult or later larval tages, we need to know when the adult moths merge from overwintering pupae. This Note escribes an inexpensive cage for determining dult emergence of the southwestern pine tip oth and other soil-pupating *Rhyacionia* spp.

Description

The cage (fig. 2) consists of an anchoring ase band pressed into the soil and an upper ortion fashioned from fiberglass screen. A strip f 24-gage galvanized sheet metal, 4-1/2 by 23 ches, is crimped along one edge at least four mes to form a 7/16-inch reinforcing bead 'ig. 3). The strip is then rolled to form a band hich, when closed, has a circumference of 22 inches. The ends of the strip are overlapped about 1 inch to form a seam that is secured with two 3/8-inch No. 7 binding head screws.

A 24- by 12-inch piece of 18- by 16-mesh fiberglass screen forms the upper portion of the cage (fig. 4). The ends of the screen are first stapled together with three holding staples. A 1/4-inch fold is then stapled along the entire width of the screen to form a finished seam. A standard stapler and 1/4- by 1/2-inch staples are suitable for closing the seam. The screen is secured to the base band and to the tree bole with pieces of 20-gage iron wire (fig. 5).

Materials List

1 Base band, 4-1/2 by 23-inch, 24-gage galvanized sheet metal.
2 Screws, No. 7 binding head.
1 Fiberglass screen, 12- by 24-inch, 18- by 16-mesh.
25 Staples, standard, 1/4- by 1/2-inch.
1 Roll 20-gage iron wire; 30-40 inches used per cage.

Cost of materials and construction is low. The most expensive item, the base band, can be fabricated and supplied complete with screws for about $1 at most tin and sheet metal shops.

---

[1] *Research Entomologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins in cooperation with Colorado State University; author is located at Albuquerque in cooperation with the University of New Mexico.*

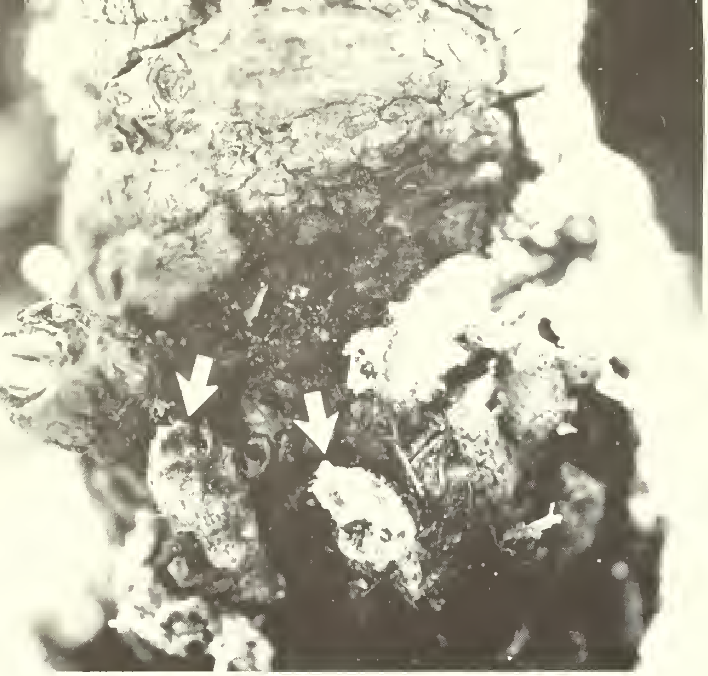


Figure 1.—Cocoons of *Rhyacionia neomexicana* around root collar of infested tree.

Figure 2.—Emergence cage in place on a small ponderosa pine.

Installation

1. Select a previously infested tree—one that shows signs of damage by shoot- or tip-feeding insects. Dry, withered terminal and lateral shoots that crumble when handled are signs of possible previous infestation. Avoid trees with excessive mammal digging around the root collar.

2. Prune away any protruding branches near the ground and along the tree bole as high as 8 to 10 inches above ground. Avoid excessive pruning, however, that may change the microclimate near the tree base. Clear rocks, limbs, and other debris away from the tree bole, but **leave** the needle litter and duff.

3. Remove screws from base band, open out, and place around the tree bole with reinforcing bead up. Close band and secure seam with screws.

4. Position band evenly around tree and press into soil with foot or rubber-headed mallet. Leave about 1 inch of band exposed for securing screen to the reinforcing bead.

5. Place fiberglass screen around the tree bole, staple ends shut with three holding staples. Fold width of screen about 1/4 inch and staple to form finished seam. Place staples close together to make a tight seam that will prevent escape of insects.

6. Place bottom of screen cylinder over reinforcing bead of band, overlapping bead at least 1/2 inch, and secure with a 30-inch piece of 20-gage iron wire. **Caution:** Make sure wire holds the screen tightly to the band **below** the reinforcing bead.

7. Press band and attached screen into soil flush with litter (fig. 2).

8. Gather top of screen cylinder into folded pleats and secure to tree bole with an 8- to 10-inch piece of 20-gage iron wire. Allow enough excess wire at the top of the cage to facilitate opening and closing the cage several times.

9. Attach identifying tag or flagging.

Field Use

These cages have been successfully used to determine adult emergence of the southwestern pine tip moth infesting ponderosa pines in Arizona. Cages were installed in late March at Chevelon, and examined at 2- to 3-day intervals until emergence was completed in early May. Cages were installed around both natural and planted pines with tree diameters at ground level ranging from 1/4 to 4 inches. Cage dimensions can be increased easily for use with larger diameter trees.

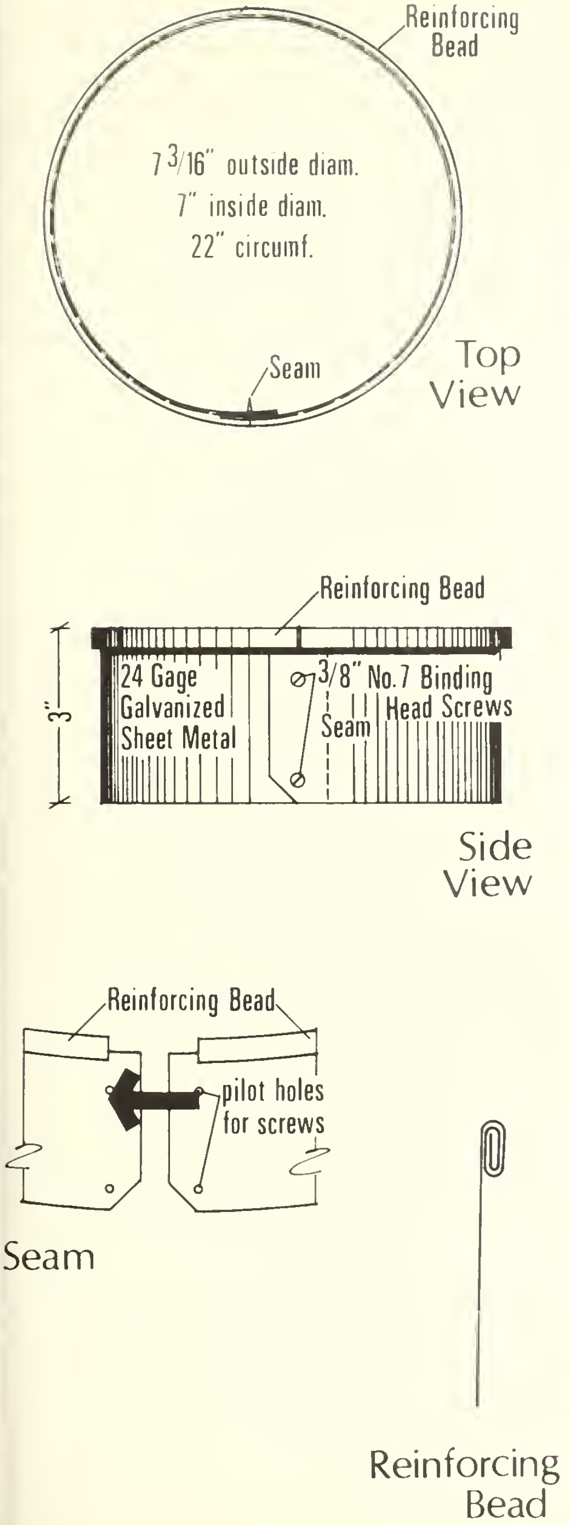


Figure 3.—Construction details for the base band.

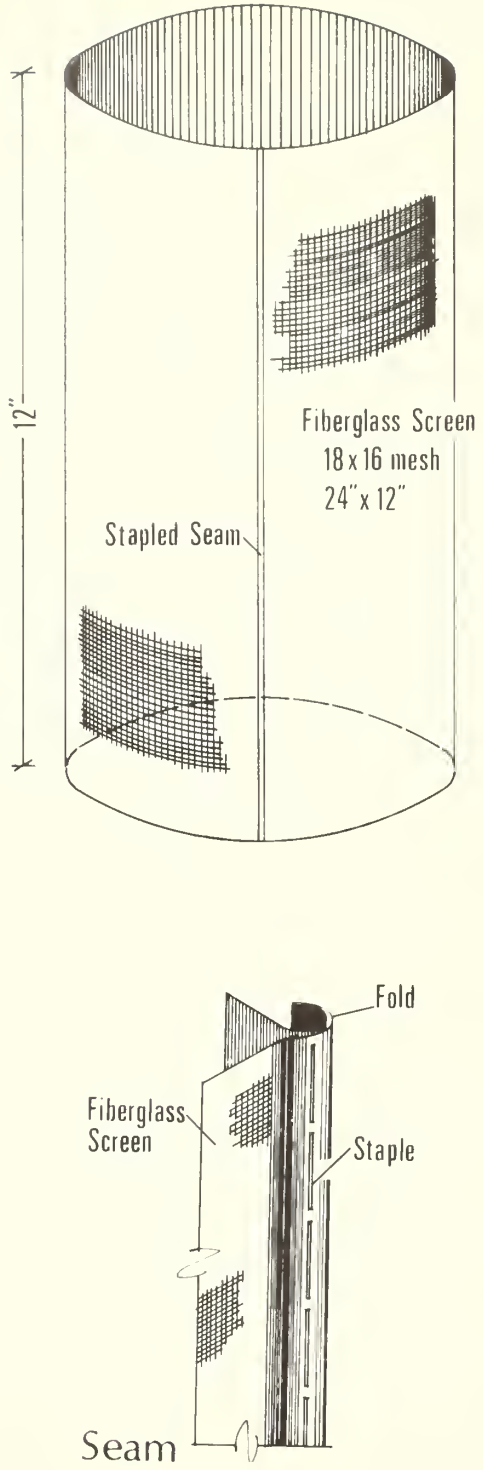


Figure 4.—Construction details for the fiberglass screen.

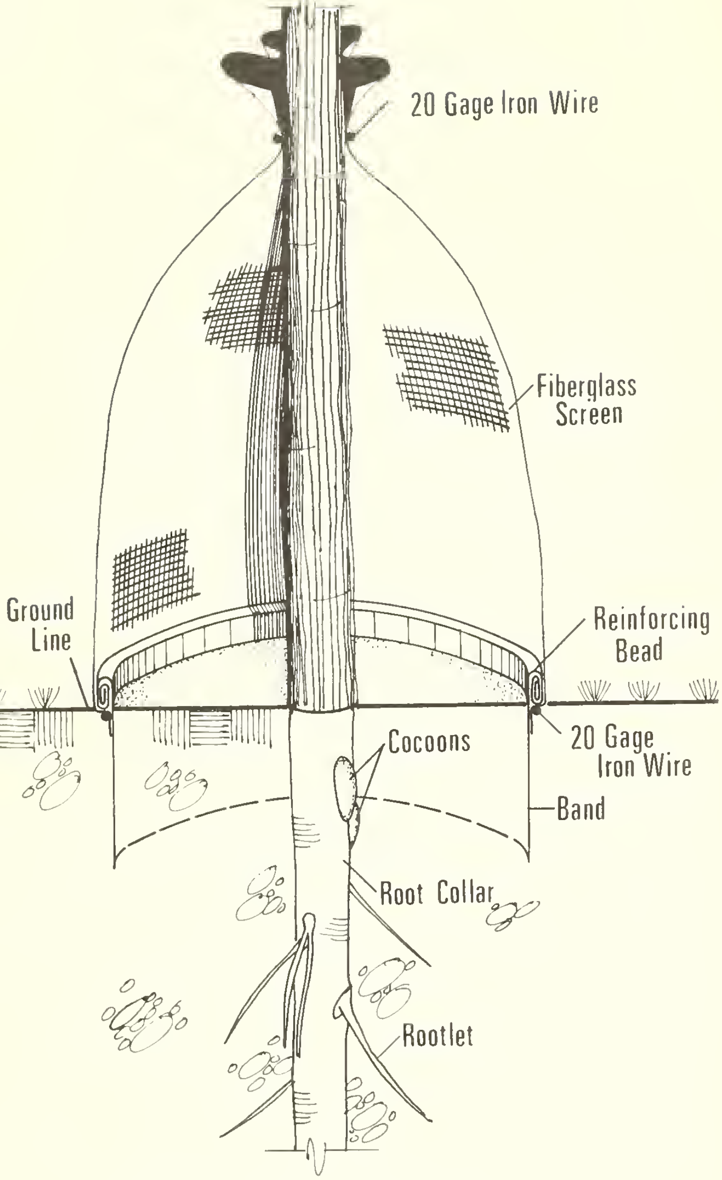


Figure 5.—Schematic diagram of emergence cage in place.

Before opening the cage, the observer should first look through the screen for moths. Adult moths are usually found resting on the screen, occasionally on the tree bole, and rarely on the surface of the litter. The cage should be opened gently because, when disturbed, moths on the screen or tree bole may drop to the ground, feigning death. Moths are more difficult to see and collect on the litter surface.

Adults can be collected by placing a 2-dram shell vial over the head-thoracic region. The moths usually respond by climbing upwards. Very few moths attempt to escape from the cages. Before closing the cage, the observer should examine all interior surfaces, including screen, tree bole, and litter.

These cages may be useful for determining adult emergence of other soil-pupating *Rhyacionia*. At least three other species of tip moths are known to pupate in the soil or at ground level with their cocoons attached to root collars or boles of host trees. The pine tip moth, *R. adana* Heinrich, overwinters as pupae attached to host tree root collars beneath the soil (Martin 1960), while the ponderosa pine tip moth, *R. zozana* (Kearfott), pupates most commonly on the bark of host pines just at ground level (Stevens 1966). An undescribed species of *Rhyacionia* found associated with *R. neomexicana* in Arizona also pupates in the soil attached to root collars of ponderosa pines, and has been collected in these emergence cages.

Literature Cited

Martin, J. Lynton.
1960. Life history of the pine tip moth, *Rhyacionia adana* Heinrich, in Ontario (Lepidoptera: Olethreutidae). Can. Entomol. 92:724-728.

Stevens, Robert E.
1966. The ponderosa pine tip moth, *Rhyacionia zozana,* in California (Lepidoptera: Olethreutidae). Ann. Entomol. Soc. Amer. 59:186-192.

Agriculture—CSU, Ft. Collins

Dcember 1973

U S D A FOREST SERVICE
RESEARCH NOTE RM- 251

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

COMPUTER-PRODUCED TIMBER MANAGEMENT PLANS:
An Evaluation of Program TEVAP

Bruce M. Edwards, Gary E. Metcalf, and W. E. Frayer[1]

TEVAP (Timber EValuation And Planning),a computerized timber management planning system, was tested over a 2-year period on the Black Hills National Forest. The system's utility in the decisionmaking process was demonstrated for both broad and local areas.

Oxford: 624:U681.3. Keywords: Allowable cut, forest management, timber management, *Pinus ponderosa, Picea glauca.*

As do other modern managers, foresters increasingly find need for more detailed inventory information. This need has developed as uses of the forest and consequent management alternatives have increased. Information must be both extensive and detailed, and yet be accumulated and analyzed rapidly and accurately.

High-speed computers are helping to make such information-handling possible. Of particular interest to foresters is the use of computers in analyzing inventory data, and subsequent use of these data in preparation of management plans for forest areas. Presently, many forest inventories are conducted at a compartment examination level. The forest is divided into management units or compartments, and then subdivided into stands. Each stand is a basic management unit with homogeneous silvicultural characteristics. Data, including location, are collected from each stand. On a computer, these data can be assimilated and comprehensive inventory reports or forest maps produced in a matter of seconds. Whenever fire, insect infestation, silvicultural treatment, growth, or other phenomena affect the stand, records can be updated quickly and easily. The forest can then be managed as a continuous, dynamic system.

Various computerized programs have been written to retrieve and consolidate these types of data for management planning. Some of these programs include FINSYS (Wilson and Peters 1967, Frayer et. al. 1968), STX (Grosenbaugh 1967), INFORM,[2] RAM (Navon 1969), and TEVAP (Myers 1970). Some deal primarily with collection and analysis of inventory data, while others are designed for resource allocation and decisionmaking. However, all are useful aids in timber management planning.

Description of TEVAP

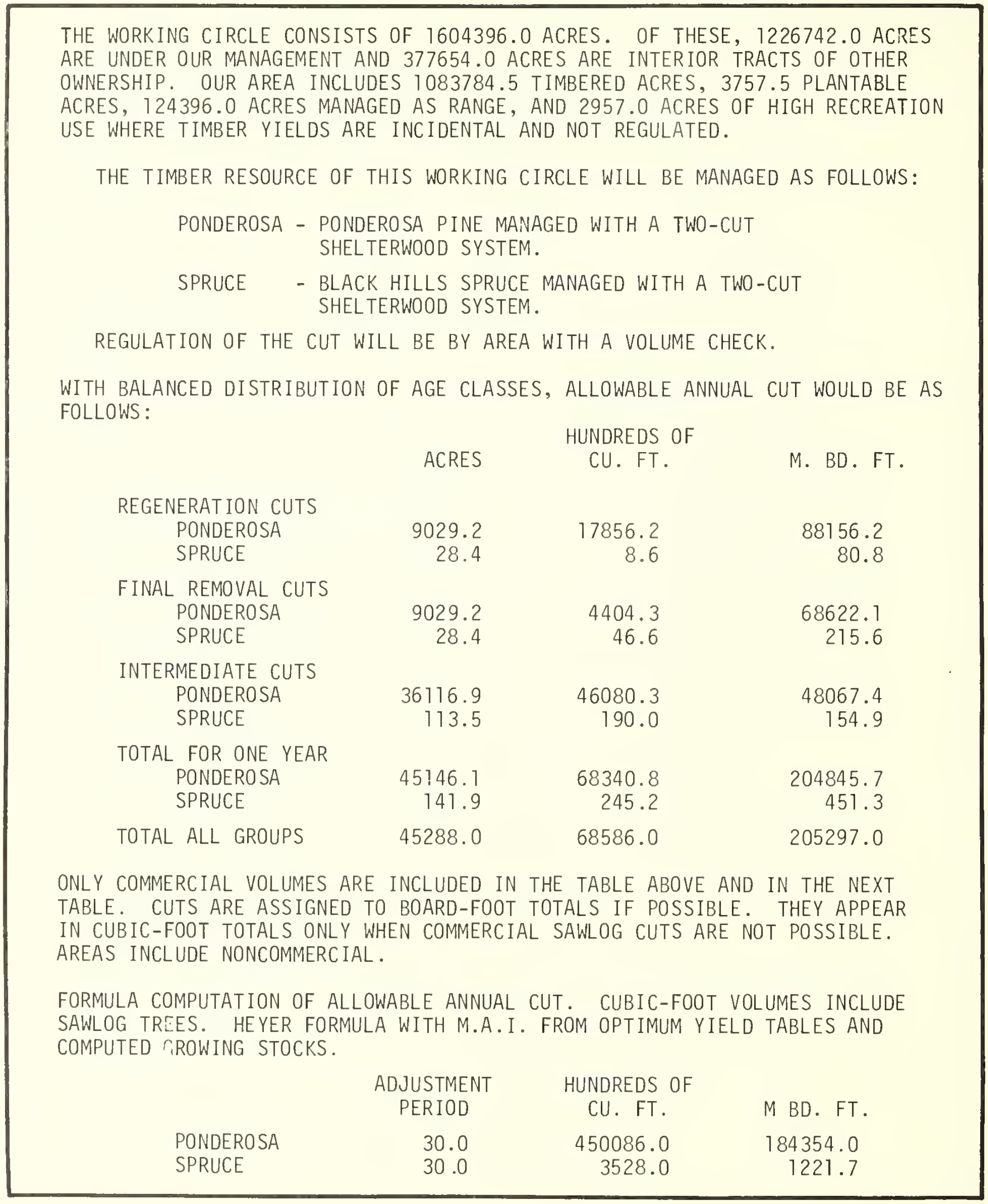
TEVAP (Timber EValuation And Planning), a computerized timber management planning system, rapidly processes forest inventory data into various tables and summaries, and prescribes management of even-aged and two-storied forest stands. Some of the summaries present the areas of the various forest types, while others present comprehensive breakdowns

---

[1] *At time of the study, the authors were, respectively, graduate student, Colorado State University; forester, timber management specialist, Black Hills National Forest; and associate professor of forest biometry, Department of Forest and Wood Sciences, Colorado State University. Study was conducted under contracts 16-215 and 16-254-CT with the Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained in cooperation with Colorado State University, at Fort Collins.*

[2] *B-R Data Systems, Inc. 1968. Analysis of present operations and development information system concept for the Forest Service. Final report to U.S. Forest Service for Contract 13-327.*

of timber volumes by forest type and site index. These summaries give a detailed description of the timber resources. In addition to these summaries, and of more importance to the manager, TEVAP calculates work prescriptions and a management plan for the forest. The work prescriptions and plan present the allowable cut, volumes to be salvaged as the result of fires or insect attacks, and the cultural needs to be implemented in developing the forest toward a balanced distribution of age classes. Essentially, TEVAP produces all the information in a comprehensive timber management plan. An example, showing part of such a management plan, is presented in figure 1. The speed and low cost at which plans are generated should make traditional methods of preparing timber management plans obsolete.



```
THE WORKING CIRCLE CONSISTS OF 1604396.0 ACRES.  OF THESE, 1226742.0 ACRES
ARE UNDER OUR MANAGEMENT AND 377654.0 ACRES ARE INTERIOR TRACTS OF OTHER
OWNERSHIP.  OUR AREA INCLUDES 1083784.5 TIMBERED ACRES, 3757.5 PLANTABLE
ACRES, 124396.0 ACRES MANAGED AS RANGE, AND 2957.0 ACRES OF HIGH RECREATION
USE WHERE TIMBER YIELDS ARE INCIDENTAL AND NOT REGULATED.

   THE TIMBER RESOURCE OF THIS WORKING CIRCLE WILL BE MANAGED AS FOLLOWS:

          PONDEROSA - PONDEROSA PINE MANAGED WITH A TWO-CUT
                      SHELTERWOOD SYSTEM.

          SPRUCE    - BLACK HILLS SPRUCE MANAGED WITH A TWO-CUT
                      SHELTERWOOD SYSTEM.

   REGULATION OF THE CUT WILL BE BY AREA WITH A VOLUME CHECK.

WITH BALANCED DISTRIBUTION OF AGE CLASSES, ALLOWABLE ANNUAL CUT WOULD BE AS
FOLLOWS:
                                          HUNDREDS OF
                               ACRES        CU. FT.            M. BD. FT.

     REGENERATION CUTS
          PONDEROSA           9029.2       17856.2              88156.2
          SPRUCE                28.4           8.6                 80.8

     FINAL REMOVAL CUTS
          PONDEROSA           9029.2        4404.3              68622.1
          SPRUCE                28.4          46.6                215.6

     INTERMEDIATE CUTS
          PONDEROSA          36116.9       46080.3              48067.4
          SPRUCE               113.5         190.0                154.9

     TOTAL FOR ONE YEAR
          PONDEROSA          45146.1       68340.8             204845.7
          SPRUCE               141.9         245.2                451.3

     TOTAL ALL GROUPS        45288.0       68586.0             205297.0

ONLY COMMERCIAL VOLUMES ARE INCLUDED IN THE TABLE ABOVE AND IN THE NEXT
TABLE.  CUTS ARE ASSIGNED TO BOARD-FOOT TOTALS IF POSSIBLE.  THEY APPEAR
IN CUBIC-FOOT TOTALS ONLY WHEN COMMERCIAL SAWLOG CUTS ARE NOT POSSIBLE.
AREAS INCLUDE NONCOMMERCIAL.

FORMULA COMPUTATION OF ALLOWABLE ANNUAL CUT.  CUBIC-FOOT VOLUMES INCLUDE
SAWLOG TREES.  HEYER FORMULA WITH M.A.I. FROM OPTIMUM YIELD TABLES AND
COMPUTED GROWING STOCKS.
                             ADJUSTMENT     HUNDREDS OF
                               PERIOD         CU. FT.          M BD. FT.
          PONDEROSA             30.0         450086.0          184354.0
          SPRUCE                30 .0          3528.0            1221.7
```

Figure 1.--Guide for management--Black Hills National Forest. Total Forest summary, February 19, 1973.

The Test

The program was tested over a 2-year period using data from the Black Hills National Forest in South Dakota. The test was to determine (1) the value of TEVAP in actually managing the timber resource of the Black Hills, and (2) costs incurred in using the program. Data were supplied by Forest Service personnel on the Black Hills. A study team at Colorado State University ran the program and made necessary alterations.

At the time of the test, the Black Hills timber resource was being managed by two different silvicultural systems. Because of the land area and wood volume involved, the most widely used was a shelterwood system for ponderosa pine (Pinus ponderosa). In the second, white spruce (Picea glauca) was initially managed under a clearcut system that was later converted to a shelterwood system. Each of these silvicultural systems is called a working group, and both groups were easily handled by TEVAP, since the necessary species-specific equations were incorporated in the program (Myers 1970). It soon became obvious, however, that more working groups would be needed on the Black Hills. One newly proposed working group was ponderosa pine managed to perpetuate esthetic and recreational values. To accommodate this change, provisions were made in TEVAP to store up to 100 working groups, of which any five could be used in a single run of the program. Although a single area may not include more than five working groups, a single version of TEVAP may be used on a regional basis where forest types and silvicultural systems may vary.

One of the problems in implementing all options of TEVAP was that, at the onset of the test, detailed in-place data for the Black Hills National Forest were not available. However, enough information was available from old inventory records to produce some in-place data. Using one of the area calculation options in TEVAP, these limited data were expanded to produce output representative of the total forest. Comparisons of TEVAP results with previous inventory summaries showed the TEVAP results to be reasonably accurate. As compartments were delineated and more in-place data gathered, the more complete information was added to the system and the management plan updated.

As in many western forests, the Black Hills National Forest consists of large amounts of timber in the same age class — in this case, however, a predominantly young age class. It is difficult to convert a rather homogeneously aged forest to a forest with a balanced age distribution, a management goal to provide a continuous and reasonably uniform supply of timber, and to help control fire, insects, and disease. TEVAP was used to help solve these conversion problems. One part of the output from TEVAP is a yield table for each site index class of each working group. This yield table shows the stand characteristics and yield per acre for a theoretical, managed stand from regeneration to final harvest cut. Using this yield table, timber volumes for the theoretical forest with a balanced distribution of age classes, were calculated by TEVAP and compared to the actual volumes on the forest. The comparisons were printed in a table showing the age classes which are deficient or have surpluses in volume. TEVAP then calculated and printed a work plan to help develop the total forest toward a balanced distribution of age classes. The work plan showed the kinds of activities to be done in the current period and the volumes to be obtained. Finally, TEVAP generated a guide to management which included a summary of forest acreage and the allowable cut for the forest.

Aside from TEVAP's use in management planning, it also gives comprehensive inventory information, including breakdowns of timber volumes by site class or forest type, and various breakdowns of forest acreages.

Results

Applying the TEVAP program to timber management in the Black Hills resulted in substantial savings in cost and time.[3] The largest of these cost savings was due to the increased efficiency in producing management plans. Past manual development of management plans required much time. Costs in excess of $25,000 per working circle were commonplace. Now, management plans can be developed at approximately $10,000 for a working circle. Aside from the savings in cost, the time savings provides forest managers with more time for other duties.

With this fast and less expensive method, management plans can be produced more often. Previously, management plans for the Black Hills were produced every 10 years. If, during this 10-year period, a large fire, insect infestation, or change in lumber needs occurred, the forest manager could only make educated guesses as to the effect of this unforeseen

---

[3] *Frayer, W. E., Metcalf, G. E., and B. M. Edwards. 1972. Simulation of a regional data center for decision making in forest management. Final report to U.S. Forest Service for Contracts 16-215, 16-254-CT.*

event on the total forest. A new management plan can now be produced whenever necessary. During the test, for example, the management plan for the entire Black Hills National Forest was updated at least twice annually at a cost of $500 per revision. This includes the cost of data manipulation, updating inventory records, and computer charges.

Although direct cost savings are often easy to find when applying computerized techniques, hidden costs can occasionally offset them. An example of such hidden costs might be expensive data-gathering processes, or increased workload on personnel. Such hidden costs were not encountered on the Black Hills. Because TEVAP can produce inventory summaries and management plans with limited in-place data, long-range inventory plans did not have to be changed. As more in-place data were gathered, more accurate TEVAP output was obtained. Managers were not overburdened with additional work, and did not have to change their inventory methods substantially.

The Black Hills test additionally demonstrated TEVAP's flexibility. The program was originally written to provide inventory analysis and management plans on a working circle scale; however, Black Hills personnel found several other uses for the program. One of these was production of management plans for individual Ranger Districts or planning areas. A second use was for calculating timber volumes on timber sale areas. TEVAP was also used as a simulation program to determine the results possible with various management alternatives.

The use of TEVAP on the Black Hills National Forest has resulted in many immediate and long-range timber management planning benefits. Fast and accurate analysis of inventory data by TEVAP not only saves time and money, but also increases reliability of planning. Better management practices became evident on the ground. As resource managers use TEVAP, their planning job not only becomes easier, but is also more thorough and comprehensive. TEVAP and its system of inventory data storage and updating help the resource planner to better view the productive timber base of the forest as a continuous dynamic system.

Literature Cited

Frayer, W. E., R. W. Wilson, R. C. Peters, and C. A. Bickford.
1968. FINSYS: An efficient data-processing system for large forest inventories. J. For. 68:902-905.

Grosenbaugh, Lewis R.
1967. STX. FORTRAN-4 program for estimation of tree populations from 3-P sample-tree-measurements. U. S. For. Serv. Res. Pap. PSW-13, rev., 76 p. Pacific Southwest For. and Range Exp. Stn., Berkeley, Calif.

Myers, Clifford A.
1970. Computer-assisted timber inventory analysis and management planning. USDA For. Serv. Res. Pap. RM-63, 53 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Navon, Daniel I.
1969. Activity analysis in wildlands management. Ann. Reg. Sci. 3(2):75-84.

Wilson, R. W., and R. C. Peters.
1967. The northeastern forest-inventory data-processing system. (Parts 1-10). U. S. For. Serv. Res. Pap. NE-61, NE-70 to NE-78. Northeast. For. Exp. Stn., Upper Darby, Pa.

Agriculture—CSU, Ft. Collins

nuary 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM- 252

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Variation of Windspeed with Canopy Cover within a Lodgepole Pine Stand

James D. Bergen[1]

The linear correlation computed for 22 points in a lodgepole pine canopy suggests independence between the point-to-point variations in speed at any level and variations of total canopy cover.

Oxford: 116:111.5. Keywords: windspeed, canopy cover, *Pinus contorta*.

Previous Work

A recent study of the variation of windspeeds rom point to point in an even-aged pine stand (Bergen 1971) indicated strong variations in speed — at the same level and at the same time — between locations only a few meters apart. These measurements were made at six levels and at points nearly equidistant from the nearest four stems; thus they should reflect not so much the lower speeds to be expected within tree crowns as compared to the space between trees, as the random variations in tree spacing and crown densities.

The estimated specific variation — that is, the variance divided by the average — and averages for the 22 windspeed profiles scaled by the speed at 11 m height are shown in table 1. The specific variation ranges from 24 to 45 percent, with the lowest values at treetop level and the highest value at approximately the location of the average maximum foliage weight of the tree crown, as established by foliage weight measurements.[2] The specific variation of the crown foliage weight at each level, found from the dissection of five tree crowns, is shown in the last column of the table. There seems to be no relation between the height trends of windspeed and foliage weight variability, although because of the small sample for the latter, no firm comparison can be made.

Convincing arguments have been made that the local variations in windspeed should be closely correlated with variations of the local canopy cover, or equivalently the skyview factor F, defined as the fraction of the field of view looking upward from below the canopy which is unobstructed by foliage. The outlines of the analysis can be found in Isobe's analysis for windspeeds in crop canopies (Isobe 1967). This concept seemed to be borne out by the relatively high windspeeds found at every level in the largest natural opening (about 5 m in diameter) in the stand (Bergen 1971), and seemed worth investigating in view of the value such a correlation would have in designing stratified sampling schemes to establish space average wind profiles in natural stands.

Current Analysis

This Note reports essentially negative results — a lack of correlation either between windspeed and the total view factor, or between windspeed and a modified view factor designed to allow for the orientation of the local canopy to the wind direction above the canopy.

---

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

[2] *Gary, Howard L. Crown structure, and vertical distribution of biomass in a lodgepole pine stand. (Manuscript in preparation at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.)*

Table 1.--Linear correlations between windspeed and canopy cover indices with associated statistics

Height (Meters)	Scaled speed $\bar{U}$	Specific variation of speed S	Speed correlation with F	Estimated upper limit of r for stand	Estimated lower limit of r for stand	Speed correlation with L	Specific variation of foliage weight
1.07	0.58	0.33	-0.28	+0.2	-0.6	-0.05	0.00
2.50	.76	.30	+ .26	+ .6	- .1	+ .31	.00
4.00	.65	.30	+ .15	- .4	- .2	+ .07	.13
5.60	.66	.45	+ .01	- .4	+ .4	- .32	.05
7.00	.49	.30	+ .18	+ .4	- .2	+ .13	.08
8.50	.74	.24	+ .37	+ .6	.0	- .04	.09

The value of F was computed for each of the 22 profile locations from a vertical photograph of the canopy, taken from a height of 50 cm above the profile base with a 45° aperture lens. The field of view at the height of the foliage maximum was a square 13 m on a side. This level was also the height of the maximum horizontal branch extension as estimated from the five tree samples.

The fraction of the field of view occupied by the sky was calculated as the average fraction of seven circular sectors filling the field of view and divided into 10° segments (fig. 1). A segment was counted totally clear or obscured, depending on whether more than half its area was occupied by foliage images.

The distribution of F for 40 points between trees in the stand, including those for which windspeeds were measured, showed an approximately normal distribution; F averaged 66 percent and ranged from 51 to 100 percent.

The sample used for the calculations was restricted to those 22 points where no single low-lying branches seemed to dominate the field of view, and where complete six-level windspeed profiles were available.

Results

As may be seen in the table, none of the computed correlations are significant, except insofar as the results rule out any close association between F and the local speed at any level.[3]

The F factor was then modified so that the orientation of the local canopies to the above-canopy wind direction could be considered. This modified F was the average length of the unobscured central fifth of the field of view measured along the above-canopy wind direction, noted as L on the table. The factor L is shown to have a specific variance of 67 percent and a linear correlation of 0.57 with F over the 40 grid points. In general, L shows no closer association with the local windspeed than F, as is evident from the last three columns in the table.

Conclusions

The results suggest two significant conclusions.

1. It appears likely either that the close association of foliage density and view factor

---

[3] *This statement is valid if the use of Fisher's Z (Panofsky and Brier 1958) for estimating the 90 percent confidence interval for some hypothetical large parent distribution, such as a forest, may be accepted. For a severely truncated distribution, such as that to be expected for the speed, such a confidence interval would be overconservative.*

Figure 1.—Typical vertical canopy photograph with superimposed grid. The arrow is in the direction of the wind above the canopy. The area HDOE is used to compute the average apparent open fetch length (L).

observed when comparing separate stands is not paralleled by measurements within a stand, or that the local airflow irregularities reflect canopy irregularities of a much smaller or of a larger scale than that involved in the average canopy density and arrangement in space of the nearest four trees. That is, the calculation may be comparing the wake of a branch with the shadow of the crown.

2. Energy balance computations using the average canopy cover and windspeed in a pine stand are probably not in any appreciable error due to the neglect of the interaction between point-to-point variations in these variables.

Literature Cited

Bergen, J. D.
1971. Vertical profiles of windspeed in a lodgepole pine stand. For. Sci. 17:314-321.

Isobe, S.
1967. A study of the extinction of momentum within plant communities from the point of view of the light extinction. Bull. Natl. Inst. Agric. Sci. [Japan] Ser. A(14):1-16.

Panofsky, H. H., and G. W. Brier.
1958. Some applications of statistics to meteorology. 224 p. Pa. State Univ. Press, Univ. Park, Pa.

Agriculture—CSU, Ft. Collins

January 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-253

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Variations of Air Temperature and Canopy Closure in a Lodgepole Pine Stand

James D. Bergen[1]

Vertical air temperature profiles were measured under various degrees of canopy closure in a lodgepole pine stand. The air temperatures were scaled by the temperature gradient over the canopy, and the point-to-point variation of this scaled temperature from its average for all locations was examined for correlation with the point-to-point deviations of canopy view factor. The results indicate independence at all the levels for which temperature was measured.

Oxford: 116:111.2. Keywords: air temperature, micrometeorology, microclimatology, forest meteorology, temperature variation, forest canopy, *Pinus contorta*.

Canopy closure has usually been considered a major factor determining forest climate. When a survey of air temperatures[2] in an even-aged pine stand indicated large point-to-point variation of air temperature, it seemed likely that these variations would be closely correlated with local deviations of canopy closure from the stand average. Such was not the case, however.

Not only was the degree of association small, it was also contrary to what would be expected from local energy balance considerations.

The pine stand had an average height of 10 meters (m) and a density of 17 stems/100 m^2. The height of maximum foliage concentration averaged about 7 m.[3]

Canopy cover was calculated from vertical photographs taken at a height of 50 cm above the base of the air temperature profile arrays. The camera lens angle was 45°, covering a square of about 13 m on a side at the height of the foliage maximum. The method of computing canopy cover is described in another Note (Bergen 1974). The variable actually used in the calculations was the skyview factor F, defined as 100 minus the canopy cover.

Air temperature was measured at heights of 1, 2.5, 4.0, 5.6, 7.0, and 8.6 m on one or both of two portable masts, with shielded bead thermistors. Air temperature was also measured at 11.5, 16.5, and 22.5 m on a fixed tower within 30 m of all the mast locations. The masts were located approximately on a grid of points.[2] Masts were actually placed approximately equidistant from the four trees nearest to each point. The air temperature could be expected to be a local maximum or minimum in such locations, while the view factor would obviously be a local maximum. Temperature profiles were measured at intervals of about 15 minutes; masts were left in position from 1 to 3 days.

To compare temperature profiles taken on different days with different above-canopy conditions, we may make the scaling analysis from another paper.[2] Thus $(T - T_h)/(T_a - T_h)$, denoted T', where T = the local air temperature, T_h = the temperature at the fixed tower top. and T_a = the temperature at 11.5 m on the

---

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

[2] *Bergen, James D. Spatial variation and scaling problems for vertical air temperature profiles in a pine stand. (Manuscript in preparation at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.)*

[3] *Gary, Howard L. Crown structure and vertical distribution of biomass in a lodgepole pine stand. (Manuscript in preparation at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.)*

fixed tower, depends only, for any particular point in the stand, on the solar elevation, the cloud cover, and wind direction. To use this relationship for the calculations to follow, only those measurements taken on clear days and within an hour of noon are considered. The wind direction above the canopy in all cases was within 10° of southwesterly.

Data from 17 positions in the stand met these requirements; of these, two were discarded because the vertical photographs were unduly influenced by one or two low-lying branches. Of the remaining 15, 12 consisted of six simultaneous pairs; that is, two profiles made on masts at different locations.

The F measurements for the 40 points in the stand show a distribution not significantly different from normal, as contrasted to the U-shaped distribution which might have been expected if points beneath crowns had been included. The range is 51 to 100 percent.

The relation of canopy closure or equivalent F factor to the vertical temperature profile apparently has not received much direct attention. The most comprehensive relevant study in the literature is that by Gohre and Lutzke (1956), where the vertical temperature profiles measured in a spruce stand and two pine stands of different stem density are compared. They distinguish between "dense" stands, where the only local temperature maximum is found in the crown, and "open" stands, where there is a canopy and stand-floor maximum. If such distinction could be applied to the small-scale variations in a stand, we would anticipate that a local temperature profile would tend toward the "dense" or "cold-floor" type as the F factor decreased, or equivalently that upper canopy temperatures would be negatively correlated with F while subcanopy temperatures would show a positive correlation.

The first prediction is hard to test with the data at hand — only about six of the locations were without a local maximum near the floor. The average F values for the "cold-floor" locations was 71, compared to 66 for the remaining locations, an insignificant difference in terms of the sample size.

The simultaneous pairs of profiles also show no tendency for the profile in the location with the highest F factor to be colder or warmer than the profile at the other location. The sign of the difference alternates evenly between the six pairs.

Using the scaling relation mentioned above, we can calculate the linear correlation over the 15 points for the average values of T' in the upper canopy, lower canopy, and subcanopy space, with the local F. The upper canopy is represented by the temperatures at 8.5 and 7 m, the lower canopy by those at 5.6 and 4.0, and so on. The results are shown in table 1,

Table 1.--Correlation of scaled air temperature measured between trees and vertical skyview factor F

Item	Level		
	Subcanopy	Lower canopy	Upper canopy
Variance of scaled air temperature	1.93	4.60	3.80
Calculated correlation with view factor F	- .56	+ .12	+ .06
90 percent confidence interval for stand correlation	+ .14 - .82	- .22 + .75	+ .47 - .47

together with the 90 percent confidence interval computed, using Fisher's Z distribution (Panofsky and Brier 1958). Since F must have a truncated distribution on physical grounds, however, this interval is probably an overestimate. The corresponding scatter diagram is shown as a composite in figure 1.

As may be seen, we can reject any appreciable positive correlation between the subcanopy air temperatures and local F factor; the most probable value is negative. Nothing can really be said about the situation in the lower canopy. In the upper canopy, there is no support for a negative correlation or the positive correlation to be expected from the subcanopy result.

While these results are discouraging in regard to designing stratified sampling schemes for forest air temperature based on canopy cover, they are welcome insofar as they imply that these two major factors in the canopy energy balance are relatively independent insofar as their point-to-point deviations from the stand average are concerned. Thus such deviations pose no serious objection to computing such quantities as evapotranspiration estimates from stand average canopy cover.

Apparently the factor F does not closely reflect the actual density of foliage above the points considered, or the canopy and subcanopy air motion is sufficient to level out any local temperature differences generated by the uneven radiation field indicated by F.

Literature Cited

Bergen, James D.
1974. Variations of windspeed with canopy cover within a lodgepole pine stand. USDA For. Serv. Res. Note RM-252, 4 p.

Gohre, K., and R. Lutzke.
1956. Der Eingfluss von Bestandesdichte und Strucktur auf das Kleinklima im Walde. Arch. fur Forstwes. 5:387-572.

Panofsky, H. H., and G. W. Brier.
1958. Some applications of statistics to meteorology. 224 p. Pa. State Univ. Press, Univ. Park, Pa.

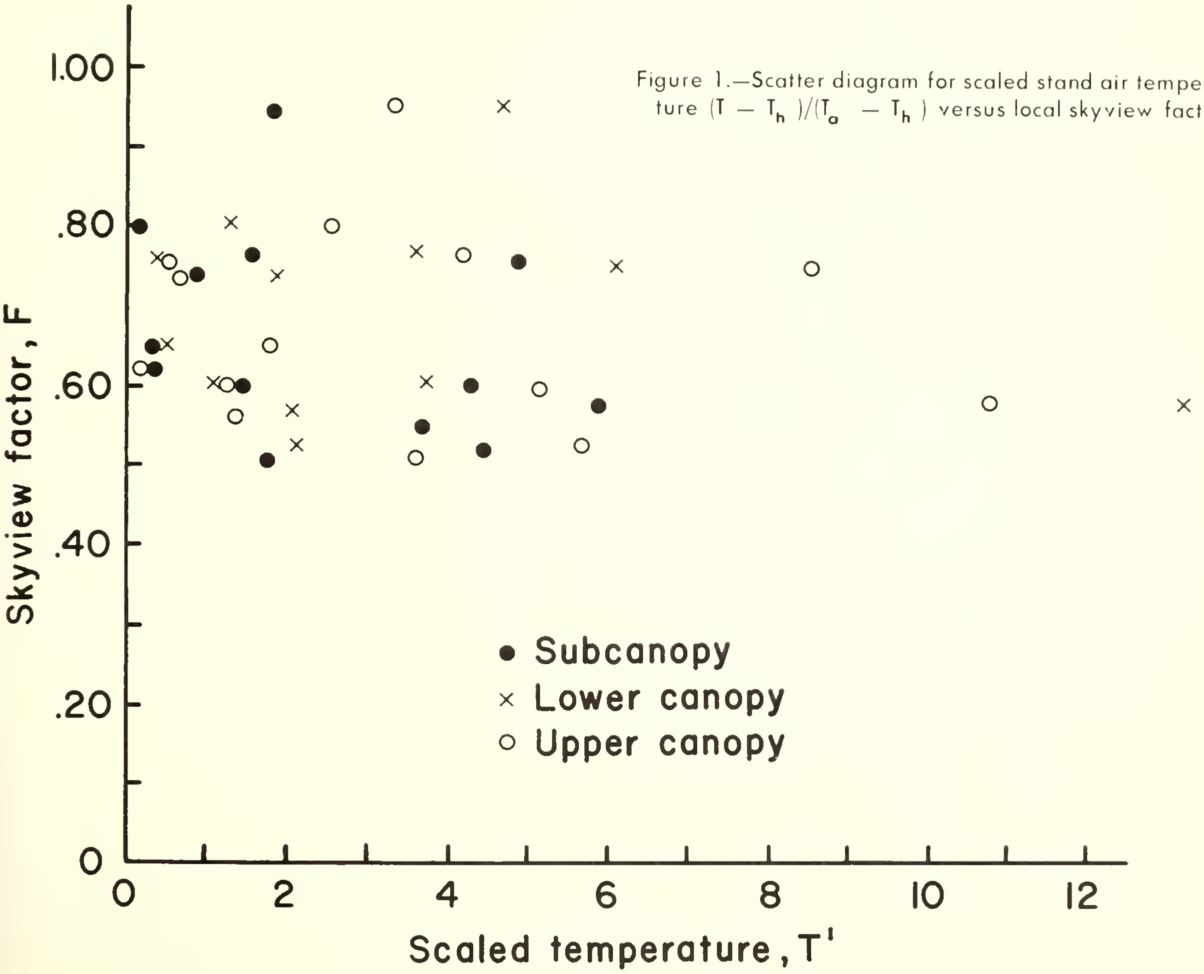


Figure 1.—Scatter diagram for scaled stand air temperature $(T - T_h)/(T_a - T_h)$ versus local skyview factor.

Agriculture—CSU, Ft. Collins

February 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-254

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Growth Characteristics of Bearberry in the Black Hills

Kieth E. Severson and E. Chester Garrett[1]

Growth of bearberry varied widely between plants and between sites. Most annual growth (66 percent) occurred during June when moisture and temperature conditions were apparently optimum. Annual growth can readily be recognized by the presence of nodes and by color changes.

Oxford: 156.2:181.61. Keywords: Wildlife habitat management, *Arctostaphylos uva-ursi*.

Bearberry (Arctostaphylos uva-ursi (L.) Spreng.), often referred to as bearberry manzanita or kinnikinnick, has been recognized as one of the most important food items in the diet of deer in the Black Hills, particularly during fall and winter[2] (Schneeweis et al. 1972, Schenck et al. 1972).

Studies to determine production and nutritive composition of this prostrate, evergreen shrub require familiarity with its growth habits and morphological characteristics. Current annual growth is difficult to recognize on some evergreen shrubs, a problem anticipated with bearberry because of the color variation among plants and because some shoots had several nodes whereas others apparently had none. Because of this wide variability, a study was initiated in 1971 to (1) gain some insight into the growth patterns, and (2) to determine which morphological characteristics could be used to aid in the recognition of annual growth.

The study was conducted in the Black Hills Experimental Forest approximately 7 miles northeast of Rochford, South Dakota.

Methods

Two areas, each with an overstory of ponderosa pine (Pinus ponderosa) and a well-developed understory of bearberry, were selected for study. Sampling began in early May 1971. Four 100-foot line transects were randomly located within each site. Each transect was divided into 12 equal segments (8.3 feet). One bearberry shoot was randomly selected within each segment. The tip of each shoot was marked by pushing a 9-inch piece of 12-gage wire into the ground beside the shoot. The wire had a small hook on the end formed to fit firmly over the shoot 3 to 6 cm from the tip. A small numbered aluminum disc was also attached to the wire to identify the shoot. The distance from the wire hook to the tip of each shoot was measured and recorded. The plants were measured once during the first 5 days of each month from May through October in 1971 and 1972.

Basal area and density of the overstory were determined for each site from the 100-foot transects. The trees in a 20-foot-wide belt, 10 feet on either side of the line, were counted and d.b.h. measured. Densities were expressed as number of trees per acre, and d.b.h. was converted to square feet of basal area per acre.

The percentage canopy cover and ground cover of bearberry were obtained by the line intercept method (Canfield 1941) on the transects. Percentage canopy cover of the overstory was determined by shade intercept.

---

[1] *Range Scientist and Range Technician, respectively, located at Rapid City in cooperation with South Dakota School of Mines and Technology; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Personal communication with Donald R. Dietz, Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, Rapid City.*

At the end of the second year, all live plants were clipped at the point of tagging, and annual growth was remeasured in the laboratory. Growth characteristics for each plant were noted by known growth patterns. Two groups of plants were randomly selected from this collection for annual growth measurements by five different observers, who were first given a brief description of annual growth characteristics of bearberry. Observer measurements were individually compared with the known annual growth derived from the monthly measurements.

Results and Discussion

Growth Characteristics

Growth characteristics of bearberry varied widely, particularly between individual plants and between sites. Mean growth was greatest both years on Site 1, however (table 1).

Table 1.--Mean monthly growth(cm) of bearberry on two Black Hills sites, 1971-72

Month	Site I		Site II		Total
	1971	1972	1971	1972	
May	0.3	0.7	0.3	0.8	2.1
June	10.3	9.2	5.3	1.9	26.7
July	1.2	3.4	.4	1.0	6.0
August	.4	1.7	.3	.5	2.9
September	.5	.8	.8	.5	2.6
Total	12.7	15.8	7.1	4.7	40.3

We were not able to draw any conclusions about why growth varied so widely, but we were able to determine some consistent differences between plants. First, there were color differences between fast and relatively slower growing plants. The stems of slower growing plants were pale to milky green, whereas the faster growing stems tended to be red to dark maroon. Plants that were pink had intermediate growth. Out of a sample of 79 plants, 73 were readily classified as green, pink, or red. Annual growth averaged 4.1, 7.8, and 19.5 cm, respectively, for these color groups.

Statistical tests also showed highly significant differences between months and between sites; no differences were noted between years.

Differences in mean monthly growth were attributed to June growth. The June increment averaged 78.8 percent of the total annual growth on Site 1 over both years, and 49.0 percent on Site 2. Over both sites, 66.3 percent of the annual increment was added during June.

Dissimilar physical and biological attributes between the two sites could account for the difference in growth between sites. Site 1 was located on a moderate (10 percent) slope with a southeast exposure. Ponderosa pine overstory was relatively open, with approximately 390 stems per acre and a basal area of 120 square feet per acre. The percentage canopy cover of the overstory and the percent of ground covered by bearberry were 42 and 43 percent, respectively. Site 2, on a very gentle (3 percent) northwest-facing slope, had about 525 ponderosa pine stems per acre with a basal area of 148 square feet. The percentage canopy cover of the overstory was 55, while 37 percent of the ground surface was covered by bearberry.

Cumulative growth on Site 1 was greater in 1972 than in 1971, whereas plants on Site 2 grew more in 1971 (table 1). Growing season precipitation was substantially higher in 1972 (table 2). It is difficult to explain this response. The increased precipitation and slightly lower air temperatures coupled with the north exposure and higher canopy cover of the overstory on Site 2 may have resulted in microclimatic temperatures less than optimum for bearberry growth.

Table 2.--Monthly precipitation (inches) from base weather station, Black Hills Experimental Forest, during growing season, 1971-72

Month	1971	1972
May	5.93	4.24
June	1.87	9.09
July	1.31	3.69
August	.50	2.63
September	2.97	.71
Total, growing season	12.60	20.36

Recognition of Annual Growth

At the end of the second growing season, all plants were clipped at the point of tagging and annual growth characteristics were closely examined in the laboratory. Annual growth could be recognized by the presence of a node and by relative color changes along the stem. Nodes are quite distinctive and completely encircle the stem, appearing as a series of reddish or brownish scales (fig. 1). There was

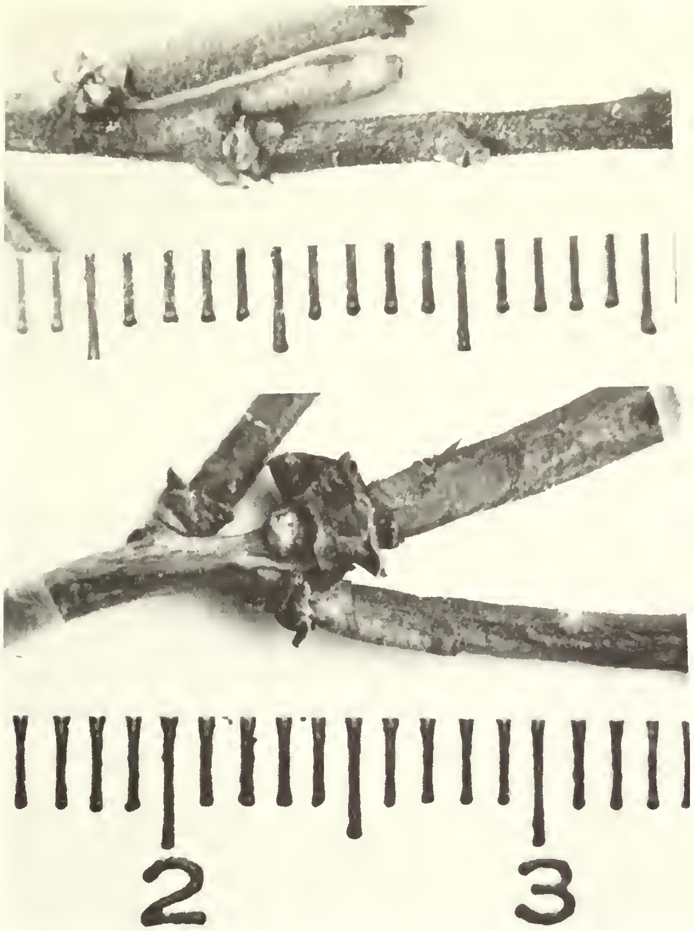


Figure 1.—Bearberry nodes—a series of overlapping scales that circle the stem. (Scale division = 1 mm)

some initial confusion in recognizing the point of annual growth, caused by the variability in growth and color between plants and by the fact that bearberry will occasionally branch above the node.

Color changes will also assist in differentiating between old and new growth. New growth on stems tends to be lighter in color and, on green stems, a pale, pinkish cast may also be evident.

There were no significant differences between the annual growth measurements by each of the observers and the known annual growth. All observers could readily recognize annual growth of bearberry after only a few basic instructions.

Literature Cited

Canfield, R. H.
1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Schneeweis, J. C., K. E. Severson, and L. E. Petersen.
1972. Part I. Northern Black Hills. p. 5-18. **In** Food habits of deer in the Black Hills. S.D. Agric. Exp. Stn. Bull. 606, 35 p.

Schenck, T. E., III, R. L. Linder, and A. H. Richardson.
1972. Part II. Southern Black Hills. p. 19-32. **In** Food habits of deer in the Black Hills. S.D. Agric. Exp. Stn. Bull. 606, 35 p.

ebruary 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-255

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Deer Use Changes after Root Plowing in Arizona Chaparral

Philip J. Urness[1]

Deer spent one-fourth to one-half as much time on root-plowed chaparral pastures seeded to lovegrass (80 acres) as in adjacent brushfields. Although high-quality forbs, of low availability in intact brush, increased greatly on treated southerly exposures, deer showed no apparent preference for these slopes. North and southeast exposures were used most heavily during spring and summer in intact brush, while south-facing slopes were used more heavily in fall and winter. Pellet-group counts showed no marked relationship between deer use and distance from cover up to 300 yards.

Oxford: 268.44:156.2. Keywords: chaparral, wildlife habitat, deer use, mechanical shrub control.

Chaparral occupies more than 4 million acres in central Arizona. The type occurs generally between 3,000 and 6,000 feet elevation, below juniper woodland or pine forest and above desert shrub or desert grassland. Management has emphasized range forage, watershed, and wildlife habitat values. Brush control, primarily to enhance livestock carrying capacity, water yield, and fire control, has become a prominent part of chaparral management programs on public lands.

Impacts of chaparral manipulation activities on wildlife, particularly deer, are the subject of considerable regional concern and research. The present study was an effort to assess deer response to conversion of shrub types to semipermanent grassland by mechanical methods on areas of moderate size. Root plowing effectively removed sprouting shrubs by grubbing subterranean rootcrowns; these species reestablish very slowly by seed.

The Study Area

Pond [1969] has described the biotic and physical aspects of the Tonto Springs Range area upon which this study was superimposed. Briefly, the area is characterized by hot summers and cool winters. Convectional storms in midsummer usually separate the very dry May-June and October-November periods. Precipitation is less than 18 inches annually, about equally divided between summer and winter patterns. Elevation is slightly below 5,000 feet, yet chaparral yields to desert grassland only a few hundred feet lower as a result of low effective precipitation and soil differences.

Temperature data are not available for the immediate study area. Mean temperature is about 35° F in January, 75° F in July. Extremes generally lie between 0° F and 100° F.

Soils are derived predominantly from granite outwash. They are residual, fine-textured, and shallow on the low ridges, alluvial, fine to coarse, and deep in swales. The area is drained to the southwest. Ridge lines trend southwest so most slopes face south-southeast or north-northwest.

Chaparral at Tonto Springs is relatively low in height, density, and species diversity. Shrub

---

[1] *Research Wildlife Biologist, located at the Station's Forest Hydrology Laboratory at Tempe, when study was conducted; Urness is now with Utah State University. The Laboratory at Tempe is maintained in cooperation with Arizona State University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

live oak[2] contributes most of the ground cover. It supplies abundant low-value browse and variable acorn crops of considerable forage value in midsummer. Much smaller but significant amounts of four other shrubs — skunkbush, hairy mountainmahogany, desert ceanothus, and wait-a-bit — occur as scattered individuals or sometimes dominate small stands. The first three are important browse for deer; wait-a-bit is seldom used. Cliffrose, Apache-plume, pointleaf manzanita, and alligator juniper are present but contribute little, quantitatively, to total cover or browse values.

Herbaceous understories in mature chaparral are poorly developed, especially on north-facing slopes. A number of cool- and warm-season grasses and scattered forbs occur on south-facing slopes and in swales. When shrubs are killed, particularly with considerable soil disturbance, a profusion of annual forbs rapidly becomes established.

Mule deer use the area yearlong, but concentrate most heavily during spring and summer. Compared to the treated pastures, cattle use was very light in adjacent chaparral (approximately 25:1).

Methods

The Tonto Springs Range study consisted of three replicates of four grazing comparisons in fenced pastures ranging from 40 to 200 acres. Root plowing was completed in 1961. Treated pastures were 40 or 80 acres in size.

Only the three 80-acre root-plowed units seeded to lovegrass were judged suitable for evaluating deer use differences. These pastures were selected on the basis that they were sufficiently large to demonstrate any correlations between deer use and distance from intact cover.

Root plowing reduced shrub density about 80 percent. Surviving shrubs, mostly shrub live oak, were hand treated with fenuron for a total kill in excess of 95 percent. However, some shrubs remained in all pastures. Both weeping and Lehmann lovegrasses were seeded, but only weeping lovegrass successfully established.

Vegetation Sampling

Treated and intact chaparral were compared through estimates of (1) shrub cover, (2) forage production, and (3) plant composition. Shrub canopy cover percentage and maximum height were estimated by species on 10- by 10-foot quadrats, using the permanent pellet-group transect stakes (described below) as plot markers. Forty plots were sampled for each slope exposure on both treated and intact stands.

Because forage production varied widely by season, plots were clipped at 3-month intervals. Ovendried weights of herbaceous forages by species, excluding seeded lovegrasses, were obtained on 9.6-foot^2 circular plots during 1968. Forty plots were clipped for each exposure in treated and intact stands using pellet-group-count transect stakes as plot markers.

Pellet-Group Counts

Fecal counts have been widely adopted as indexes of population size and range use (Eberhardt and Van Etten 1956, McCain 1948, Rogers et al. 1958, Smith 1964). Sampling intensities required for acceptable population estimates vary by density of groups, size of area, desired accuracy, and many other factors. Most studies indicate the need for large samples despite high populations and acceptance of relatively broad confidence limits on the estimate.

Deer densities in Arizona chaparral are low, and since man-hour costs to obtain precise estimates are prohibitive, sampling was minimal compared to those areas where the technique was developed. However, deer-use differences in the magnitude of two to three times were hypothesized between intact chaparral and root-plowed areas. Population estimates within ± 20 percent of the mean (95 times out of a 100) are sufficient in view of the large but indeterminate sampling error inherent in the fecal-count technique. Thus it was decided, in advance of sampling, that unless a difference exceeded the lowest population estimate by 100 percent, habitat selection had not changed significantly despite a considerable alteration of that habitat.

Sampling units consisted of permanent belt transects (10.89 by 400 feet or 1/10 acre) divided into four 100-foot segments. Ten transects located in treated and adjacent native chaparral parallel to and at 100-foot intervals from the boundary fence formed the basis for determining size-of-treatment effects on deer-use patterns. Transects were mechanically spaced with random starts along the treatment boundary. A tape stretched between permanent stakes, marking each 100-foot segment, served as the midline of the belt transect. Scattered or peripheral groups were counted if more than 25 individual pellets fell within the transect. Groups were cleared initially, then counted and cleared at 3-month intervals for 3 years.

---

[2] *Common and botanical names of plants mentioned are listed at the end of this report.*

Shrub live oak dominated the low chaparral at the Tonto Springs site. Herbaceous understories were poorly developed.

Root plowing plus followup chemical treatment reduced shrub density over 95 percent. Weeping lovegrass was established by seeding.

In addition, pellet counts showed a selection by deer for south exposures on root-plowed pastures and north slopes in intact chaparral. To verify this observation, five prevalent slope aspects — southeast, south, southwest, northwest, and north — were sampled. Twenty 100-foot transects located by random starts on these exposures in two of the paired pastures provided a better picture of habitat segment selection by deer.

Treatment Effects

Deer-habitat values are difficult to define in either chaparral or root-plowed stands. At best, "good" habitat is judged on vague criteria, and losses in one value may be more than compensated by increases in another (for instance, cover reduction may be offset by increased herbaceous forage production). Differences in vegetation on the two areas are sufficient to make objective measurements and subjective assessment of impacts important to land managers in their decisionmaking process.

Vegetation Complex

Root plowing, plus fenuron followup, strongly reduced shrub frequency and cover. Frequency (expressed as presence in 10- by 10-foot plots) averaged almost 100 percent for shrub live oak and 70 percent for skunkbush in untreated stands. Frequency of these species was reduced nearly in half on root-plowed slopes (table 1). Response of other woody plants was more variable; hairy mountainmahogany was nearly eliminated on all slopes, while broom snakeweed and wait-a-bit were reduced on some slopes and increased on others.

Coverage estimates revealed more about treatment impacts than did frequency, at least 5 to 10 years after treatment. Total shrub canopy cover averaged about 50 percent on intact stands and less than 10 percent on root-plowed areas. Shrubs in treated stands were half as tall as those in adjacent untreated brush.

Herbaceous species changed more markedly than shrubs. Production of forbs and native grasses increased greatly on southerly exposures (fig. 1), averaging over 300 pounds per acre in treated pastures compared to about 50 pounds per acre in chaparral. Production differences on northerly exposures were small, production was actually higher on untreated north slopes. Pond[3] estimated seeded lovegrass pro-

Table 1.--Treatment effects on woody plants in root-plowed stands compared to intact chaparral, Tonto Springs, Arizona

Treatment and exposure	Mean maximum height	Mean cover	Frequency (10- by 10-foot plots)				
			Shrub live oak	Skunkbush	Mountainmahogany	Snakeweed	Wait-a-bit
	Inches	*Percent*					
TREATED (ROOT PLOWED):							
SE	29	5	53	30	0	30	35
S	20	2	35	33	5	33	38
SW	23	3	30	28	0	53	32
NW	30	9	58	53	0	83	0
N	32	11	58	48	5	58	3
Mean	27	6	47	38	2	51	22
UNTREATED:							
SE	48	48	93	58	75	50	45
S	50	46	100	75	35	78	68
SW	55	45	98	45	40	50	28
NW	62	57	100	88	55	43	23
N	56	50	98	70	50	73	5
Mean	54	49	98	67	51	59	34

---

[3] *Unpublished production plot data are on file at the Forest Hydrology Laboratory, Rocky Mountain Forest and Range Experiment Station, Tempe, Arizona.*

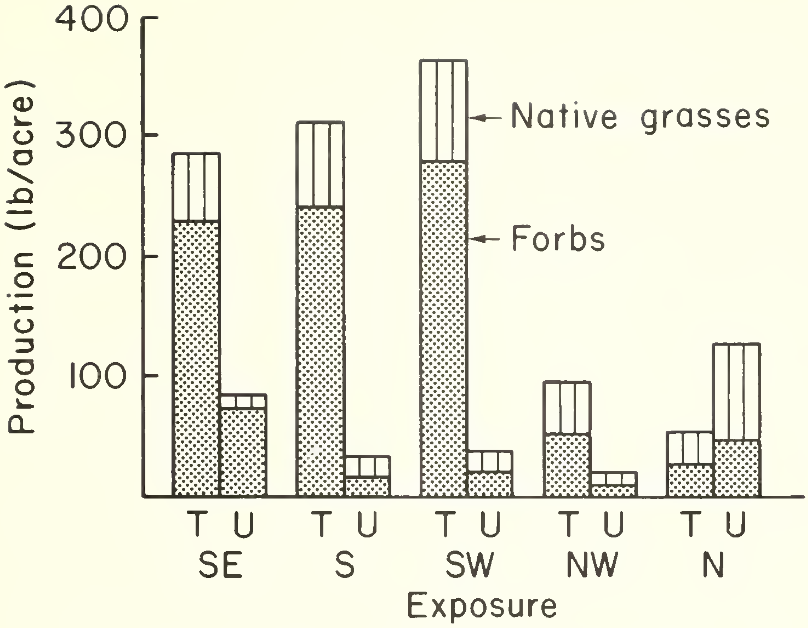


Figure 1.—Forb and grass production, excluding seeded lovegrass, from exposure plots in root-plowed chaparral (T) and untreated chaparral (U).

duction at about 1,200 pounds per acre. Thus total herbaceous forage production on treated south slopes apparently was 20 to 30 times greater than in intact chaparral. Deer use lovegrass only lightly, however, so effective increases in usable forage were more on the order of sixfold.

Deer Use Patterns

Deer consistently used treated areas less (table 2). Time spent by deer on the root-plowed pastures was roughly one-half to one-fourth that in intact brush. Except for the 1967 estimates, which were affected by a severe, early-December storm, the deer densities on untreated chaparral were relatively uniform. Year-to-year differences on root-plowed areas were highly variable, possibly reflecting fluctuations in production of preferred forage species. Precipitation timing and temperature strongly influenced forb growth on the treated areas. Dry, cold winters produced little spring growth of forbs.

Table 2.--Deer density estimates on treated (root plowed) and intact chaparral, Tonto Springs, Arizona

Sample and treatment	[1]1966	1967	1968	1969	Mean
	Deer per section per year				
PARALLEL TRANSECTS:					
Treated	7.5	1.7	0.7	--	3.3
Untreated	10.0	3.6	8.0	--	7.2
EXPOSURE TRANSECTS:					
Treated	--	--	1.4	2.7	2.1
Untreated	--	--	9.3	8.2	8.8

[1] Counts actually are for a period from April through March of the next year.

The value to wildlife of "edges" where vegetation types or successional stages meet is almost axiomatic among biologists. Indeed, many studies have shown these areas receive greater use by deer and other big game (Reynolds 1966, Taber and Dasmann 1958). However, pellet-group transects parallel to and in 100-foot increments from the treatment boundary did not indicate any preference by deer for the immediate border area (fig. 2). If anything, there was a slightly negative response in the first 100 feet out in either direction from the treatment boundary.

Within the limitation of the 80-acre pastures sampled, there was no indication that use declined toward the center of the treatment until the 10th transect. This suggests treatments of 80 acres or less are completely used in this area. At some greater size, use levels likely would decline as distance from cover increased.

Exposure plot samples showed a heavier use of southeast and north slopes in spring and summer in untreated brush, presumably because they receive less intense insolation. Conversely, south and southwest slopes were used slightly more in winter, northwest slopes were used least.

Effects of slope on deer use in root-plowed areas were weak, although north slopes were more important in spring. Uniform use of treated slopes was not expected, since forb production was much higher on southerly exposures (fig. 1).

Discussion

The consistently lower deer use of 80-acre root-plowed sites, specifically those with chemical followup, could, simplistically, be interpreted as a loss of habitat values in the magnitude of 50 to 75 percent. Such a view is questionable, however, because pellet-group counts index time spent on areas, not relative values received. That is, in comparing root-plowed pastures to intact brush we are, in essence, judging areas where deer only feed against areas where feeding as well as all other activities are carried on (resting, ruminating, etc.).

Although it can be stated with reasonable assurance that deer spend from one-half to one-fourth as much time on heavily treated areas as in surrounding brushfields, what is gained during this period may compensate for reduced cover and other values (provided treatment size is moderate). Moreover, root plowing without chemical control of surviving shrubs would have less impact on deer use, as noted by Loe and White (1972). Much of the increased forb production on root-plowed pastures consists of high-quality species of low occurrence in brushfields. These are the kinds of forages most needed to supplement browse diets that are often low in certain nutrients (Swank 1958, Taber and Dasman 1958, Urness et al. 1971).

Although this study was limited in scope, several guidelines can be offered to chaparral land managers whose objectives are to improve livestock carrying capacity and retain deer habitat values. First, regardless of acreage treated, the control areas should not exceed about 300 to 400 yards in width. The obvious value of brushland areas suggests a fairly high percentage of chaparral be left intact, although no absolute formula can be provided. Until more exhaustive studies are made, perhaps no more than 50 percent of any area should be treated. This recommendation is consistent with the value of brushfields for livestock recognized by Pond et al. (1968).

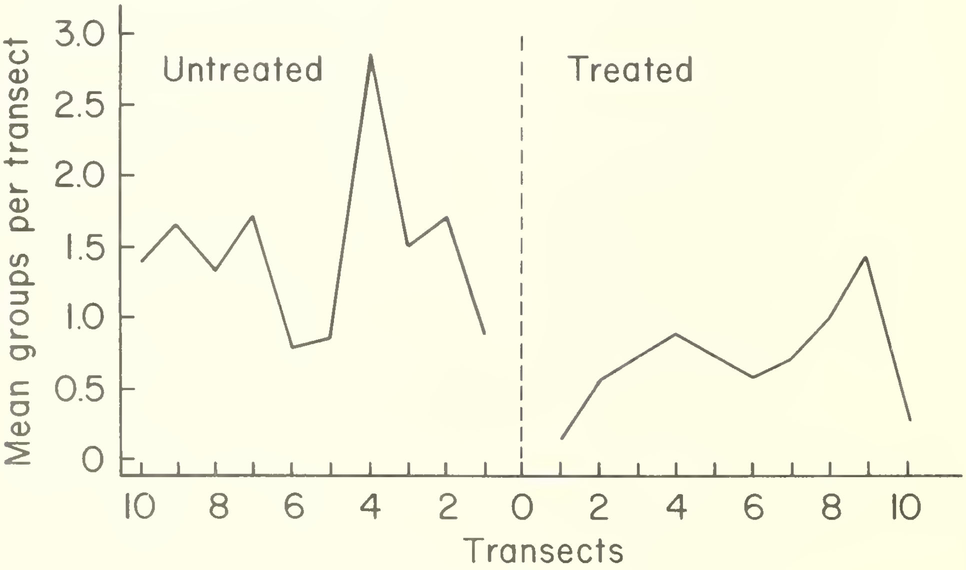


Figure 2.—Mean deer pellet groups on transects parallel to and in 100-foot increments from the root plow: chaparral boundary.

Furthermore, specifying that only certain slopes be treated is not advisable. The data indicate that deer shift seasonally in the habitat segment they select (fig. 3). North slopes in chaparral were used more extensively in spring and summer, while south-facing slopes were more important in fall and winter. Therefore, some intact brush should be left on all exposures in reasonable juxtaposition. In this area, characterized by numerous low parallel ridges, it is possible to root plow in irregular strips and small patches, designing unobtrusive patterns which treat and retain some areas on all slope situations.

Large treated blocks, which are objectionable from almost any esthetic criterion, are not compatible with optimum diversity. Diversity is an important consideration since much criticism of public rangeland improvements has alleged, sometimes unfairly, that they benefit the livestock industry at the expense of wildlife. Loe and White (1972), however, showed that root plowing increased slightly the number of bird species represented in the general area, and increased total bird numbers over 30 percent. Small mammal populations differed only slightly between root-plowed and intact stands.

In conclusion, there is a potential adverse impact of root plowing on habitat values for deer and other wildlife only if treatments are large and complete. Properly done, treatments should not reduce overall populations if sufficient cover is retained. The creation of a high-quality forage resource in treated pastures no doubt increases the value of adjacent chaparral, but it is not certain that this resource affects deer population levels materially.

Literature Cited

Eberhardt, L., and R. C. Van Etten.
1956. Evaluation of the pellet group count as a deer census method. J. Wildl. Manage. 20:70-74.

Loe, Steve A., and Leslie D. White.
1972. Rootplowing on the Prescott National Forest and its effects on birds and mammals. USDA For. Serv., Prescott Natl. For., 21 p. Prescott, Ariz.

McCain, R.
1948. A method for measuring deer range use. Trans. N. Am. Wildl. Conf. 13:421-441.

Pond, Floyd W.
[1969]. Grazing values on undisturbed chaparral versus areas converted to grass: the Tonto Springs Range. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn. 13 p. Fort Collins, Colo.

Pond, Floyd W., James L. Kukal, and Eddie Balmes.
1968. Chaparral: a good cow home during deep snow. Ariz. Cattlelog 26(2):17, 18, 20, 22.

Reynolds, Hudson G.
1966. Use of openings in spruce-fir forests of Arizona by elk, deer and cattle. U.S. For. Serv. Res. Note RM-66, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

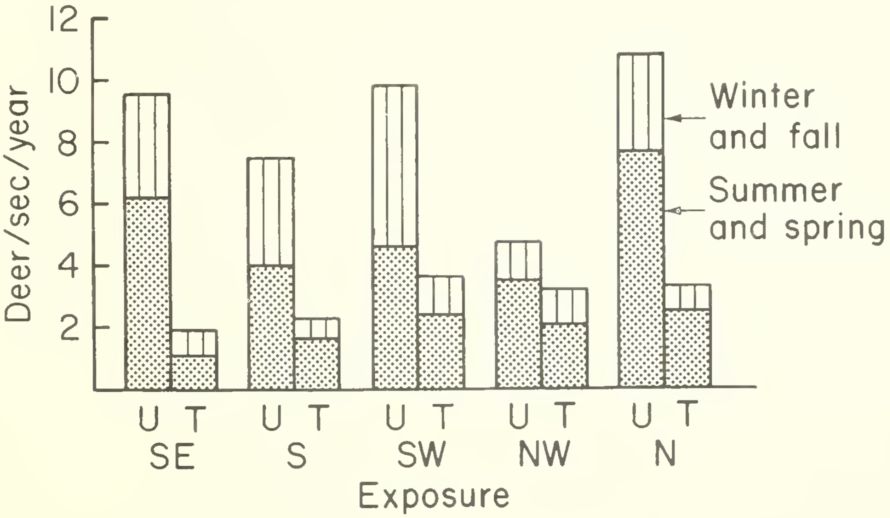


Figure 3.—Seasonal deer use of predominant slopes in untreated chaparral (U) and root-plowed pastures (T), in terms of the seasonal ratio of total use expressed as deer per section per year.

Rogers, Glenn, Odell Julander, and W. Leslie Robinette.
1958. Pellet-group counts for deer census and range-use index. J. Wildl. Manage. 22:193-199.

Smith, Arthur D.
1964. Defecation rates of mule deer. J. Wildl. Manage. 28:435-444.

Swank, Wendell G.
1958. The mule deer in Arizona chaparral and an analysis of other important deer herds. Ariz. Game & Fish Dep. Wildl. Bull. 3, 109 p.

Taber, Richard D., and Raymond F. Dasmann.
1958. The black-tailed deer of the chaparral; its life history and management in the north coast of California. Calif. Dep. Fish & Game, Game Bull. 8, 163 p.

Urness, Philip J., Win Green, and Ross K. Watkins.
1971. Nutrient intake of deer in Arizona chaparral and desert habitats. J. Wildl. Manage. 35:469-475.

Common and Botanical Names of Plants Mentioned

Apache-plume	*Fallugia paradoxa* (D. Don) Endl.
Ceanothus, desert	*Ceanothus greggii* A. Gray
Cliffrose	*Cowania mexicana* D. Don
Juniper, alligator	*Juniperus deppeana* Steud.
Lovegrass, Lehmann	*Eragrostis lehmanniana* Nees
Lovegrass, weeping	*Eragrostis curvula* (Schrad.) Nees
Manzanita, pointleaf	*Arctostaphylos pungens* H.B.K.
Mountainmahogany, hairy	*Cercocarpus breviflorus* A. Gray
Oak, shrub live	*Quercus turbinella* Greene
Skunkbush	*Rhus trilobata* Nutt.
Snakeweed, broom	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Wait-a-bit	*Mimosa biuncifera* Benth.

Agriculture—CSU, Ft. Collins

arch 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-256

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Sleeved Pit Gage for Summer Precipitation

Kendall L. Johnson[1]

Performance of a pit gage was greatly improved by using a 5-gallon cream can as a sleeve. Four years of experience have shown the improved pit gage to be nearly ideal for keeping the gage vertical and free of soil, and facilitating quick removal and reinsertion of the gages for periodic weighing.

Oxford: 111.77. Keywords: Rain gages.

Measurement of summer precipitation in treeless, windswept areas has long been a severe problem. Raindrops transported beyond their free-fall trajectory by wind often introduce large and unacceptable errors in measurement. Solutions to this problem have centered on (1) protecting the gage against wind, or (2) sinking the gage into the ground to remove it from the wind's influence as much as possible.[2] This last approach has become known as the standard sunken or pit gage.

Most pit gage installations suffer from a basic defect: inadequate control of the pit. Typically, the initial hole is made only slightly larger than the gage itself. Over time, however, sluffing of the pit sides introduces several problems. First, keeping the gage vertical within the widening hole becomes increasingly difficult. Second, the gage must be cleaned of soil material slumping against its sides at every service date, particularly where data are based on weight of the can and its contents. Third, the widening hole renders splash shields less effective and finally unusable. These problems together steadily reduce the pit gage's effectiveness against wind, make the data less reliable, and finally lead to abandonment of the site.

An improved pit gage to overcome these problems was developed at our research site on the windswept plains of south-central Wyoming.

Pit Gage Design

One obvious solution to the problems described is to equip the pit gage with a ground sleeve. A properly installed sleeve would keep the gage vertical at all times, shield it from soil material, facilitate the use of splash shields, and allow ready removal and reinsertion of the gage at every service date. Although various kinds of metal, masonry, or plastic sleeves could be used, we have found that a 5-gallon cream can from a local dairy makes a near-perfect sleeve. Its inside diameter of 8½ inches and its length of about 20 inches make it nearly ideal for the standard 8-inch-orifice rain gage. In addition, its stainless steel construction renders it virtually immune to soil corrosion.

The pit gage should be installed on a level, open site, free of any shadowing by shrubs or other objects within an angle of 45° from the vertical gage centerline. After a hole large

---

[1] *Research Hydrologist, located at Station's Research Work Unit at Laramie, in cooperation with the University of Wyoming; Station's central headquarters at Fort Collins, Colorado, in cooperation with Colorado State University.*

[2] *Kurtyka, J. C. 1953. Precipitation measurements study. Ill. Water Surv. Invest. 20, 178 p.*

enough to accept the cream can has been excavated, a bed of gravel 2 to 4 inches thick is installed to promote drainage away from the gage. The cream can, with a hole cut in its bottom, is placed on the gravel and carefully backfilled in a vertical position so that it protrudes above the soil surface about ½ to 1 inch (fig. 1). Additional gravel is placed within the sleeve to bring the gage orifice about ½ to 1 inch above the sleeve lip, a height sufficient to keep most surface debris out of the gage.

A splash shield, formed of two 2- by 2-foot squares of bulk furnace filter or other suitable material, is secured to the ground surface around the gage orifice in an offset diamond pattern (fig. 1). This dimension has been adequate for our use, keeping the majority of large raindrops and most hailstones from splashing or bouncing into the gage. The pit gage is completed by installation of a rodent screen of ¼-inch hardware cloth, suspended 8 to 10 inches below the orifice from wires either hooked over the gage lip or punched into the gage sides. The rodent screen has effectively kept these small animals out of the gage contents, thereby eliminating a problem affecting precision.

The sleeved pit gage can be installed and put into service quickly, in most instances under an hour. Cost of materials will depend on prices paid for the cream can or other sleeve material. We were able to find old cans for 50¢ each; total costs did not exceed $7, excluding fencing against livestock where necessary.

Applications

A network of 20 sleeved pit gages has functioned perfectly over a 4-year period (fig. 2). The gages remained vertical and free of soil material, and were quickly removed and reinserted during periodic weighing. Because data collection is rapid and easy (fig. 3), more intensive sampling networks can be maintained at the same operating costs.

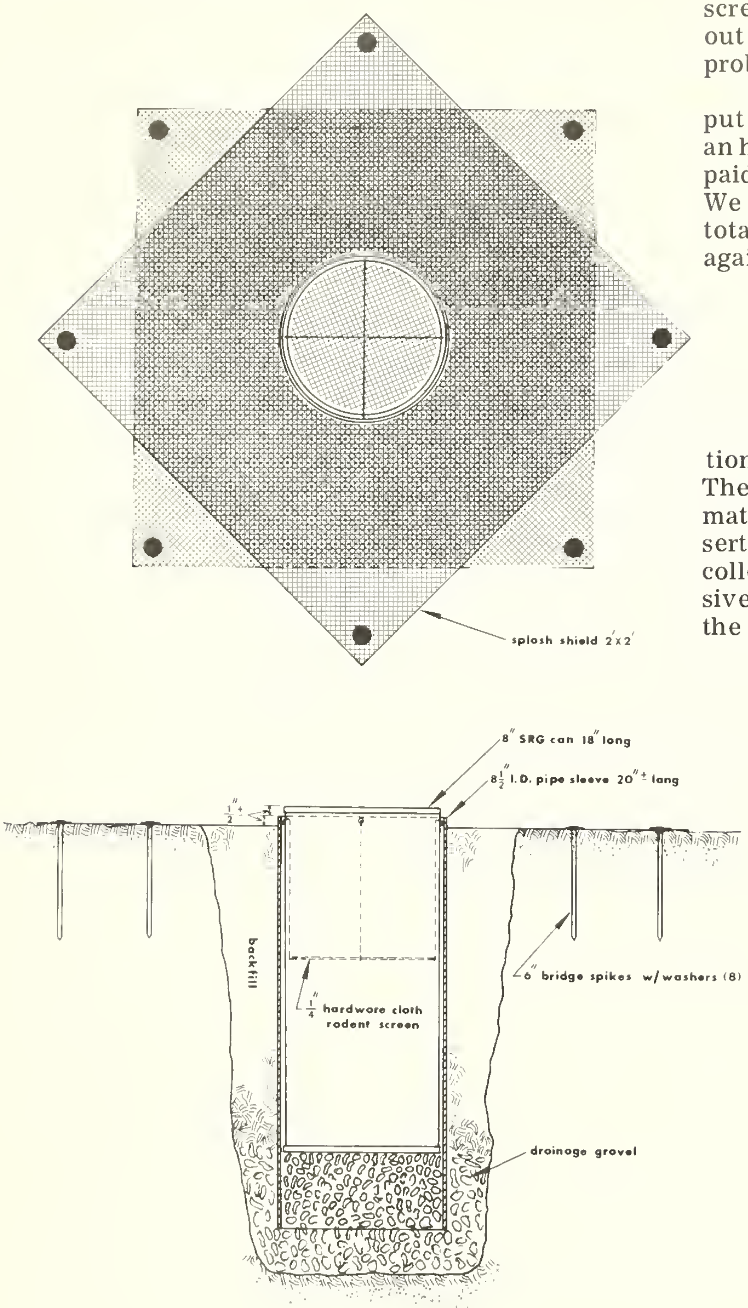


Figure 1.—Cutaway diagram of a sleeved pit gage installation.

Figure 2.—A functioning sleeved pit gage in a typical windswept situation.

Figure 3.—The gage can be easily lifted out of its sleeve for servicing.

arch 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-257

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Mulching Planted Ponderosa Pine Seedlings In Arizona Gives Mixed Results

W. J. Rietveld and L. J. Heidmann[1]

Mulching of 3-0 spring-planted ponderosa pine seedlings on difficult sites with clear and black polyethylene, petroleum-emulsion, volcanic cinders, woodchips, and dead grass sod was generally ineffective. None of the mulches significantly improved survival, but in a few instances polyethylene increased height growth. Black polyethylene was the only effective mulching material that persisted through the study; the other mulches deteriorated rapidly or were easily disturbed, and became ineffective.

Oxford: 232.425.3:235. Keywords: Mulches, *Pinus ponderosa*.

Guidelines for artificial reforestation in the Southwest (Schubert et al. 1969, 1970) make little mention of mulching materials and techniques because of lack of research. Various attributes of mulches—retention of soil moisture, possible increase in soil temperature, and protection of seedlings from competition—along with successful experiences elsewhere (DeByle 1969, Fraser 1968, Loewenstein and Pitkin 1970, Takatori et al. 1963) prompted experimentation with mulching materials to improve planting success on difficult sites.

We found, however, that a one-time application of mulches at the time of planting gives mixed results. Many problems were encountered, several of them unexpected, which resulted in either the mulch being destroyed or rendered ineffective.

Study Areas and Methods

The study consisted of two plantations of 3-0 ponderosa pine (Pinus ponderosa Laws.) established on mechanically prepared sites (except for herbicide plots at A-1 Mountain)—one on watershed 12 (clearcut) of the Beaver Creek Project in 1967, and one on the A-1 Mountain burn, near Flagstaff, in 1968. Both locations were difficult planting sites, with site index around 55 (Minor 1964) and stony clay loam soils. At each location, the experimental plot consisted of four replications of six mulch treatments: (1) petroleum mulch,[2] a water emulsion of petroleum resins sprayed on the ground, (2) black polyethylene, (3) clear polyethylene, (4) volcanic cinders, (5) woodchips (watershed 12 only), (6) herbicide-killed grass (A-1 Mountain only), and (7) no mulch. Each mulched spot was 18 inches square. The polyethylene squares were slit in the center to fit over the seedlings, and were weighted down with rocks; cinder and woodchip mulches were 2 inches deep; the dead grass mulch was achieved by spraying live grass cover with dalapon and planting seedlings in the dead sod.

Soil temperature and moisture at 2- to 4-inch and 10- to 12-inch depths under the mulches were measured with thermocouples and moisture resistance blocks, respectively. Data were

---

[1] *Plant Physiologist and Silviculturist, respectively, located at Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *ENCAP Agricultural Mulch was supplied by the ESSO Research and Engineering Company. Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

also taken on seedling survival, height growth, and time of root-growth initiation (some seedlings were excavated) and bud burst

Results and Discussion

The first-year results at watershed 12 were disappointing (table 1). Neither survival nor total heights of mulched seedlings were significantly different from the controls. At A-1 Mountain, on the other hand, most mulches slightly decreased survival, but improved height growth of surviving seedlings (table 1). Only "dead grass" significantly decreased survival; the grass was not completely killed, and competed for moisture. Other studies at nearby locations have shown that, with complete grass kill, survival may be as high as 99 percent after 1 year (Heidmann, unpublished data). All of the treatments, except the dead grass, significantly increased first-year height growth of surviving trees at A-1 Mountain. The polyethylene-mulched seedlings grew most.

The results were slightly different at the time the study was terminated in 1970 (table 1). Overall survival dropped considerably, but the first-year trends persisted. Survival was highest on the control plots, but only the dead grass treatment was significantly lower. Seedlings mulched with black polyethylene at watershed 12 and both polyethylenes at A-1 Mountain were significantly taller.

The mulches had no detectable effect on time of initiation of root growth or bud burst.

During the first growing season, soil moisture was significantly higher under the polyethylene and cinder mulches, while soil temperature was reduced under the cinder and woodchip mulches at the 2- to 4-inch depth only. None of the mulches had any consistent influence on soil moisture or soil temperature in the root zone (10 to 12 inches), although variation was high. Apparently, height growth of the seedlings was favored by the combination of higher soil moisture and warmer soil temperature under the polyethylene mulches, but not by higher soil moisture with cooler soil temperature under cinders.

Interfering factors contributed to the lack of response to mulching. Mulches were often destroyed or rendered ineffective. Many of these factors were unsuspected at the beginning of the experiment. The petroleum mulch rapidly deteriorated from the action of weathering processes — especially freezing and thawing, solar radiation, and soil microorganisms — and finally disappeared from the impact of large raindrops and hailstones. It did not remain long enough to exert much influence. The woodchip mulch also washed away quickly. The clear polyethylene mulch acted as a greenhouse for weeds which developed vigorously beneath it and bulged the mulch up from the ground. Moreover, the mulch disintegrated from solar radiation by late summer of the first growing season. The black polyethylene mulch did not suffer these problems. Overall, the black poly-

Table 1.--Survival and height of planted ponderosa pine seedlings, by mulch treatment, at end of first year and at end of study

Mulch	Watershed 12 (planted 1967)				A-1 Mountain (planted 1968)			
	Survival		Height		Survival		Height	
	1968	1970	1968	1970	1969	1970	1969	1970
	Percent		*cm*		*Percent*		*cm*	
Petroleum	65	31.3	7.0	24.9	71.0	53.8	10.8*	15.2
Black polyethylene	61	37.5	7.3	25.8**	78.3	56.3	12.3*	19.0*
Clear polyethylene	65	42.5	7.3	25.4	63.8	51.3	12.6*	18.6*
Cinders	64.5	40.0	5.5	22.8	92.0	53.8	9.8**	12.8
Wood chips	69	26.3	6.1	24.5	--	--	--	--
Dead grass	--	--	--	--	53.3*	32.5**	6.9	11.4
Control	63	35.8	6.7	23.9	80.0	62.5	8.0	13.0

* Significant at 0.01 level.
** Significant at 0.05 level.

ethylene and cinder mulches were most persistent.

A larger mulched area would most likely produce an increment of improved survival and growth, but would still be subject to the interfering factors discussed above.

Although the effect of the mulches on survival in this study was disappointing, mainly because the mulches broke down, a study conducted in the same area in 1960 showed that a mulch of three rocks significantly improved survival (Heidmann 1963). The rocks tend to stay in place, and thus continue to provide beneficial effects. Dead grass sod can effectively conserve soil moisture (Heidmann 1969), but the grass cover should be uniformly heavy and killed completely by the herbicide.

Conclusions

It was not possible to assess the benefit of these mulches over a several-year period since the mulches deteriorated and the benefits were lost. Therefore, the results at the conclusion of the study in 1970 are not as meaningful as those after 1 growing season. Replacing disturbed mulches is not practical. Mulches which stay in place, such as rocks or other relatively unmovable material, are to be preferred.

On the basis of this study, the value of mulches as an aid to survival and growth of ponderosa pine seedlings in the Southwest remains uncertain. Even though some of the mulches improved height growth significantly, survival was still unacceptable. On difficult planting sites, satisfactory results can be achieved by using complete site preparation, planting vigorous trees carefully, and giving them initial protection from competition, wildfire, and livestock.

Literature Cited

DeByle, Norbert V.
1969. Black polyethylene mulch increases survival and growth of a Jeffrey pine plantation. Tree Planters' Notes 19(4):7-11.

Fraser, J. W.
1968. Mulches and seed spot temperatures. For. Chron. 44:64-65.

Heidmann, L. J.
1963. Effects of rock mulch and scalping on survival of planted ponderosa pine in the Southwest. U.S. For. Serv. Res. Note RM-10, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Heidmann, L. J.
1969. Use of herbicides for planting site preparations in the Southwest. J. For. 67:506-509.

Loewenstein, H., and F. H. Pitkin.
1970. Ponderosa pine transplants aided by black plastic mulch in Idaho plantation. Tree Planters' Notes 21(4):23-24.

Minor, Charles O.
1964. Site-index curves for young-growth ponderosa pine in northern Arizona. U.S. For. Serv. Res. Note RM-37, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Schubert, Gilbert H., Robert W. Pearl, and L. J. Heidmann.
1969. Here's how — a guide to tree planting in the Southwest. USDA For. Serv. Res. Pap. RM-49, 18 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Schubert, Gilbert H., L. J. Heidmann, and M. M. Larson.
1970. Artificial reforestation practices for the Southwest. U.S. Dep. Agric., Agric. Handb. 370, 25 p.

Takatori, F. H., L. F. Lippert, and F. L. Whiting.
1963. Petroleum mulch aids germination and stand establishment in preliminary vegetable crop studies. Calif. Agric. 17(3):2-3.

Agriculture—CSU, Ft. Collins

March 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-258

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

The Independence of the Point-to-Point Variations in Windspeed and Temperature in a Lodgepole Pine Stand

James D. Bergen[1]

The correlation between local variations in air temperature and windspeed at particular levels in a pine stand are examined for evidence of persistent momentum transport by thermal convection. The results argue against such an effect; the point-to-point deviations appear to be independent.

Oxford: 111.84;111.2;111.5;907.3;U536.2. Keywords: Forest meteorology, convection, micrometeorology, air temperature, wind, *Pinus contorta*.

Recent measurements of windspeed and temperature profiles in an even-aged lodgepole pine stand indicated large point-to-point differences for both variables measured between trees at the same height and time.[2] [3] These differences appeared to be random, with no trend along either the downwind or crosswind direction. Such variation raised the question as to whether the subcanopy flow consists of a network of local density flows in response to the horizontal pressure gradients generated by the temperature field, rather than the large-scale pressure gradient.

If subcanopy thermal circulations were this pronounced, we would expect a strong negative correlation throughout the live crown between windspeed and temperature. Locations where air temperatures were lower than average would be regions of descending currents, bringing high-speed air from above the canopy. In contrast, the "warm spots" would be regions of ascent, with low-speed air moving into the above-canopy flow. On the other hand, if cool spots in the stand were associated with higher-than-average drag, the regions of strong downward momentum flux would also have offsetting above-average drag. The temperature does not appear to have any significant correlation with the local canopy cover for these locations, however,[4] and the canopy cover is generally conceded to be a relatively good index of local foliage density.

The temperature profiles were measured at noon on clear days with shielded bead thermistors at each of 6 levels at 17 locations. Windspeed profiles were measured during clear weather at the same heights. Details of the measurements may be found in two previous papers;[2] [3] full data on the physical structure of the stand appears in a paper by Gary.[5]

---

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

[2] *Bergen, James D. 1971. Vertical profiles of windspeed in a pine stand. For. Sci. 17:314-321.*

[3] *Bergen, James D. Vertical air-temperature profiles in a pine stand: Spatial variation and scaling problems. (In press, For. Sci.)*

[4] *Bergen, James D. Variation of air temperature and canopy closure in a lodgepole pine stand. USDA For. Serv. Res. Note RM-253, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.*

[5] *Gary, H. L. Crown structure and vertical distribution of biomass in a lodgepole pine stand. (Manuscript in preparation at the Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.)*

In the calculation to follow, the noon temperature profiles have been scaled by the temperature drop above the canopy; that is,

$$T' = \frac{T - T_h}{T_a - T_b}$$

where T_h is the temperature at the 22-m height and T_a the temperature at 11.5 m on a fixed tower within 30 m of the points of measurement. This scaling is examined in detail in a previous paper.[3] The windspeed (U) has been scaled by the friction velocity (U_*) above the canopy as estimated from windspeeds on the reference tower.[2] Windspeed and temperature measurements were restricted to times when the flow was southwesterly above the canopy. The profiles of the scaled speed were found to be relatively independent of U_* and of the Richardson's number at the reference tower.

Compatible wind and temperature profiles were available for 17 points (fig. 1). Linear correlations were computed over these points for the average scaled temperatures (T') and speeds (U/U_*) in the subcanopy, the lower canopy, and the upper canopy. These averages were computed for the consecutive pairs of measurements at the 1, 2.5, 4.0, 5.6, 7.0, and 8.5-m levels for the airspeed and temperature averages, and are shown in table 1.

Table 1.--Correlation matrix, temperature, and scaled windspeed

Canopy level	Sub-canopy	Middle canopy	Upper canopy
Subcanopy:			
Windspeed	1.00	0.65	0.81
Temperature	1.00	.77	.59
Windspeed vs. temperature	- .10	- .05	- .21
Middle canopy:			
Windspeed		1.00	.38
Temperature		1.00	.45
Windspeed vs. temperature		- .10	- .34
Upper canopy:			
Windspeed			1.00
Temperature			1.00
Windspeed vs. temperature			.37

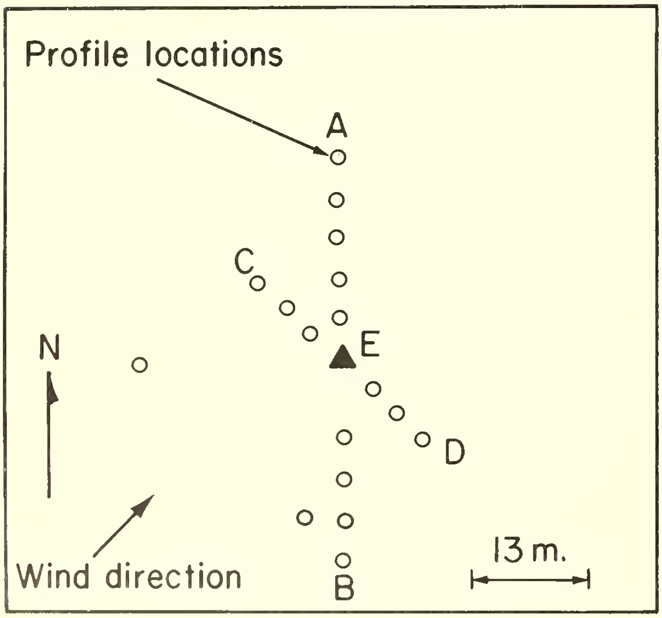


Figure 1.—Location of temperature-windspeed profiles.

As may be seen, there is no substantial negative correlation between temperature and windspeed at any level. In fact, the wind and temperature profiles show relatively little coherence as judged from the second and third columns of the table.

To the extent that the horizontal temperature differences and the average temperatures computed for the locations of figure 1 are representative of the local stand temperature field the local pressure distribution must be determined by either the synoptic gradient or the flow above the canopy. In particular, there appears to be no appreciable transport of momentum into the canopy by large-scale thermal currents.

The apparent independence of the wind and temperature fields would also tend to support the use of stand averages of temperature and windspeed when using energy balance techniques to estimate evaporation at the forest floor.

Agriculture—CSU, Ft. Collins

pril 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM - 259

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Roundheaded Pine Beetle[1] Outbreak in New Mexico:

Associated Stand Conditions and Impact

Robert E. Stevens[2] and Harold W. Flake, Jr.[3]

The roundheaded pine beetle, Dendroctonus adjunctus Blandford, infests Pinus ponderosa Laws. in mixed second-growth stands in the Sacramento Mountains of south-central New Mexico. In six areas, losses ranged from near 0 to over 50 percent of the ponderosa pine stand component, both in number of trees and basal area. Overall, living ponderosa pine averaged 45.8 ft^2 basal area per acre, while infested and dead averaged 15.8 ft^2. Infested trees averaged 6.5 inches d.b.h.; uninfested trees, 7.4 inches.

Oxford: 145:719.92. Keywords: Scolytidae, *Dendroctonus adjunctus, Pinus ponderosa.*

The roundheaded pine beetle infests ponderosa pine, Pinus ponderosa Laws., in the southwestern United States, and other species of pines southward to Guatemala (Chansler 1967). In the past 5 years it has caused considerable tree mortality in the Sacramento Mountains of south-central New Mexico. One survey report[4] refers to losses such as ". . . basal area stocking reduced up to 50 percent in some areas . . ." and "... up to 40 infested trees per acre in selected areas."

Since an extensive gross acreage has been infested during the recent outbreak (fig. 1), land managers — primarily private individuals, Forest Service, and Bureau of Indian Affairs — have needed more information on how much damage the infestation has actually caused. Researchers have needed similar information to judge how much and what kind of effort to allocate to the roundheaded pine beetle. Data were therefore collected in 1971 and 1972 to determine impact — solely on the timber stands themselves — of the roundheaded pine beetle in representative infestation areas in the Sacramento Mountains.

We attempted to answer these questions: What were affected stands like before the beetle outbreak? How much has the infestation changed stand density? Has species composition been altered? What size trees are attacked? What tree crown classes are most likely to be attacked? How are trees growing in the infested stands? Is there regeneration to replace lost trees? How much dwarf mistletoe is present in the infested stands?

---

[1] *Dendroctonus adjunctus Blandford (Coleoptera: Scolytidae).*

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

[3] *Entomologist, Southwestern Region, USDA Forest Service, Albuquerque, New Mexico.*

[4] *Flake, Harold W., Jr. 1970. Unpublished forest insect survey report on file at Southwestern Region, USDA For. Serv., Albuquerque, N.M.*

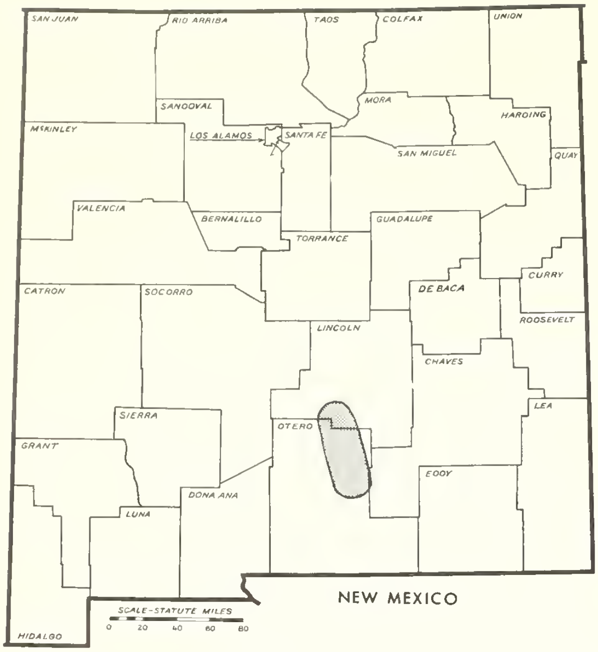


Figure 1.—Roundheaded pine beetle infestation area, New Mexico, 1968-72.

Methods

Six sample areas were chosen to represent what we judged were typical infested stands. Areas 1, 2, and 3 (1/20-acre plots) were examined in 1972; areas 4, 5, and 6 (1/10-acre plots) were examined in 1971.

Area	Approximate location	Approx. infested acreage	No. plots
1	4 mi NE Cloudcroft Sec. 21, T15S, R13E	80	40
2	5 mi NW Sacramento Sec. 21, T17S, R13E	200	40
3	7 mi N Ruidoso Sec. 20, T10S, R13E	80	40
4	4 mi NW Sacramento Sec. 20 & 21, T10S, R13E	190	92
5	8 mi NW Mayhill Sec. 24, T15S, R14E	230	115
6	6 mi NE Cloudcroft	528	248

The infested stands included varying mixtures of ponderosa pine, southwestern white pine (P. strobiformis Engelm.), white fir (Abies concolor (Gord. and Glend.) Lindl.), pinyon (P. edulis Engelm.), juniper (Juniperus spp.), oak (Quercus spp.), Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), and quaking aspen (Populus tremuloides Michx.).

Circular plots were established at 2-chain intervals along parallel lines generally 5 or 10 chains apart. Within each plot we recorded species and diameter of all trees over 4 inches d.b.h. Ponderosa pines were classified as alive, infested, or recently dead (killed during the current beetle outbreak). Practically no older snags were present, and no effort was made to record them. Mortality in species other than ponderosa pine was essentially zero.

In areas 1, 2, and 3, additional information was obtained on: (1) presence or absence of dwarf mistletoe, (2) amount of regeneration from seedlings to saplings up to 4 inches d.b.h. within four square 1-milacre subplots clustered at plot centers, (3) crown class of each ponderosa pine, and (4) recent growth of a single dominant or codominant ponderosa pine as indicated by increment cores.

Results

Losses attributed to beetle activity varied considerably between sample areas. Reduction in the ponderosa pine component ranged from more than 50 percent in area 1 to about 10 percent in areas 3 and 4 (table 1). Current beetle-caused mortality, as indicated by numbers and basal area of currently infested trees, varied from zero in area 5 to almost 10 percent of the green stand in area 1 (table 2). Overall (all areas combined), the remaining green, uninfested ponderosa pine stand averaged 45.8 ft^2 basal area per acre; 15.8 ft^2 were infested or dead.

Average diameter of living and killed trees was generally about the same (table 2), 7.4 and 6.5 inches d.b.h. respectively, when averages for all six sample areas are combined. Area 3, where several large trees were infested, was an exception. There may be a tendency for the larger trees to be infested if beetle activity is relatively light. This is seen in areas 4 and 6, in which currently infested trees make up 0.9 ft^2 basal area per acre or less.

Species composition was altered in several instances. In area 1, ponderosa pine comprised about 60 percent of the basal area prior to infestation, but in 1972 it made up only about 30 percent; Douglas-fir replaced pine as the dominant species (table 1). At the other extreme, species composition in areas 3, 4, and 5 was hardly affected.

Table 1.--Live basal area (ft² per acre) of all species in 1972, and ponderosa pine only in 1968 (before infestation), roundheaded pine beetle infestation area, Lincoln National Forest, New Mexico[1]

Area	Ponderosa pine 1968	Ponderosa pine 1972	Southwestern white pine	White fir	Douglas-fir	Pinyon	Juniper	Oak	Aspen	Total
1	62.0± 6.5	26.7±3.0	4.1±1.4	0.4±0.2	41.2±4.7	0	0	1.0±0.8	0.8±0.8	74.2
2	114.0±10.4	79.6±8.7	4.8±3.5	0	15.9±4.2	0	1.3±1.3	5.7±2.1	0	107.3
3	36.1± 5.4	32.7±5.3	0	0.3±0.2	5.0±2.3	12.7±2.6	8.8±2.6	3.5±1.5	0	63.0
4	22.5± 8.2	19.7±2.2	4.1±0.8	2.4±1.0	12.7±1.8	2.6±0.6	2.5±1.0	0	0	44.0
5	62.2± 9.9	58.8±9.8	1.9±0.6	0.5±0.3	14.1±3.3	13.8±3.1	22.4±5.1	1.3±0.9	0	112.8
6	72.0± 2.9	57.3±2.7	3.5±0.5	0.9±0.5	14.5±1.5	0.4±0.5	0.6±0.2	0	0	77.2

[1] Values for ponderosa pine in 1968 estimated by combining 1972 values for green, infested, and recently killed trees; values for other species from 1971 and 1972 surveys.

Table 2.--Depletion of ponderosa pine stand component resulting from 1968-72 roundheaded pine beetle outbreak, Lincoln National Forest, New Mexico (Mean values per acre, all trees $\geq$ 4 inches d.b.h.)

Area and stand component	Stems	Basal area	Diameter breast height
	Number	*ft²*	*Inches*
Area 1:			
Living trees	99.5±11.3	26.7±3.0	6.6±0.4
Infested trees	10.0± 3.7	2.6±1.0	6.4±0.5
Dead trees	109.5±16.3	32.7±5.9	7.0±0.5
Area 2:			
Living trees	171.5±17.3	79.6±8.7	8.2±0.4
Infested trees	7.5± 2.6	2.7±1.0	7.9±0.5
Dead trees	98.5±15.0	31.7±5.2	7.0±0.7
Area 3:			
Living trees	87.5±14.7	32.7±5.3	7.4±0.7
Infested trees	1.0± 0.7	1.1±0.9	13.0±0.5
Dead trees	9.5± 3.5	2.4±0.9	6.5±0.4
Area 4:			
Living trees	66.4± 7.2	19.7±2.1	6.8±0.3
Infested trees	1.5± 0.6	0.5±0.2	7.3±0.2
Dead trees	9.7± 1.8	2.3±0.2	6.2±0.3
Area 5:			
Living trees	137.4±19.1	58.8±9.8	7.7±0.5
Infested trees	0	--	--
Dead trees	20.9± 5.6	4.3±1.2	5.8±0.5
Area 6:			
Living trees	153.9± 7.7	57.3±2.7	7.4±0.2
Infested trees	1.4± 0.5	0.9±0.4	9.2±0.2
Dead trees	48.9± 3.9	13.8±1.1	6.6±0.2

Losses tended to be concentrated in codominant trees, although there were as many infested and dead intermediates as codominants in area 3 (table 3).

Table 3.--Ponderosa pine crown classes (percent of trees), roundheaded pine beetle infestation area, Lincoln National Forest, New Mexico, 1972

Area and stand component	Dominant	Codominant	Intermediate	pr
Area 1:				
Living	16.0	56.8	18.1	
Infested and dead	17.9	62.7	12.6	
Area 2:				
Living	10.2	54.5	25.7	
Infested and dead	2.8	67.0	20.8	
Area 2:				
Living	6.0	71.4	20.1	
Infested and dead	9.5	42.8	42.8	

Dwarf mistletoe was present in 85 p of the trees on area 1, 57.5 percent on area 2, and 30 percent on area 3.

Coniferous regeneration was present on a majority of sampled subplots:

Area	Percent of subplots stocked with– Pine	Other conifers	Hardwoods
1	17.5	57.5	42.5
2	35	30	70
3	42.5	67.5	62.5

Radial growth of sampled trees on areas 1 to 3 was slow:

Area	No. trees	Mean number rings, last radial inch
1	31	18.1 ± 3.2
2	38	19.1 ± 7.2
3	21	29.0 ± 12.0

Discussion

Stands supporting this outbreak of roundheaded pine beetle are characterized by a mixture of species, ponderosa pine generally predominating. The pines are small, mostly around 6 to 8 inches d.b.h. Dwarf mistletoe infection is common; Hawksworth and Lusher (1956) also found dwarf mistletoe on over 50 percent of their plots in the ponderosa pine type of the same general area.

Loss was lightest (green vs. infested and dead) in stands in which southwestern white pine, white fir, pinyon, juniper, and oak made

suffered severe mortality. At worst, the ponderosa pine has been thinned, and the species mix has been altered. Other species, unaffected by the roundheaded pine beetle, are still present to maintain forest cover.

Roundheaded pine beetle outbreaks appear to be relatively short lived in second-growth stands such as these, and they may tend to be recurrent. The outbreak we have recorded here seems now to have mostly subsided. We will return to the same area in a few years to reevaluate stand characteristics and attempt to judge what the longer-term effects of the infestation were.

Literature Cited

Chansler, John F.
1967. Biology and life history of *Dendroctonus adjunctus* (Coleoptera: Scolytidae). Ann. Entomol. Soc. Am. 60:760-767.

Hawksworth, F. G., and A. A. Lusher.
1956. Dwarf mistletoe survey and control on the Mescalero-Apache Reservation, New Mexico. J. For. 54:384-390.

Agriculture–CSU, Ft. Collins

pril 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM- 260

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Automatic Data Acquisition and Reduction System

Richard A. Sommerfeld[1]

A system for recording and automatically reducing up to 41 channels of slowly varying data has been designed. For recording, the data are multiplexed into a very slow speed, analog tape recorder. Playback can be done at speeds up to 1000 times as fast as the recording speed, using a 60 IPS tape playback unit. A digital clock provides time control and the data are digitized and punched onto paper tape at playback. The paper tape can then be used to input the data to conventional computer systems for various analysis and editing operations. The cost of the system is comparable to high reliability strip charts, for the same number of channels. Total system accuracy for input voltages in the ranges ±0.1 to ±10 v is ±0.3 percent.

Oxford: 524.41. Keywords: Data recording methods.

Many studies in meteorology and geophysics require recording slowly varying voltages over time periods on the order of months. Such records are commonly made with clock-driven strip-chart recorders, but the recovery of data from strip charts is a laborious process. We wanted to record the deformations of a snowpack for about 4 months, using 22 deformation sensors. We also wanted records of windspeed, wind direction, and air temperature. Because the job of recording this amount of information on strip charts and then recovering the data would have been overwhelming, we assembled a recording system which incorporates a very slow-speed, analog tape recorder, time-sharing data multiplexers, and a digital time code generator (fig. 1).

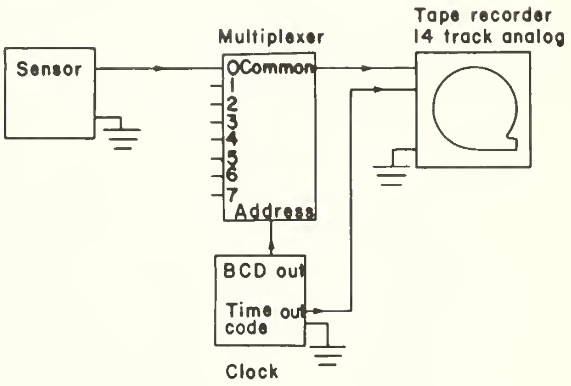


Figure 1.—Block diagram of the data acquisition system showing the flow of data from a single sensor, through a clock controlled multiplexer and onto one track of the tape recorder. Other sensors may be connected to other multiplexer channels or directly into the tape recorder. A time code which is synchronized with the multiplexer switching is recorded on one tape track.

Data are recovered with a normal speed tape recorder, a time-code translator, a multiplexer, and a digital controller. The digital controller allows the data to be read by a digital voltmeter and then printed on a teletype and punched on a paper tape. The punched paper tape is read into a remote terminal linked to a time-sharing computer, edited with an available program, and dumped onto digital magnetic tape, (fig. 2), for computations with a local computer.

---

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

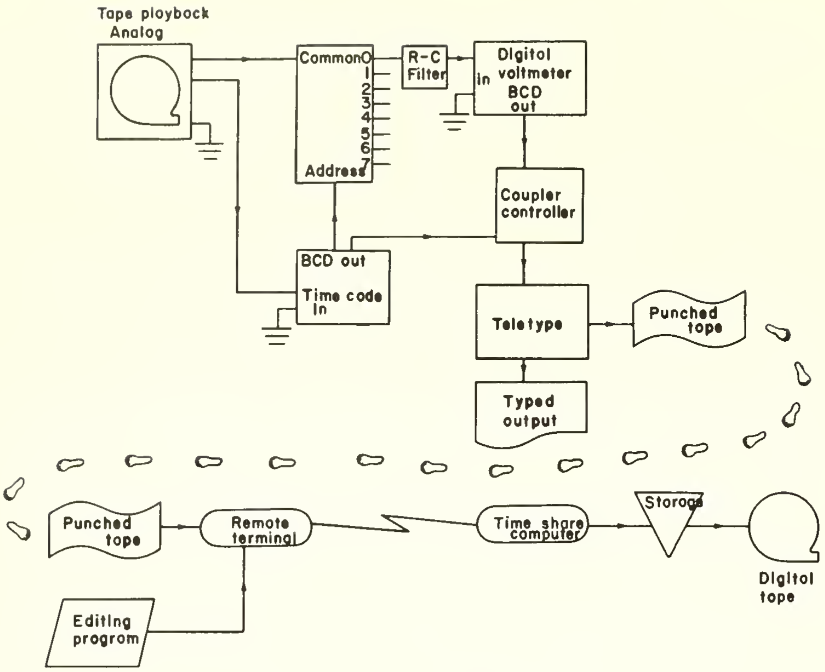


Figure 2.—Block diagram of the data reduction system. The time-code track is translated by the clock which in turn controls the multiplexer and the coupler-controller. The data flows through the multiplexer, is conditioned by the filter and digitized by the voltmeter. The coupler-controller causes teletype to type and punch the time and the digitized data. The punched tape is read into a remote terminal linked to a time-sharing computer. It is edited and dumped onto computer compatible digital tape.

The major advantage of this system is the automatic data processing, which greatly decreases the time necessary to reduce the data and eliminates clerical errors. The original analog recording is made with a minimum of data conditioning so that, as nearly as possible, the original signal can be recovered.

Equipment[2]

The tape recorder in this system is a Teledyne-Geotech model 19429, which records 14 tracks on 1-inch magnetic tape. Running at 0.06 inch per second, this recorder is capable of recording up to 17.5 days on 7,200 ft of 1-mil tape on a 14-inch reel. At this speed the FM frequency response is DC to 10 Hz. With direct recording, the frequency range is 0.2 to 125 Hz.

The time-code generator is a Datatron model 3150. It generates a modulated 100-Hz carrier, IRIG C time-code signal which codes the day (Julian), hour, minute, and second. The signal is recorded on one tape track using direct recording. The time-code generator also has a binary coded digital time output which is used to switch the multiplexers.

Since we record more sensors than the 13 free tape tracks, we use time-sharing multiplexers to record 8 sensors per track. The multiplexers are eight, single-pole, solid-state switches which are addressed by three lines of binary code (fig. 3). The multiplexers, which

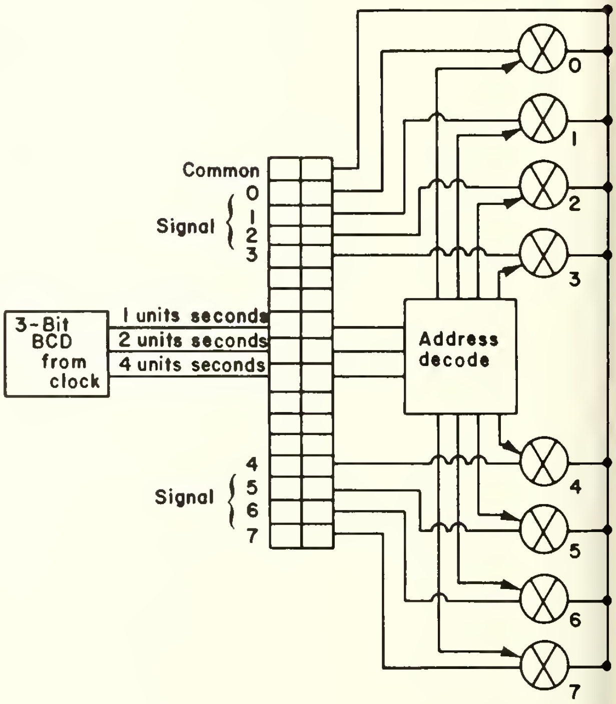


Figure 3.—Schematic diagram of a multiplexer. The BCD time code from the clock is decoded by the address decoder, which closes each of the eight switches in turn. For data acquisition the eight data channels are switched sequentially onto the common output. For data reduction the recorded signal is fed into the common. Each signal is switched to the proper output at the proper time. The time code track on the tape, translated by the clock, maintains the necessary synchronization.

---

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

are sold as small encapsulated modules, were mounted on printed circuit boards. These boards plug into a rack which supplies their required power and connects the inputs, outputs, and the address terminals to appropriate connectors on a front panel. The clock has binary coded digital (BCD) outputs for the tens and the units places of seconds. We wanted the multiplexers to switch once a second, so we used the binary outputs for units seconds to address the multiplexers. Since there are only 8 switches on the multiplexers, and 10 units seconds, 2 of the input signals are double-recorded on each cycle. The switching sequence is 0, 1, 2, 3, 4, 5, 6, 7, 0, 1 (fig. 4). The fact that channels 0 and 1 are double-recorded aids in identifying the different channels when playing the tape back.

The tape playback unit is a Honeywell model 7600. It can play back at speeds up to 120 inches per second, so that the data can be read 2,000 times faster than it is recorded. However, the time responses of the time-code translator and the multiplexers are such that they will not operate at speeds above 60 inches per second (time factor of 1,000). At 60 inches per second, a 7,200-foot reel of tape plays back in 24 minutes, roughly 1.5 minutes for each day of original recording time. The recovery of 120 days' data from one sensor takes about 4 hours, including tape changing, rewinding, and so forth.

The clock code track on the tape is decoded by a time-code translator (Datatron model 3000). This translator also has BCD time-code outputs which are used to control the same type of multiplexer as used for recording. With the clock switching the multiplexer in synchronization with the taped signal, the proper signal is switched to its proper output. A simple RC filter network provides a 5-minute (original recording time) running average of the signal, and holds the voltage level between switching. Because the input impedance of the voltmeter is very high ($>10^{10}\Omega$), it does not significantly drain the network when sampling the voltage.

The ones channel of the BCD units-hours output of the translator is also used to trigger the controller (Hewlett-Packard Coupler-Controller model 2570A). Every second hour (on the dropout of the signal) the controller causes the voltmeter to read and the teletype to type and punch on paper tape the day, hour, and voltage reading. The controller is also programed to print a numerical sensor identifier on each line. The format is shown in figure 5.

When all the data from a single sensor are recorded on paper tape, the tape is read into an XDS 940 time-sharing computer, using a remote terminal. It is stored there temporarily on disc files. This computer has a convenient editing program which is used to delete data which are known to be in error, and to add calibration measurements performed during data recording. When the editing is completed the data are dumped onto digital magnetic tape which is compatible with a local computer. Computations on the data are then easily performed.

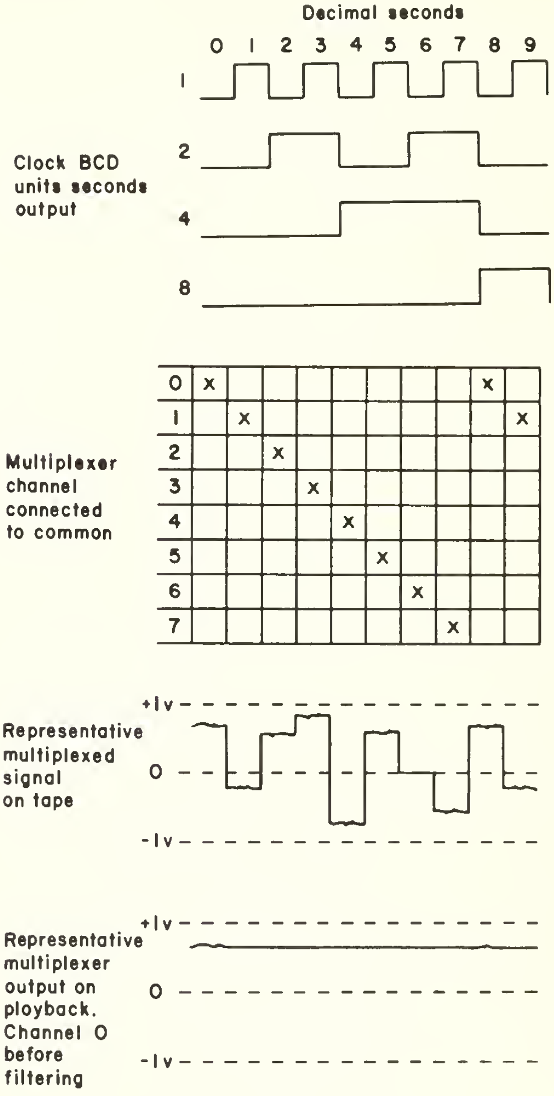


Figure 4.—Multiplexer timing diagram. Units decimal seconds are shown across the top with the logic levels for the BCD units seconds outputs just below. Next the multiplexer channel connected to the common at each second is shown. Since the 8 units seconds is not connected to the multiplexer, it receives the same BCD signal for 0 and 8 and for 1 and 9 decimal seconds thus double recording multiplexer channels 0 and 1 on each cycle. The next diagram is a representative single cycle of data as recorded on tape and fed into the multiplexer with the signal which appears at the 0 channel shown below. These various occurrences are synchronized by the clock system.

Sensor Code	Date	Time	Data	Calibration	
	065	190		-010320E-4	
				-053700E-5	418
1112	065	200	-074757E-5		
1112	065	220	-075774E-5		
1112	066	000	-077039E-5		
1112	066	020	-078349E-5		

Figure 5.—Final data format including inserted calibrations.

Conclusions

The system used is very flexible. It is capable of making long-term recordings of slowly varying voltage in the ranges ±0.1 to ±10 V. An accuracy of ±0.3 percent was achieved with the total system, and higher accuracy is possible with extra care. The recording system has run for 12 days without any attention, and the normal maintenance involved only tape changes and very minor adjustments of the recording amplifiers. Much of the reliability can be ascribed to the fact that the system was assembled from standard units of high reliability with a minimum of custom parts. Care of the recording system is well within the capability of most electronics technicians. The data editing has been done by a clerk-typist who was trained to operate the remote terminal.

The use of analog data recording insures that very nearly the original signal may be recovered. The signal can be conditioned as it is being played back. If the sensor signal is not multiplexed, it is recorded continuously. This reduces the number of possible data channels but allows the monitoring of transient phenomena which might be missed by a digital system with the same long-term recording capability. With the high-speed playback, the data can be scanned for transient phenomena very efficiently.

In its current configuration with four multiplexers, our system can record 41 data channels, 32 multiplexed and 9 not multiplexed. The initial cost of the system is about $40,000 and compares favorably with the cost of high-reliability strip-chart recorders for the same number of data channels. If the playback system can be used in other applications, its contribution to the total system cost is reduced proportionally. In such a case the initial acquisition cost for 20 data channels may be lower than a strip-chart system of the same capability. In addition, the automatic data processing saves at least a factor of 10 in the time required to reduce the data, and eliminates clerical errors in transferring and processing the data.

pril 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-261

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Conversion of Tree-Volume Equations to the Metric System

Clifford A. Myers and Carleton B. Edminster[1]

Presents factors for converting volume equations of the form $V = a + b D^2 H$ from U. S. Customary to metric units.

Oxford: 516:511. Keywords: Tree volume estimates, *Pinus ponderosa, Pinus contorta, Picea engelmannii.*

Interest in and use of metric units is increasing in the United States. Foresters are beginning to wonder what familiar relationships may look like after adoption of the metric system. A convenient opportunity to look ahead is provided by cubic-foot volume equations of the form $V = a + b D^2 H$.

Changing volume equations from U. S. Customary to metric units requires three conversion factors. Exact values adopted by the National Bureau of Standards (Chisholm 1967) are:

Inches to centimeters — multiply by 2.54
Feet to meters — multiply by 0.3048
Cubic feet to cubic meters — multiply by 0.028316846592

Conversion of cubic volume equations in current use (table 1) to equations in metric units (table 2) requires three multiplications:

1. Multiply the original regression coefficient b by 0.01440 to obtain the metric coefficient b′.
2. Multiply the original intercept a by the cubic-feet-to-cubic-meters factor, above, to obtain the new intercept a′.
3. Multiply the original $D^2 H$ limit (table 1) by 1.96644768 to obtain the equivalent limit in centimeters and meters (table 2). This step is necessary where two equations are used for a relationship because of nonlinearity over the desired range of $D^2 H$.

After these multiplications have been made, computed volumes are in cubic meters (V′) instead of the original cubic feet (V).

Numerical values given in the three steps are produced from published exact values as follows:

$$2.54 \times 2.54 \times 0.3048 = 1.96644768$$
$$0.028316846592 \div 1.96644768 = 0.01440$$

As examples of the conversion from Customary to metric units, two Black Hills ponderosa pines have the following dimensions and total volumes:

8.5 inches d.b.h., 50 feet tall, 8.02 cubic feet
18.5 inches d.b.h., 90 feet tall, 74.6 cubic feet

The same trees have these dimensions and volumes in metric units:

21.6 centimeters d.b.h., 15.24 meters tall, 0.227 cubic meter
47.0 centimeters d.b.h., 27.43 meters tall, 2.112 cubic meters

---

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

Table 1.--Coefficients of tree volume equations for selected western conifers, U. S. Customary units

Species	Utilization	D^2H Limit	Intercept a	Coefficient b	Reference
Ponderosa pine, Black Hills	Total	≤ 6000	0.030288	0.002213	Myers 1964a
	Total	> 6000	-1.557103	0.002474	
	4-in. Top	≤ 6700	-1.032297	0.002297	
	4-in. Top	> 6700	-2.257724	0.002407	
Lodgepole pine, Colo., Wyo.	Total	≤ 7000	0.027967	0.002777	Myers 1964b
	Total	> 7000	3.446454	0.002332	
	4-in. Top	≤ 7000	-1.045780	0.002798	
	4-in. Top	> 7000	2.836222	0.002256	
Ponderosa blackjack, Ariz., N. Mex.	Total	≤ 6000	0.5870	0.001824	Myers 1972
	Total	> 6000	-1.091458	0.002103	
	4-in. Top	≤ 6500	-0.20550	0.001770	
	4-in. Top	> 6500	-2.061477	0.002056	
Engelmann spruce, Colo., Wyo.	Total	≤ 22500	0.06439	0.00239	Myers and Edminster 1972
	Total	> 22500	10.41663	0.00193	
	4-in. Top	≤ 27900	-0.83010	0.00232	
	4-in. Top	> 27900	13.11320	0.00182	
Ponderosa yellow pine, Ariz., N. Mex.	Total	> 5180	-0.402357	0.002302	Myers 1972
	4-in. Top	> 5180	-1.440832	0.002255	

Table 2.--Coefficients of tree volume equations for selected western conifers, metric units

Species	Utilization	D^2H Limit	Intercept a'	Coefficient b'
Ponderosa pine, Black Hills	Total	≤ 11800	0.0008577	0.0000319
	Total	> 11800	-0.0440922	0.0000356
	10-cm Top	≤ 13200	-0.0292314	0.0000331
	10-cm Top	> 13200	-0.0639316	0.0000347
Lodgepole pine, Colo., Wyo.	Total	≤ 13800	0.0007919	0.0000400
	Total	> 13800	0.0975927	0.0000336
	10-cm Top	≤ 13800	-0.0296132	0.0000403
	10-cm Top	> 13800	0.0803129	0.0000325
Ponderosa blackjack, Ariz., N. Mex.	Total	≤ 11800	0.0166220	0.0000263
	Total	> 11800	-0.0309066	0.0000303
	10-cm Top	≤ 12800	-0.0058191	0.0000255
	10-cm Top	> 12800	-0.0583745	0.0000296
Engelmann spruce, Colo., Wyo.	Total	≤ 44200	0.0018233	0.0000344
	Total	> 44200	0.2949661	0.0000278
	10-cm Top	≤ 54900	-0.0235058	0.0000334
	10-cm Top	> 54900	0.3713245	0.0000262
Ponderosa yellow pine, Ariz., N. Mex.	Total	> 10190	-0.0113935	0.0000331
	10-cm Top	> 10190	-0.0407998	0.0000325

Literature Cited

Chisholm, L. J.
1967. Units of weight and measure, International (metric) and U.S. Customary. U.S. Dep. Commerc. Natl. Bur. Stand. Misc. Publ. 286, 251 p.

Myers, Clifford A.
1972. Volume, taper, and related tables for southwestern ponderosa pine. U. S. For. Serv. Res. Pap. RM-2, 24 p. (Rev.) Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Myers, Clifford A.
1964a. Volume tables and point-sampling factors for ponderosa pine in the Black Hills. U.S. For. Serv. Res. Pap. RM-8, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Myers, Clifford A.
1964b. Volume tables and point-sampling factors for lodgepole pine in Colorado and Wyoming. U.S. For. Serv. Res. Pap. RM-6, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Myers, Clifford A., and Carleton B. Edminster.
1972. Volume tables and point-sampling factors for Engelmann spruce in Colorado and Wyoming. USDA For. Serv. Res. Pap. RM-95, 23 p. Rocky Mt. For. and Range. Exp. Stn., Fort Collins, Colo.

Agriculture—CSU, Ft. Collins

April 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM- 262

ORE ST SERVICE
.S. DEPARTMENT OF AGRICULTURE

:KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Timing Cacodylic Acid Treatments for Control of Mountain Pine Beetles in Infested Ponderosa Pines

Robert E. Stevens,[1] Donn B. Cahill,[2] C. Kendall Lister,[2] and Gary E. Metcalf[3]

Careful timing is critical to success in post-attack use of cacodylic acid against mountain pine beetles. Acid must be introduced into infested trees before any larval galleries exceed 0.5 inch in length to achieve satisfactory beetle mortality. Since the beetle attack period may last more than 1 month, more than one visit per area will be necessary to locate and properly treat all the trees that become infested.

Oxford: 414:453. Keywords: Insecticides, herbicides, insect control, Scolytidae, *Dendroctonus ponderosae*, *Pinus ponderosa*.

Results of a 1968 field test in the Black Hills of South Dakota indicated that cacodylic acid (dimethylarsenic acid) could be effective in control of mountain pine beetles (Dendroctonus ponderosae Hopk.) infesting ponderosa pine (Pinus ponderosa Laws.) (Chansler et al. 1970). Since timing of the acid application was seen as a critical factor, and the desirability of an extended treating period was recognized, a series of small field tests was started in 1969 to determine if applications made later in the season than immediately after attack might still be effective. The necessity of further study was reinforced by the apparent failure of a separate, more extensive field test in the Black Hills in 1969, one carried out in roughly the same manner as the successful 1968 project. The approach in all these instances, as well as the experiments related here, was to introduce the material after beetle attack, in an attempt to prevent brood development.

Methods

Two similar experiments were conducted in 1969, one in the Black Hills and one in the Front Range of the Colorado Rockies, in Larimer County. In each instance, a group of recently (1969 attack) infested trees was chosen, and randomly selected individuals were treated with cacodylic acid at intervals as late as into November (in South Dakota). Similar experiments were conducted in the Black Hills in 1970, and in Colorado in 1972. Treating techniques, using full-strength Silvisar® 510,[4] were as described by Chansler et al. (1970). Establishment data on the four experiments are as follows:

---

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

[2] *Entomologists, Branch of Forest Pest Control, U.S. Department of Agriculture, Forest Service, Denver, Colorado 80225.*

[3] *Forester, Medicine Bow National Forest, Laramie, Wyoming 82070.*

[4] *Trade name for a solution manufactured by the Ansul Company, Marinette, Wisconsin, that contains the equivalent of 5.7 pounds of cacodylic acid per gallon. Trade names and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.*

Experiments and treatment dates	Number of trees Treatments	Checks	Mean tree diameter (Inches)
South Dakota, 1969 Sept. 5,19 Oct. 3,17,31 Nov. 14	24	12	11.9
Colorado, 1969 Sept. 11,18 Oct. 2,16,30	25	10	13.3
South Dakota, 1970 Aug. 21,28 Sept. 4,12,23	25	10	--
Colorado, 1972 Aug. 17,25 Sept. 6,15,25	25	10	12.3

Typically, five trees were treated on each date (four in the South Dakota 1969 test), and two trees were designated as that treatment's checks.

Egg and larval gallery length, brood, and bluestain development were recorded from two galleries each in check trees at time of treatment, to determine if one or more of these characteristics could be used as timing guidelines. Bluestain was judged (1) absent, (2) just identifiable (light), or (3) well developed.

The results of the experiments were evaluated prior to emergence the summer following treatment; that is, the 1969 treatments were evaluated in summer 1970. Bark samples, 6 by 6 inches square, were removed from north and south sides of trees at about eye level. Length of egg gallery and numbers of live insects were recorded.

In the 1969 Colorado experiment, north and south bark samples were also removed from the mid and upper infested portions of the bole, and several trees were felled for this purpose in the 1969 South Dakota experiment. The eye-level samples always had the most live insects, however, and in the remaining experiments only eye-level samples were taken.

The results from north and south samples were combined, and the numbers of insects and length of egg galleries were computed on a square-foot basis. In the final evaluation, data were combined for the check trees; that is, gallery length and insect numbers from all check trees were pooled for each experiment. One-way analysis of variance with log $(x + 0.1)$ transformation of counts (x) was used for comparison of treatments and checks.

Results and Discussion

All trees were equally attacked, as measured by mean length of egg gallery: treated 94.7 in/ft^2, checks 101.4.

The mean number of surviving mountain pine beetles in infested ponderosa pines versus the time of the cacodylic acid treatment in the four experimental areas was as follows (means followed by the same letter are not significantly different at the 0.05 level):

Experiments and treatment dates	Survivors (Number/ft^2)
South Dakota, 1969	
Sept. 5	17.0 a
Sept. 19	59.0 b
Oct. 3	77.5 b
Oct. 31	103.0 b
Nov. 14	50.0 b
Check	89.2 b
Colorado, 1969	
Sept. 11	13.2 a
Sept. 18	8.0 a
Oct. 2	2.0 a
Oct. 16	37.2 ab
Oct. 30	12.4 a
Check	47.0 b
South Dakota, 1970	
Aug. 21	0.0 a
Aug. 28	3.6 a
Sept. 4	30.8 b
Sept. 12	16.0 ab
Sept. 23	4.8 a
Check	50.8 b
Colorado, 1972	
Aug. 17	0.0 a
Aug. 25	4.8 a
Sept. 6	0.8 a
Sept. 15	3.6 a
Sept. 25	20.4 b
Check	45.6 b

The 1969 results from South Dakota were unsatisfactory. Even in the earliest treatment (September 5), a mean of 17 beetles per ft^2 survived. While this value was significantly different from those of the other dates, and the check, it would not result in a "decreasing" infestation according to the commonly used criteria (Knight 1960). All later treatments allowed development of in excess of 50 beetles per ft^2 — totally unacceptable. The 1969 Colorado results were somewhat more encouraging — all but one treatment differed from the check — but no clear-cut timing pattern was established.

It was felt that most of the 1969 treatments were probably too late, even though only eggs were noted and bluestain was at best lightly developed at the time of the first treatments. This prompted earlier treatments in 1970 and 1972, which fairly well spanned the time period following attack during which we could expect effectiveness.

The 1970 South Dakota trial was an improvement over that of 1969, but the numbers of living beetles in the two earlier September treatments (30.8 and 16.0 per ft^2) were still too high to be considered satisfactory, and were not significantly different from the checks.

Extra care was taken in frilling and applying the material in 1972, and the results of this test were acceptable (means of 0, 4.8, 0.8, and 3.6 living beetles per ft^2 for the treatments through September 15). All differed significantly from the check.

Bluestain does not seem practically useful as a guideline for timing, as it is impossible in the field to identify developmental stages that might be indicators of the trees' ability (or lack thereof) to translocate the acid. Certainly by the time bluestain is well developed (table 1), it is too late to kill the beetles. On a practical basis, if bluestain is detectable the chances for success with acid are poor.

Length of larval mines appears to provide a more useful guideline. With the exception of the 1969 South Dakota experiment, results were generally good if cacodylic acid was applied before any larval mines were greater than 0.5 inch long.

Throughout these experiments, we have been impressed with the importance of making a good frill and using sufficient material. These details cannot be overemphasized.

The duration of the attack period is another important consideration. We have seen that acid must be introduced soon after attack. While all infested trees may be successfully treated on — say — August 25, more trees may well be attacked in the same area during the following 1 or 2 weeks. If only a single pass is made through the area, some infested trees may not get treated, and some of the value of the program may be wasted. While August 20 is generally a good date to consider for the mean mass attack (McCambridge 1964), we must remember this is the **mean** mass attack date, and many attacks occur earlier and later. Also, weather conditions can make major changes in this "average" picture. For example in Colorado in 1969, an extended period of cool, rainy weather in mid to late August appeared to extend the attack period markedly, possibly almost to mid September.

In summary, we believe that the post-attack cacodylic acid method can be successful in killing beetles if proper attention is given to timing and other operational details. As Chansler et al. (1970) pointed out, good treatment in itself is not sufficient to insure good control; area layout, spotting, and other operational considerations are equally critical. Poor performance in one or more of these areas can make a good job of treating a totally wasted effort.

Table 1.--Gallery, brood and bluestain conditions at time of treatment, 1969-72

Experiment location and treatment date	Mean egg gallery length	Brood status	Bluestain	Longest larval mines
	- - Inches - -			*- Inches -*
South Dakota 1969				
September 5	10.0	Eggs	None	0
September 19	15.7	Larvae	Light	0.5
October 3	12.8	Larvae	Light	1.0
October 17	18.7	Larvae	Well developed	1.3
October 31	24.3	Larvae	Well developed	1.8
November 14	27.6	Larvae	Well developed	1.8
Colorado 1969				
September 11	5.2	Eggs	Light	0
September 18	22.1	Larvae	Light	.5
October 2	31.2	Larvae	Light	1.0
October 16	14.0	Larvae	Well developed	1.5
October 30	37.8	Larvae	Well developed	1.0
South Dakota 1970				
August 21	2.8	Eggs	--	0
August 28	12.4	Larvae	--	.5
September 4	15.2	Larvae	--	1.2
September 12	16.0	Larvae	--	.8
September 23	15.8	Larvae	--	1.5
Colorado 1972				
August 17	3.9	Eggs	None	0
August 25	12.8	Larvae	None	--
September 6	8.5	Larvae	Light	--
September 15	--	Larvae	Light	.8
September 25	--	Larvae	Well developed	2.0

"--" No data available.

Literature Cited

Chansler, John F., Donn B. Cahill, and Robert E. Stevens.
1970. Cacodylic acid field tested for control of mountain pine beetles in ponderosa pine. USDA For. Serv. Res. Note RM-161, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Knight, Fred B.
1960. Sequential sampling of Black Hills beetle populations. U.S. Dep. Agric. For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 48, 8 p. Fort Collins, Colo.

McCambridge, W. F.
1964. Emergence period of Black Hills beetles from ponderosa pine in the central Rocky Mountains. U.S. For. Serv. Res. Note RM-32, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key — out of the reach of children and animals — and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely
FOLLOW THE LABEL
U.S. DEPARTMENT OF AGRICULTURE

Agriculture—CSU, Ft. Collins

uly 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-263

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Grafting Ponderosa Pine Scions on the Parent Root System

Richard W. Tinus[1]

Describes grafting pine scions on parent rootstock. Reproductive success is much higher than by direct rooting, and is better distributed over the parent population.

Keywords: Grafting, *Pinus ponderosa*.

For many purposes, it is advantageous to grow scions of desirable parent trees on root stock of the same genotype. Usually this is accomplished by rooting scions directly, but most species of pine are difficult to root (Hare 1970, Isikawa 1968, McDonald and Hoff 1969, Mirov 1944, Watanabe et al. 1968). By age 11 years, rooting ability of ponderosa pine has declined to about 7 percent, and this ability is concentrated in 10 to 15 percent of the tree population (Tinus, unpubl.).

This Note describes a grafting technique which has the advantages of scion rooting without the incompatability problems associated with ordinary grafting (Copes 1967). After several years of experiments, the following procedure has been found most effective.

Figure 1.—Surface root system is exposed by digging with a screwdriver and the hands.

In the spring when the ground has thawed, but buds are still dormant, the litter and surface soil around the base of the tree to be reproduced are shoveled away without digging into the root zone. The surface root system is then exposed by digging with a screwdriver and the hands (fig. 1). The roots should be protected from direct sun and drying by digging under the shade of a tarp. Next, scions are cut from the crown of the tree and veneer-grafted into the side of roots of the same diameter as the scion. The roots remain attached to the mother tree (fig. 2). The union is wrapped with a grafting rubber, sealed with grafting wax or tree sealing compound, and the scion enclosed in a clear polyethylene bag. The bag has been found necessary to reduce transpiration stress until the graft union forms.

To prevent overheating in the plastic bags, the grafts are covered with a conical "tent" of brown kraft paper, burlap, or shade cloth, sup-

---

[1] *Principal Plant Physiologist, located at the Shelterbelt Laboratory, Bottineau, in cooperation with North Dakota State University - Bottineau Branch and Institute of Forestry. Station's central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

ported by lath (fig. 3) and tied to the bole of the tree at the top. The lower edge is buried. The top of the paper covering is left open on the north side for ventilation. Plenty of air space must be left between the paper cover and the scions.

Figure 2.—Dormant scions are veneer-grafted onto matching roots of the same tree.

Figure 3.—Grafts are bagged with polyethylene. The conical lath structure is covered with a brown kraft paper sunshade.

By midsummer the successfully grafted scions will begin to flush. When flushing begins, the plastic bags are removed and the graftlings cut from the parent tree. As much root below the graft as practical should be included — usually 25 to 40 cm. The cut ends are dusted with fungicide and then either potted and placed in a sweatbox, or placed in a propagating bench under intermittent mist. Because most of the fine roots are lost when the rootstock is excavated, the graftlings must be treated as if they were unrooted scions. Three months is usually sufficient for reestablishment of a new fine root system.

In 5 years of trials, 386 grafts were made on 24 trees 8 to 13 years of age. Graft union occurred on 247 (64 percent), and 89 graftlings became established trees (23 percent). This is about three times better than can be expected if scions from 8- to 13-year-old trees are rooted directly. Furthermore, grafting and rooting success were well distributed over the parent population, whereas, ability to root scions directly was concentrated in a small proportion of the genotypes (Tinus, unpubl.).

Literature Cited

Copes, D. L.
1967. A simple method for detecting incompatibility in 2-year-old grafts of Douglas-fir. U.S. For. Serv. Res. Note PNW-70, 8 p. Pacific Northwest For. and Range Exp. Stn., Portland, Oreg.

Hare, R. C.
1970. Factors promoting rooting of pine cuttings. North Am. For. Biol. Workshop [East Lansing, Mich., Aug. 1970] 1:n.p. (Abstr.).

Isikawa, Hirotaka.
1968. Basic studies on the formation of adventitious roots in the cuttings of the species, mainly *Pinus* and *Larix* that have difficulty rooting. Bull. Gov. For. Exp. Stn., Tokyo, Japan, p. 77-109.

McDonald, Gerald I., and Raymond J. Hoff.
1969. Effect of rooting mediums and hormone application on rooting of western white pine needle fascicles. USDA For. Serv. Res. Note INT-101, 6 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Mirov, N. T.
1944. Experiments in rooting pines in California. J. For. 42:191-204.

Watanabe, Mosatoshi, Giro Isa, and Soichi Sano.
1968. Effects on the rooting of Japanese red pine cuttings by misting and medium heating treatments. J. Jap. For. Soc. 50:87-92.

Agriculture—CSU, Ft. Collins

July 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-264

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Aspen Sucker Growing from an Engelmann Spruce Stump

John R. Jones[1]

A root from an adjacent aspen entered the base of a spruce stump, grew upward nearly to the top, then back down into the soil on the other side. This path suggests that some mechanism tends to keep lateral aspen roots near the substrate surface. The root later produced a sucker through the top of the stump.

Keywords: *Picea engelmannii, Populus tremuloides.*

In June 1951, fire destroyed an extensive forest on Escudilla Mountain in Arizona. Parts of the burn were quickly occupied by dense stands of root suckers from fire-killed quaking aspen (*Populus tremuloides* Michx.) that had grown in the pre-fire mixed conifer forest.

In October 1973, what appeared to be an aspen seedling was found growing from the stump of an Engelmann spruce (*Picea engelmannii* Parry) on the area, beneath a small gap in the canopy of 10 m aspens. Aspen seedlings have only occasionally been reported from the western United States (Barnes 1966, Ellison 1943, Larson 1944), and apparently never from a stump or fallen tree. It was therefore photographed (fig. 1) and the stump dug apart to examine the aspen root system.

Figure 1.—Stump of fire-killed spruce with small aspen growing from top.

The "seedling" proved to be a root sucker. In 1967 a lateral root from a nearby aspen had penetrated the base of the spruce stump from one side, grown upward nearly to the top of the

---

[1] *Principal Plant Ecologist, located at Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

stump, and, a year later, back into the soil on the other side (fig. 2). In 1971 it produced the sucker.

Aspen characteristically has many lateral roots, mainly within about 60 cm of the soil surface. It is these that sprout to produce new aspen stems, mostly at depths of only 10-15 cm (Baker 1925, Barnes 1966, Day 1944, Gifford 1966, Weigle and Frothingham 1911). Behavior of the root reported here suggests a strong physiological mechanism tending to keep such roots close to the substrate surface.

Figure 2.—Aspen root, with sucker, exposed by breaking away the decayed spruce stump.

Literature Cited

Baker, F. S.
  1925. Aspen in the central Rocky Mountain region. U.S. Dep. Agric. Bull. 1291, 46 p.
Barnes, B. V.
  1966. The clonal growth habit of American aspens. Ecology 47:439-447.
Day, M. W.
  1944. The root system of aspen. Am. Midl. Nat. 32:502-509.
Ellison, L.
  1943. A natural seedling of western aspen. J. For. 41:767-768.
Gifford, G. F.
  1966. Aspen root studies on three sites in northern Utah. Am. Midl. Nat. 75:132-141.
Larson, G. C.
  1944. More on seedlings of western aspen. J. For. 42:452.
Weigle, W. G., and E. H. Frothingham.
  1911. The aspens: their growth and management. U.S. Dep. Agric. For. Serv. Bull. 93, 35 p.

Agriculture—CSU, Ft. Collins

U S D A FOREST SERVICE
RESEARCH NOTE RM- 265

OREST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Spot Seeding Trial with Southwestern White Pine and Blue Spruce

John R. Jones[1]

Following rodent reduction, 300 seed spots each of southwestern white pine and blue spruce were sown on three mixed conifer clearcuttings. Germination was abundant. Despite favorable slope aspects, absence of heavy herbaceous competition, good cold air drainage, and initial rodent reduction, very few seedlings survived to the middle of the third summer. Major known causes of death were frost heaving, predation, and burial by soil movement. Importance of these factors differed between species. Additional seeding trials should emphasize broadcast seeding.

Keywords: Seeding, rodents, frost heaving, *Pinus strobiformis, Picea pungens*.

Large areas of mixed conifer forest in the Southwest are occasionally deforested by fire, and small areas by fire or logging. Natural reforestation of such areas is usually very slow except where aspen root suckers take over the site.

Experience has shown that such openings can be successfully reforested with nursery-grown seedlings if careful attention is given to species selection, seed source, site preparation, and the details of proper shipping, storage, handling, and planting. But planting is relatively expensive. Seeding is much cheaper, although at present quite unreliable. Seeding in prepared spots requires much less seed than does broadcast seeding. This study examined problems and prospects of spot seeding.

Literature Review

In a series of seeding experiments in mixed conifer forest in southern New Mexico, Krauch (1956) found repeatedly that rodents destroyed spot seedings unless the seed was protected. An Arizona study showed that, where grass was seeded shortly after germination of pine seeds, seedling survival dwindled almost to zero within 3 years (Jones 1967), presumably under conditions of severe dry season moisture stress induced by the grasses (Embry 1971). Frost heaving can also kill many seedlings (Schubert 1970).

Methods

This study was carried out on three small clearcut strips near one another at about 8,900 ft elevation in east-central Arizona on variable

---

[1] *Principal Plant Ecologist, located at Station's Research Vork Unit at Flagstaff, in cooperation with Northern Arizona Jniversity; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

easterly and northerly slopes. Normally covered with snow throughout the winter, the sites are presumably less subject to frost heaving than many. They were baited with sodium fluoroacetate (compound 1080) at three strategic times to reduce predation by rodents on seeds and seedlings.

The species selected for seeding were southwestern white pine (*Pinus strobiformis* Engelm.) and blue spruce (*Picea pungens* Engelm.). White pine roots deeply the first year, to about 8 inches. Blue spruce penetrates only 2-4 inches the first year. Seedlings of both species seem to tolerate full sunlight well.

Six hundred staked spots were sown, in 10 rows with 30 pairs of spots in each row. Within each pair of spots, one selected at random was protected from rodents by a 4-mesh hardware-cloth cone. The pairs of spots were also in pairs, one pair randomly assigned to spruce, the other to pine. Due to a logistics problem, however, only 120 blue spruce pairs, instead of 150, included a screened spot. Species comparisons include only those pine spots paired with similarly treated spruce spots.

Laboratory germination was 66 percent for the blue spruce and 52 percent for the white pine. To provide an average of three viable seeds in each seed spot, five seeds were placed in each spruce spot and six in each pine spot. That should have assured at least one good seed in almost every spot.

Each spot was loosened with a mattock before seeding, to prepare the seedbed and ascertain that the spot was not underlain by a stone or by organic debris buried during logging or slash piling. Seeds were then placed on the loosened surface and lightly pressed into the ground by foot.

Seeding was on June 27 and 28 and July 8 and 9, 1970. A heavy shower on June 23 was followed by several days of typical dry-season weather. On June 29, high humidities and cloudiness began, presaging the monsoon. Showers became frequent and substantial beginning July 8.

In 1970 all seed spots were examined for germination and mortality on July 28-29, September 8-9, October 9-10, and October 28. Rodent screens were removed on October 9-10 so they would not be pushed downhill by snow and possibly damage seedlings. They were not put back on. The second year, 1971, all spots were examined for additional germination and mortality on May 4-5, July 24, and October 15. In 1972, only those spots were examined that had surviving seedlings when last previously examined; the dates were May 14 and July 7.

In 1971 the areas were inadvertently seeded with grass by Forest personnel, and a few spots were destroyed by a bulldozer. Numerous unseasonable showers in May and June 1972 maintained good soil moisture, however, and therefore competition from grass did not seem serious at that time.

Field examinations were discontinued in July 1972 because few seedlings were still alive.

Germination data were analyzed statistically, but not mortality data. Mortality causes were not independent. For example, because more unscreened than screened seedlings were killed by predators the first summer, fewer were subsequently exposed to frost heaving. Also, assignment of cause was sometimes a matter of judgment and subject to error. Furthermore, the factors influencing those judgments were not entirely the same at different times or for different treatments. Thus, while it is informative to examine and consider mortality data, statements of statistical probability are not justified.

Germination

Germination was defined by the presence of a seedling or seedling stub aboveground; 852 pine and 549 spruce are known to have germinated. Of the spruce that germinated, 64 percent came up before July 28, 1970, although many additional seedlings (34 percent) came up between then and September 8. White pine was slower; many (37 percent) germinated by July 28, but most (61 percent) appeared between then and September 8. Very few germinated after September 8; an occasional seed of both species germinated in 1971. The percentage germinating after July 28 was lower on unscreened spots than on screened spots. This is probably because unscreened seeds that did not germinate promptly were exposed to predators longer and had a greater chance of being eaten.

Fifty-six percent of screened white pine seeds and 55 percent of screened blue spruce seeds germinated, figures roughly equaling results in the germination chamber. For unscreened spots, the figures were 38 and 27 percent, respectively, for pine and spruce. Ninety-three percent of screened and 85 percent of unscreened pine spots had at least one seed germinate on them. For spruce, the values were 88 and 62 percent. A few spots were buried by soil washing before germination could be checked. If they are left out of the calculations, 96 percent of screened pine spots and 93 percent of screened spruce spots had at least one seedling emerge.

The difference between the numbers of seeds germinating on screened and unscreened spots (fig. 1) was highly significant statistically. That is in line with the observation of opened seedcoats on or around a number of unscreened

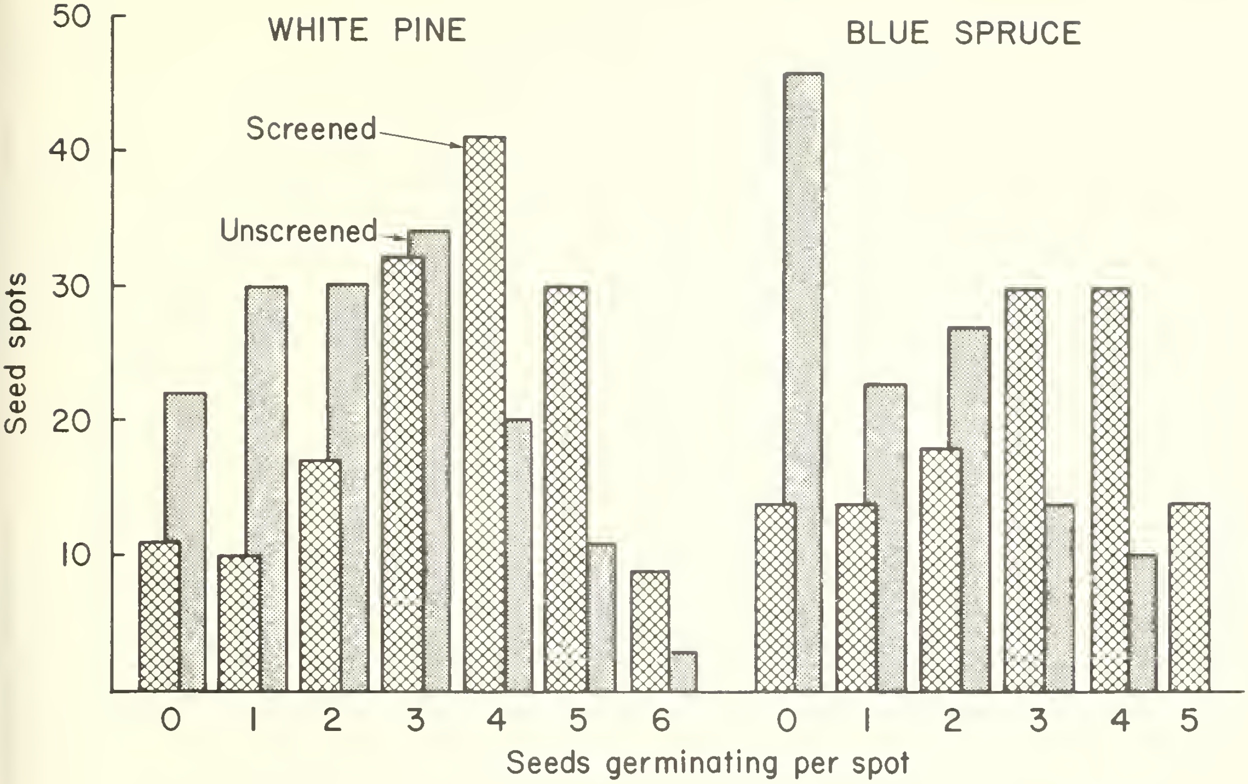


Figure 1.—Frequencies of different numbers of seed germinating on screened and unscreened spots.

spots. The difference between screened and unscreened spots was greater for spruce than for pine, suggesting that predators prefer seed of blue spruce to that of white pine. The species difference was not statistically significant, however.

Table 1.--Stocking on July 7, 1972, 2 years after seeds were sown

Species and treatment	Stocked spots		Total seedlings	
	Any live seedling	Vigorous seedling	Alive	Vigorous
	Percent		*Number*	
Spruce, screened (120 spots)	1	1	2	2
Spruce, unscreened (180 spots)	0	0	0	0
Pine, screened (150 spots)	21	7	72	20
Pine, unscreened (150 spots)	10	2	23	4

Mortality

Seedling mortality began immediately after germination. A number of seedlings were recorded as having emerged only on the basis of the tiny stubs left by rodents and perhaps other predators. Some damage suggested clipping by birds (Noble and Shepperd 1973). After 2 years only 97 seedlings remained, many of them in poor condition, out of the total known germination of 852 pine and 549 spruce (table 1). Of the 97 survivors, only 26 seemed vigorous.

Figure 2 shows what became of the rest. Because the columns represent percentages of seedlings, differences between columns are not influenced by the greater germination on screened spots.

Seedling Predation

Rodent reduction with compound 1080, although quite temporary, seems to have protected unscreened seedlings fairly well. Seedlings are most likely to be eaten during the first days and weeks after germination, when they are most succulent. Further, Douglas-fir tube seedlings (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) were planted on one of the study blocks shortly after the seed spots were sown. Losses to rodents were moderate. On nearby areas untreated with 1080, all the tubelings were eaten.

Seedling predation on screened spots was less than half that on unscreened spots, but still was significant. Because predation did not stop entirely when stems became woody, some took place after the screens were removed. Some occurred earlier because elk, cattle, and deer dislodged a number of screens. A few screens were undermined by washing. Some seedlings were cut although their screens were in place, suggesting predation by insects. In the greenhouse, caterpillars occasionally eat the tops of young seedlings, and can do considerable damage in a few days. Cutworms were occasionally found by digging around wilted seedlings.

In an earlier study (Jones 1967), rodents tunneled under a number of screens to get to seed, but not to seedlings. There was almost no evidence of tunneling here.

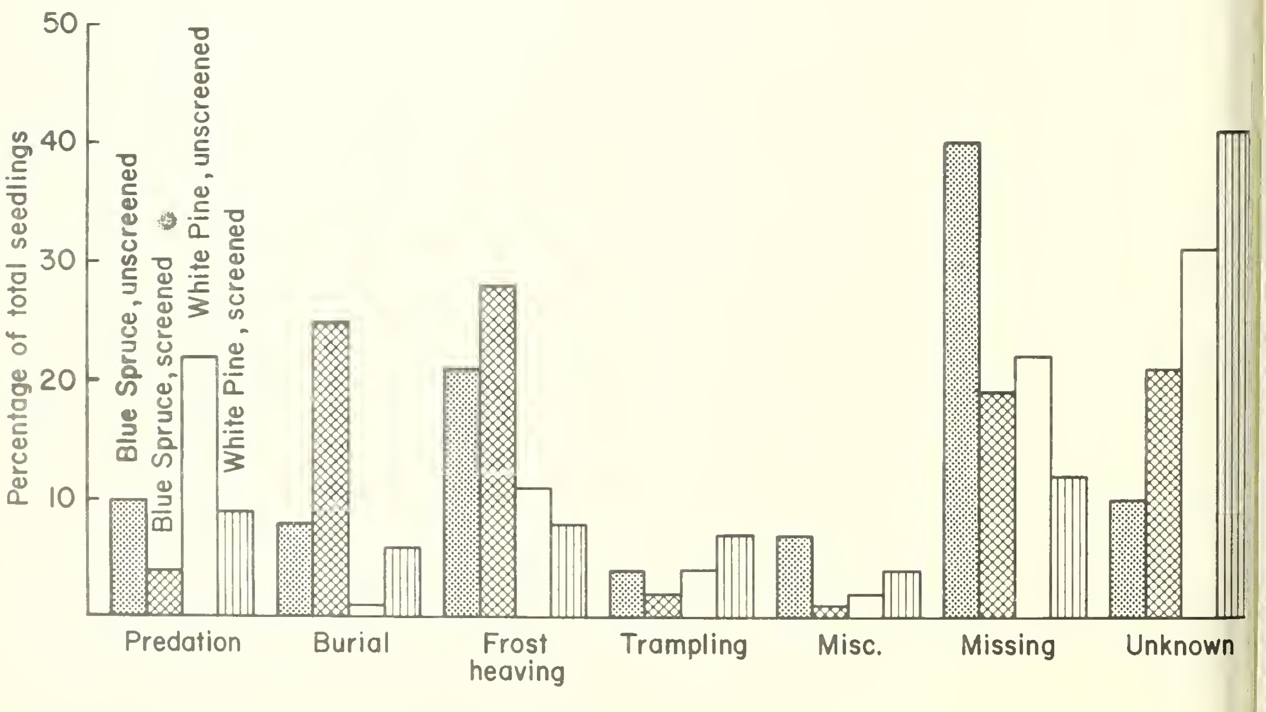
Occasional seedlings died during emergence when their cotyledons stuck in the ground and the hypocotyl broke. Recognizable evidence of this situation generally remains, but a few such seedlings may have been wrongly diagnosed as killed by predators.

A substantial number of seedlings in the Missing category probably were victims of rodents. That is especially true of spruce, whose tiny seedling stem leaves a stub that is difficult to see. Thus predation on spruce seedlings may in fact have approached or even exceeded predation on pine seedlings. Digging for evidence of predation commonly was not possible without disturbing seeds or other seedlings in the seed spot.

Buried Seedlings

Partial burial of seedlings by soil washing was common and usually did not seem harmful. Complete burial was a major source of death among spruce, whose seedlings are very small. Burial was common the first summer. It was most serious on screened spots, partly because screens tended to collect sediment, and partly because more seedlings survived predation on screened spots and were available for burial.

Figure 2.—Seedling mortality, by causes.



Frost Heaving

Frost heaving did not occur until seedling numbers had already been substantially reduced by predators and, in the case of spruce, by burial. Otherwise the importance of frost heaving would have been greater. On the other hand, snow cover was substantially subnormal during both winters. Frost heaving might possibly have been less had snow cover been normal.

The difference between screened and unscreened spots is probably due to chance. The screens had been removed before significant frost heaving occurred, so could have had little if any direct influence. Nor do the percentages surviving predation and burial, and available for frost heaving, seem to account for treatment differences.

Frost heaving seems to have killed considerably more spruce than pine, with its much larger root system. Many spruce were totally uprooted and lay on the surface. Some spruce listed as missing undoubtedly had frost heaved and subsequently washed downhill.

Pine seedlings whose deaths were ascribed to frost heaving commonly lay on the ground only partly uprooted, or even remained upright but considerably raised. Some pine seedlings survived, even though raised half an inch or more. Not infrequently, one pine seedling would be prone and largely uprooted, while others an inch or two away seemed unraised. Presumably some of the unraised seedlings had also undergone the kind of stress that had uprooted their neighbors. Some, perhaps many, of the pine listed as dead of unknown causes may have died from damage done when ground freezing and heaving put upward stress on the root collar of a firmly anchored seedling.

A few seedlings, broken off just below the surface, were listed as victims of frost heaving. This resembled cutworm damage, but occurred during the cold season. Others broken off may have been washed away and listed as missing.

Soil raised by needle frost seems to have buried a few seedlings. They were listed as killed by frost heaving rather than by burial.

Trampling

An impressive 187 spots out of 600 were disturbed by elk, cattle, or deer. They were either stepped on, slid on, or screens were kicked off. Numerous spots were disturbed more than once. Yet trampling was not a major cause of death of these flexible young seedlings. Most were simply stepped on and seemed to recover, although a few of these may have died later from the effects and been listed under **unknown**. More serious than being stepped on was scuffing and, on steeper slopes, being slid on. Such action was likely to break or at least partially uproot seedlings.

Elk, which were numerous and frequented the clearcuttings in spring, summer, and fall, caused most seed spot disturbance. Cattle were present for only about 3 months a year. Deer tracks were not numerous, and deer, of course, step more lightly.

Miscellaneous Identified Causes

Washing out was a significant minor cause of spruce deaths, but killed very few pine. Typically the seedling was not washed out entirely. Rodent screens seem to protect substantially against washing out.

A few pine hypocotyls broke during germination. More often a few cotyledons broke off during emergence. The latter did not seem to kill seedlings, although such damage may have weakened seedlings and contributed to later deaths by other causes.

Seedlings on several white pine spots were killed by a bulldozer, and on two by an off-road vehicle. No spruce were killed by these events because no spruce had survived there.

Missing

There were many unaccounted for seedling disappearances. Probably the biggest causes were predation and the washing away of frost-heaved seedlings. It is hard to think of other factors that would cause the disappearance of so many seedlings. **Missing** was the largest category for spruce, which was also the likeliest to heave entirely out of the ground and the hardest to find when cut by a predator. Although roots and stubs of many seedlings listed as missing might have been found by digging, such digging generally would have disturbed seeds or other seedlings.

Unknown

Deaths listed as **unknown** do not include missing seedlings. No meaningful interpretation can be made of difference between species and treatments in the **unknown** category.

When a seedling is found dead with no evidence of cause, it is tempting to ascribe death to moisture stress. With relatively little herbaceous competition, however, moisture conditions should have remained rather favorable below the upper 2 inches or so of soil throughout the dry season (Embry 1971). Considering rooting depths and previous experience, it is questionable that pine seedlings died from moisture stress unless their root systems had been damaged by insects, disease, or frost heaving (Jones 1967, 1971, 1972). Some or even many pine deaths tallied under **unknown** may have been caused by frost heaving that broke the inner bark of well-anchored seedlings, but that is speculation. Another possibility is disease.

Spruce, with its tiny root system, may be considerably more susceptible to drought killing in the absence of root injury, though it is not clear that such drying was, in fact, an important source of spruce deaths.

Other

In some regions, heat girdling and snow blight are often identified as important seedling killers. In this study, no lesions from heat girdling were found. Such absence may reflect in part the infrequency of examinations combined with the transient nature of the lesion after death. If heat girdling had been common, however, a number of cases would almost surely have been encountered with the cause still apparent. The scarcity of heat girdling was probably due to the northerly and easterly aspects, and to the wet soils and cloudy skies usual during the summer.

No seedlings were recognized as killed by snow blight.

Conclusions

Spot seeding provided a very low ratio of seedlings to seed, and of spots stocked to spots sown, after only 2 years. Success was poor despite favorable slope aspects, absence of heavy herbaceous competition, generally good cold air drainage, substantial rodent control, and high germination percentage.

Spot seeding does not look promising as a means of regenerating mixed conifer clearings in the Southwest, even if chemical control of rodents is permitted. Seedlings that escape one hazard are repeatedly exposed to others. Species with especially small seedlings are particularly poor candidates, but even species with relatively large seedlings seem unlikely to provide adequate stocking.

In contrast to spot seeding, broadcast seeding attempts to surmount obstacles by sowing so many seeds that even a small ratio of seedlings to seed will adequately restock the area. Furthermore, heavy broadcast seeding seems able to feed the predators without critically reducing the seed available for germination. Spreading a mixture of inviable oats to satiate the rodents has also been suggested. Further research on seeding mixed conifer clearings should examine broadcast seeding rather than spot seeding.

Meanwhile, to restock mixed conifer clearings promptly, the manager should plant, unless aspen sprouts abundantly and is acceptable.

Literature Cited

Embry, Robert S.
1971. Soil water availability in an Arizona mixed conifer clearcutting. USDA For. Serv. Res. Note RM-206, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Jones, John R.
1967. Regeneration of mixed conifer clearcuttings on the Apache National Forest, Arizona. U.S. For. Serv. Res. Note RM-79, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Jones, John R.
1971. Mixed conifer seedling growth in eastern Arizona. USDA For. Serv. Res. Pap. RM-77, 19 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Jones, John R.
1972. Moisture stresses in Arizona mixed conifer seedlings. USDA For. Serv. Res. Pap. RM-86, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Krauch, Hermann.
1956. Management of Douglas-fir timberland in the Southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 21, 59 p. Fort Collins, Colo.

Noble, Daniel L., and Wayne D. Shepperd.
1973. Grey-headed [Gray-headed] juncos important in first season mortality of Engelmann spruce. J. For. 71:763-765.

Schubert, Gilbert H.
1970. Ponderosa pine regeneration problems in the Southwest. Regeneration Ponderosa Pine Symp. [Corvallis, Oreg., Sept. 1969] Proc. 1970:1-4.

PESTICIDE PRECAUTIONARY STATEMENT

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

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

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

ly 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-266

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Cubic-Foot Volume Tables for White Spruce in the Black Hills

Lawrence D. Beagle[1]

Two tables give volumes in total and merchantable cubic feet. Total volumes include all stemwood from ground line to tip of tree, while merchantable volumes include stemwood from a 1-foot stump to a 4-inch d.i.b. top.

Keywords: *Picea glauca*, volume tables.

White spruce (*Picea glauca* var. *densata* Bailey) makes up less than 4 percent of the volume of all forest growing stock in the Black Hills. Because of its moderate value and limited occurrence, little need has been felt, up to now, for spruce management working tools. Recent timber sales, however, have included both mixed stands of ponderosa pine and white spruce, and pure spruce stands. These sales have pointed up the increasing need for white spruce volume tables. The two tables presented in this Note give volumes in total and merchantable cubic feet for white spruce in the Black Hills.

Data used to prepare these tables were obtained in 1947 by Black Hills National Forest personnel from a small sample of trees on four timber sales in the Nemo area. Volumes of half-log sections (each 8.15 feet long) to a 4.0-inch d.i.b. (diameter, inside bark) top were computed by Smalian's formula and summed to obtain tree volumes. An additional diameter measurement at 3.5 feet above stump height allowed us to calculate volumes of butt half-logs in two sections to account for the typical butt swell in the lower bole of white spruce.[2]

For the total cubic-foot table, the volume of the uppermost section (above the 4.0-inch d.i.b.) was computed as though it were a cone. Stump volumes were computed as cylinders. Thus, total cubic-foot volumes include all stemwood (i.b.) from ground line to the tip of the tree, while merchantable cubic-foot volumes include only the stemwood (i.b.) between a 1.0-foot stump and a 4.0-inch d.i.b. top.

Values in both tables were computed by regressions of the dependent variable, volume (V), on a combined independent variable, diameter at breast height, outside bark, squared (D^2) times total height (H). Regression equations are given in table footnotes for use where direct computation of volumes is preferred.

---

[1] *Forestry Research Technician located at Rapid City in cooperation with South Dakota School of Mines and Technology; Station's headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *As a check on the accuracy of Smalian's formula for estimating volume in the butt half-log section, some comparative estimates were made on a sample of trees. Butt half-log volumes were estimated by neiloid formula as well as by planimetering data plotted on standard Forest Service tree measurement forms (Form 558a). These volumes were not substantially different, over the full range of tree sizes, from volumes estimated by Smalian's formula.*

Table 1.--Gross volumes of entire stem in cubic feet, white spruce in the Black Hills

Cubic feet inside bark
Entire stem including stump and top

Total height from ground to tip

Diameter breast height outside bark (Inches)	Total height in feet									Basis: Trees
	20	30	40	50	60	70	80	90	100	
	Volume in cubic feet									
5	3.3	4.0	4.6							
6	3.8	4.8	5.7	6.6						
7	4.4	5.7	6.8	8.1						2
8	5.1	6.7	8.2	9.8	11.3					6
9	5.9	7.8	9.8	11.7	13.6					16
10		9.1	11.5	13.8	16.2	18.6				7
11		10.5	13.4	16.2	19.0	21.9				4
12			15.4	18.8	22.1	25.4	28.8			4
13			17.6	21.5	25.4	29.3	33.2			5
14			20.0	24.5	29.0	33.5	38.0			11
15				27.7	32.9	38.0	43.2			1
16				31.2	37.0	42.8	48.6	54.5		2
17				34.8	41.4	47.9	54.5	61.0		3
18				38.7	46.0	53.3	60.6	68.0		3
19					50.9	59.0	67.1	75.3		0
20					56.0	65.0	74.0	83.0		2
21						71.3	81.2	91.1		1
22						77.9	88.7	99.5		1
23							96.6	108.4	120.2	1
24								117.6		
Basis: Number trees										69

Block indicates extent of basic data.
Derived from: $V = 2.04 + .00214\ D^2H$.
Standard error of estimate: ± 3.35 cubic feet or 13.1 percent.
Tabular values computed from midpoints of diameter and height classes; e.g., midpoint of the 10-inch diameter class is 10.5 and midpoint of the 40-foot height class is 40.

Table 2.--Gross merchantable volumes in cubic feet to a 4.0-inch top, white spruce in the Black Hills

Cubic feet inside bark
Merchantable stem excluding stump and top

Top diameter 4.0 inches inside bark
Stump height 1.0 foot

Diameter breast height outside bark (Inches)	Total height in feet									Basis: Trees
	20	30	40	50	60	70	80	90	100	
	Volume in cubic feet									
5	2.7	3.3	3.9							
6	3.2	4.0	4.9							
7	3.7	4.9	6.0	7.2						2
8	4.4	5.9	7.4	8.8	10.3					7
9	5.1	7.0	8.8	10.6	12.5					17
10		8.2	10.4	12.7	14.9	17.2				7
11		9.5	12.2	14.9	17.6	20.3				4
12			14.2	17.4	20.6	23.8	25.0			4
13			16.3	20.0	23.8	27.5	29.0			5
14			18.6	22.9	27.2	31.5	35.8			11
15				26.0	30.9	35.8	40.7			1
16				29.2	34.8	40.3	45.9	51.4		2
17				32.7	38.9	45.2	51.4	57.7		3
18				36.4	43.3	50.3	57.3	64.3		3
19					48.0	55.8	63.5	71.3		0
20					52.9	61.5	70.0	78.6		2
21						67.5	76.9	86.3		1
22						73.7	84.1	94.4		1
23							91.6	102.8	114.1	1
24								111.7		
Basis: Number trees										71

Block indicates extent of basic data.
Derived from: $V = 1.45 + .00204\ D^2H$.
Standard error of estimate ± 2.99 cubic feet or 12.6 percent.
Tabular values computed from midpoints of diameter and height classes; e.g., midpoint of the 10-inch diameter class is 10.5 and midpoint of the 40-foot height class is 40.

July 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-267

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Using Aerial Measurements of Forest Overstory and Topography to Estimate Peak Snowpack

Frederic R. Larson, Peter F. Ffolliott, and Karl E. Moessner[1]

On sites where slope steepness and aspect vary widely and several forest overstory size and density classes are intermixed, only topographic attributes need be measured. All of the tested photo scales (1:3,000; 1:6,000; 1:15,840) were satisfactory. On nearly level sites where size and density classes are homogeneous, forest overstory attributes also must be measured, and the 1:15,840 scale is best.

Keywords: Snow survey, aerial photography, *Pinus ponderosa*.

Although the quantity of water flowing from upland watersheds varies considerably from year to year, demand normally exceeds supply in the Southwest. To satisfy demands will require more intensive upland watershed management. This in turn will require new inventory techniques for determining quantity and distribution of water held in snowpacks under forest stands (Warskow 1971). Reservoir managers, although concerned with maximizing stored water at the end of spring runoff, must not allow reservoirs to become full too soon and create a flood hazard.

Direct inventories of snowpack water equivalent on large basins are currently uneconomical (Warskow 1971). An alternative may be to estimate snowpack water equivalent indirectly from measurements of forest overstory and topography obtained from aerial photos. As a first step in this direction, this exploratory study[2] was designed to empirically identify what relationships exist between peak snowpack water equivalent measured on the ground in ponderosa pine stands of Arizona and forest overstory and topography attributes measured on aerial photos. Peak water equivalent may be a key indexing criterion to estimate potential snowpack water yield from a basin (Ffolliott and Thorud 1972). Hopefully, results from this study may subsequently lead to syntheses of inventory systems for indirectly estimating snowpack conditions on large basins.

Study Areas

Data were obtained on the Beaver Creek watershed, located on the Coconino National Forest, and on the Apache National Forest near the Campbell Blue drainage.

Ponderosa pine comprises over 85 percent of the forest cover on the Beaver Creek study area, with an intermingling of Gambel oak (*Quercus gambelii* Nutt.) and alligator juniper (*Juniperus deppeana* Steud.). Timber was last cut prior to 1950, when half of the merchantable sawtimber was removed. Current sawtimber volume averages 2,000 ft^3 per acre. Site index (Meyer 1961) ranges from 60 to 70 ft.

Topography on Beaver Creek varies from essentially level to slopes exceeding 45 percent. Elevation ranges from 7,300 to 7,700 ft. Soils, derived from volcanics, are classified into the Brolliar and Siesta-Sponseller soil management areas (Williams and Anderson 1967). Annual

---

[1] *Larson is an Associate Silviculturist, Rocky Mountain Forest and Range Experiment Station, located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University. Ffolliott is Associate Professor of Watershed Management, University of Arizona, Tucson. Moessner, formerly Photogrammetrist, Intermountain Forest and Range Experiment Station, Ogden, Utah, is retired.*

[2] *This study was supported in part by funds provided by the U.S. Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379.*

precipitation averages 24 inches, half of which occurs between November 15 and April 15.

Ponderosa pine comprises over 95 percent of the forest cover on the Campbell Blue study area, with Gambel oak and quaking aspen (*Populus tremuloides* Michx.) intermingled. Timber was last cut in 1966-67, when an estimated 40 percent of the merchantable sawtimber was harvested. Sawtimber currently averages 1,650 ft^3 per acre. Site index (Meyer 1961) varies from 55 to 70 ft.

Gently rolling topography with few slopes exceeding 15 percent characterize Campbell Blue. The mean elevation is 8,010 ft, with a range of 100 ft. Soils are derived from volcanics. Annual precipitation at Alpine, Arizona, 7 miles north, is about 22 inches, almost half of which occurs between October 1 and May 31.

Methods

Three photo flights were made over Beaver Creek (fig. 1) to obtain photo scales of 1:3,000, 1:6,000, and 1:15,840. Two photo flights were made over Campbell Blue to obtain photo scales of 1:6,000 and 1:15,840. A Zeiss[3] aerial photo camera was used with a focal length of 8-1/4 inches. Kodak Plus X Panchromatic film was exposed through a minus blue filter at 1/500 of a second at stop f-8.

On Beaver Creek, a 9-dot-per-square-inch grid was overlaid on 1:15,840 photos, which were stratified by forest crown cover, aspect, and slope percent (Larson et al. 1971). One grid point was picked at random from each stratum, and a cluster of three sample plots was located around that point. Seventy-five plots were located.

On Campbell Blue, 40 individual sample plots were initially located on the ground, and subsequently identified on the photos. The plots were established on sites representative of the forest cover, as judged from the ground. Each plot characterized a homogeneous timber size class and density.

Center points of all sample plots were pinpointed on aerial photos for each scale. Forest overstory and topographic characteristics were then estimated[4] on 1/5-acre circular plots centered over each plot. Average total height of the dominant stand was determined from parallax wedge measurements, and total crown cover percent was determined by comparing photo images with a crown density scale. Topographic measurements included aspect to the nearest 45° and slope steepness to the nearest 5 percent. Aspect and slope steepness were determined from scale line orientation and parallax measurements (Moessner 1964).

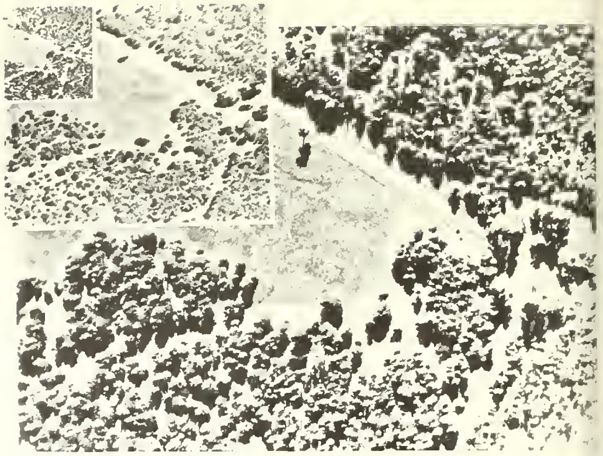


Figure 1.—A portion of the Beaver Creek Study area on aerial photos with scale of 1:15,840, 1:6,000, and 1:3,000, respectively.

The internal sample plot design, on both study areas, consisted of five permanent measurement points arranged in a diamond-shaped pattern within a circular 1/5-acre plot.

Total snow depth and water equivalent were measured with a Federal snow sampler and scale (fig. 2) at each measurement point on both study areas to characterize the snowpack through the season (table 1). Data were obtained during the winters of 1967-68 and 1968-69 on Beaver Creek and during the winters of 1968-69 and 1972-73 on Campbell Blue.

Weather Events

Distribution of 1967-68 winter precipitation was atypical on Beaver Creek, primarily as a result of record snowfall in December (Enz 1968). Approximately 95 inches of snow containing over 10 inches of water fell in a 1-week period. Little wind accompanied this storm, and snow distribution was uniform. Thereafter,

Figure 2.—Determining water equivalent of snowpack with a Federal snow sampler and scale.

---

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

[4] *Photo estimates were made by Karl E. Moessner.*

Table 1.--Summary of snowpack characteristics on warm and cool sites

Plots and dates	Precipitation increments[1]	Average snowpack, water equivalent	
		Warm sites	Cool sites
	Inches	- *Inches* -	
BEAVER CREEK PLOTS:			
1968--			
January 7	9.6	8.5	9.0
20	.1	8.1	8.9
February 10	2.5	8.8	9.3
24	2.4	8.3	10.3
March 9	.1	5.3	7.8
30	2.4	1.5	3.9
April 27	1.7	.1	.4
1969--			
February 22	13.5	5.4	7.3
March 8	3.5	7.6	9.4
15	2.3	9.4	11.1
29	.3	5.2	8.3
April 12	.1	.3	1.6
May 2	.5	0	.1
CAMPBELL BLUE PLOTS:			
1969--			
January 1	1.9	1.8	2.3
February 22	4.0	1.6	2.5
March 8	1.0	1.5	2.5
15	.7	1.9	3.0
1973--			
January 27	5.7	1.4	1.9
February 18	3.1	3.4	3.6
March 17	2.9	3.8	5.6

[1] Includes rain and snow, measured in unshielded standard gages.

storms depositing 0.1 to 2.5 inches of water occurred at intervals of 6 to 15 days, yielding a total winter precipitation of 18.8 inches. Maximum air temperatures ranged from 45° to 60° F between storms. Peak snowpack water equivalent was measured on February 10.

Distribution of 1968-69 winter precipitation was more typical on Beaver Creek, although warm weather prevailed throughout December and January. The first measurable snow fell in mid-February. Several storms depositing 0.4 to 1.6 inches of water occurred in late February and early March. Maximum air temperatures between storms ranged from 36° to 48° F. A warming trend followed the last winter storm, with daily air temperatures from 50° to 64° F. Peak water equivalent accumulation was measured following a storm on March 14. Total winter precipitation was 20.2 inches.

The timing of weather events at Campbell Blue was similar to Beaver Creek during the winter of 1968-69. However, only 7.6 inches of winter precipitation was recorded. Peak water equivalent was measured on March 15.

In 1972-73, the first measurable snow fell on Campbell Blue in early November, depositing 0.4 inch of water. Thereafter, storms depositing 0.1 to 1.9 inches of water occurred at intervals of 5 to 14 days. Peak water equivalent was measured on March 17. Total winter precipitation was 11.4 inches.

Results

Peak snowpack accumulation of water equivalent, expressed as a percent of the maximum peak accumulation measured on the study area, was estimated from aerial photos on the basis of: (1) slope steepness and aspect expressed as potential direct beam insolation (Frank and Lee 1966); and (2) crown cover and height of the dominant stand measured on aerial photos and expressed as a single forest cover variable (crown cover x height). Expressing estimated peak snowpack water equivalent as a percent of the maximum measured peak provides a basis for estimating conditions on each sample plot independent of the annual precipitation.

Water equivalent reached a peak 2 weeks earlier on warm aspects (SE, S, SW, and W) than on cool aspects (NW, N, NE, and E) on the Beaver Creek study area during the winter of 1967-68 (table 1). However, for all plots the average peak accumulation occurred on February 10, and a t-test for the two dates by aspect showed no significant difference.

Of all independent variables tested on both study areas, the combination of slope steepness and aspect was most significant. Slope and aspect measurements were converted to potential insolation (Frank and Lee 1966) received on an index date that represented the measurement period. The index date was February 20 in 1967-68, and March 21 in 1968-69 and in 1972-73. All regressions using potential insolation as the only independent variable were significant ($\alpha = 0.05$) in predicting percent of peak water equivalent.

The addition of the forest overstory variable in regressions developed for Beaver Creek increased the accountable variation by only 4 percent. The randomly selected sample plots resulted in the measurement of forest stands with several size classes and densities intermixed, which may have obscured the effect of forest overstory. Furthermore, the wide range (0 to 45 percent) in slope-steepness classes and the number of sample plots in all aspect classes created diverse potential insolation values, possibly overshadowing the influence of forest overstory.

Since all measurements of slope steepness and aspect were similar for all photo scales (Larson et al. 1971), only one equation is needed to predict snowpack condition for each year of study on the Beaver Creek plots:

Water year	Intercept b_0	Slope coefficient b_1	Correlation coefficient	$S_{y \cdot x}$
1967-68	114.6	-0.0692	0.51	11.4
1968-69	125.9	-.0788	.46	11.9

$Y = b_0 + b_1x_1$

where

Y = percent of peak snowpack water equivalent.

x_1 = potential insolation on index date (Feb.20 for 1967-68; Mar.21, 1968-69) in langleys (Frank and Lee 1966).

$S_{y \cdot x}$ = Standard error about regressions in percent of peak snowpack water equivalent.

Potential insolation was also important on Campbell Blue, but since the maximum slope steepness class was only 15 percent, the range of potential insolation values was reduced. The forest overstory variable was a significant addition on Campbell Blue, possibly because sample plots were chosen for homogeneity of timber size classes and densities. The addition of this variable to the equations increased the accountable variation measured on 1:15,840 photos by a greater amount than on larger scale photos. Thus, only the equation based on 1:15,840 photos is presented for each year of study on the Campbell Blue plots:

Water year	Intercept b_0	Slope coefficients b_1	b_2	Correlation coefficient	$S_{y \cdot x}$
1968-69	287	-0.257	-20.3	0.70	17.4
1972-73	255	-.223	-12.2	.63	15.4

$Y = b_0 + b_1x_1 + b_2x_2$

where

Y = percent of peak snowpack water equivalent.

x_1 = potential insolation on index date (Mar.21) in langleys (Frank and Lee 1966).

x_2 = common logarithm of forest crown cover in percent times the average total height of the dominant stand in feet.

$S_{y \cdot x}$ = standard error about regression in percent of peak snowpack water equivalent.

Conclusions

1. It is possible to relate peak snowpack water equivalent measured on the ground to forest overstory and topography attributes measured on aerial photos.
2. On sites where slope steepness and aspect vary widely and several forest overstory size and density classes are intermixed (as on Beaver Creek), only topographic attributes need be measured, and any of the tested photo scales may be utilized. However, on nearly level sites where forest overstory size and density classes are homogeneous (as on Campbell Blue), forest overstory attributes must also be measured. The 1:15,840 photo scale was empirically better for these measurements.
3. Prior to synthesizing an operational inventory system for indirectly estimating snowpack conditions on large basins, it will be necessary to further assess relationships such as developed in this exploratory study in terms of yearly climatic variability. Also, the applicability of such relationships must be extended to represent conditions basinwide.

Literature Cited

Enz, Richard W.
1968. Water supply outlook for Arizona (as of Jan. 15, 1968). U.S. Soil Conserv. Serv. Publ., 11 p.

Ffolliott, Peter F., and David B. Thorud.
1972. Use of forest attributes in snowpack inventory-prediction equations. J. Soil and Water Conserv. 27:109-111.

Frank, Ernest C., and Richard Lee.
1966. Potential solar beam irradiation on slopes. U.S. For. Serv. Res. Pap. RM-18, 116 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Larson, Frederic R., Karl E. Moessner, and Peter F. Ffolliott.
1971. A comparison of aerial photo and ground measurements of ponderosa pine stands. USDA For. Serv. Res. Note RM-192, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Meyer, Walter H.
1961. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agric. Tech. Bull. 630, 59 p. (Rev.)

Moessner, Karl E.
1964. Estimating slope percent for land management from aerial photos. U.S. For. Serv. Res. Note INT-26, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Warskow, William L.
1971. Remote sensing as a watershed management tool on the Salt-Verde Watershed. Appl. Remote Sensing of Earth Resour. in Ariz. (ARETS) Symp. [Tucson, Ariz. Nov. 1971] Proc. 2:100-108.

Williams, John A., and Truman C. Anderson, Jr.
1967. Soil survey of Beaver Creek area, Arizona. U.S. Dep. Agric., For. Serv. and Soil Conserv. Serv., in cooperation with Ariz. Agric. Exp. Stn. 75 p. Gov. Print. Off., Wash., D.C.

Agriculture—CSU, Ft. Collins

July 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-268

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effect of Heat Treatment on Germination of Alkali Sacaton[1]

O. D. Knipe[2]

A small percentage of alkali sacaton *(Sporobolus airoides)* seeds germinate after heating at 121° C; none germinate after heating at higher temperatures. Imbibition is reduced by heating at 65°C; after imbibition no germination occurs if seeds are imbibed and heated at 60°C on 7 or more successive days.

Keywords: Seed germination, *Sporobolus airoides*.

Summer midday soil-surface temperatures in the Southwest frequently range between 60° and 65° C.[3] Attempts to establish grasses in the area by seeding are usually unsuccessful. It seems possible that such high temperatures may contribute to the failure of grass seeds to germinate.

Cartledge et al. (1936), Davis (1947), and Siegel (1953) reported that survival increased with decreasing moisture content of heat-treated seeds, and that heating delayed germination and produced other phenotypic as well as genotypic effects.

Capon and Van Asdall (1967) found that several desert annual seeds stored at 167° F (75° C) for 4 weeks failed to germinate, and that continued storage beyond 4 weeks at 122° F (50° C) progressively diminished germinability.

The purpose of this study was to determine if heat treatment reduces the germinability of dry and water-imbibed seeds of alkali sacaton (*Sporobolus airoides*).

Methods and Materials

Since germination of alkali sacaton seeds varied considerably with size (Knipe 1970), two sizes of seeds (size 1 — large, measuring 1.5 x 1 mm, and size 3 — small, measuring 1 x 0.6 mm, all air-dried) were used.

The research consisted of five distinct tests as follows: (1) Dry seeds subjected to 71°C for 15 minutes, 30 minutes, 1 hour, 3 hours, and 6 hours, (2) dry seeds subjected to 54° and 65°C for 6 hours daily for up to 12 days, (3) dry seeds subjected to successively higher temperatures for increasing time periods until temperatures which preclude germination were reached, (4) seeds imbibed for successive time periods and subjected to heat treatments of 65° and 71° C, and (5) seeds imbibed for 24 hours and subjected to heat treatments of 60°C for 1 hour on successive days.

After heat treatment, the seeds in each study were germinated in darkness at constant 32°C, conditions shown previously to be optimum for germination of alkali sacaton (Knipe 1967, 1969). Each study consisted of four 100-seed

---

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

[2] Associate Plant Ecologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins in cooperation with Colorado State University. Research reported here was conducted while the author was assigned to Albuquerque, New Mexico: he is now located at the Station's field unit in Tempe, in cooperation with Arizona State University.

[3] Unpublished data in the files of the Rocky Mountain Forest and Range Experiment Station, Albuquerque, New Mexico.

replications germinated in 11 cm diameter petri dishes on two thicknesses of standard blue germination blotter paper moistened with 18 ml distilled water. Percentage germination was determined after 72 hours, but the seedlings were observed for 14 days to determine if heat treatment resulted in abnormal seedlings. Unheated check samples were germinated simultaneously for comparison with heat-treated seeds. A seed was considered germinated when its radicle and plumule had attained a length of 1 mm. The seeds used in the study were collected within the Rio Puerco watershed area of west-central New Mexico. The seeds were a 2-year-old lot that were hand collected, cleaned, and stored in cloth bags under laboratory conditions.

Results and Discussion

Effect of maximum natural temperature on dry seeds.—Treatment of dry seeds for up to 6 hours at 71°C had no apparent effect upon either germination or seedling normalcy.

Effect of recurrent maximum natural temperature on dry seeds.—Heat treatments of 54° and 65°C for 6 hours daily for up to 12 days had no apparent effect on germination or seedling normalcy of dry size 1 or size 3 seeds.

Maximum tolerable temperature.—Germination of dry size 1 seeds was not reduced at temperatures lower than 121°C (table 1). Although only a small percentage of seeds treated at 121°C germinated, the seedlings appeared normal. Seeds heated at 135°C, regardless of duration of exposure, failed to germinate.

Table 1.--Percent germination of size 1 alkali sacaton seeds subjected to various periods of pregermination heat treatment

Pre-germination temperatures (°C)	Germination by preheating periods				
	10 min	30 min	1 hr	3 hr	6 hr
			Percent		
None (check)			98		
38	95	97	98	100	100
46	99	98	98	97	98
54	97	98	95	99	96
63	98	98	99	99	98
71	96	98	98	96	96
79	88	89	95	95	96
93	85	92	98	97	97
107	89	96	89	92	96
121	8	12	6	2	1
135	0	0	0	0	0

These results show that dry alkali sacaton seeds are remarkably well adapted to survival under temperature extremes far in excess of those likely to occur in nature.

Effect of maximum natural temperature on imbibed seeds.—Size 1 seeds imbibed 24 hours or less in distilled water before treatment of 65°C for 1 hour germinated as well as unimbibed and nonheat-treated seeds. However, longer imbibition before heat treatment reduced germination considerably with no germination obtained for seeds imbibed more than 40 hours. Size 3 seeds responded similarly but germination percentages were lower.

The effect of heat treatment of 71°C after imbibition was greater than 65°C and greater on size 3 seeds than on size 1 seeds (table 2). Heat treatment of 71°C after only 4 hours' imbibition reduced germination of size 3 seeds, while 8 hours was required to reduce germination of size 1 seeds.

Table 2.--Percent germination of size 1 and 3 alkali sacaton seeds subjected to various pregermination temperatures for 1 hour after various periods of imbibition

Time imbibed prior to heating (hr)	Germination by--			
	Seed size 1		Seed size 3	
	65°C	71°C	65°C	71°C
		Percent		
None (check)	97		82	
4	98	96	84	62
8	100	80	84	42
12	94	63	84	30
16	92	63	83	32
20	94	28	80	26
24	96	28	76	9
28	40	0	48	0
32	42	0	43	0
36	7	0	6	0
40	10	0	10	0
44	0	0	0	0
48	0	0	0	0

It should be noted that approximately 50 percent of the size 1 seeds had sprouted by 28 hours after the start of imbibition, while only 10 percent of size 3 seeds had sprouted after 32 hours.

The reductions were in all instances greater than the number of sprouts present; obviously growth processes within the seeds were severely affected as were those of seeds which showed signs of sprouting. It is also obvious that there was a point in the within-the-seed growth stage at which damage occurred at 71°C and not at 65°C.

Effect of usual natural temperatures in imbibed seeds.—The results of the first three tests showed that dry seeds of alkali sacaton are not damaged by temperatures that are likely to occur in nature. Test 4 showed that heat treatment at 65°C after 28 hours' imbibition reduced germination, and after 40 hours' imbibition, killed the seeds. Since these conditions represent the extremes that are likely to occur in nature, Test 5 was designed to determine the effect of conditions more likely to occur in nature. Size 1 seeds were imbibed for 24 hours and subsequently subjected to heat treatment for 1 hour at 60°C each day for 1 to 8 days. Treatment for 3 days reduced germination slightly, and germination was consistently reduced further by each successive day of treatment. There was no germination after 7 days of treatment. Thus, alkali sacaton seeds are killed by recurrent wetting and drying under conditions that can be expected to occur in nature.

The mechanism responsible for reduction in germination percentage due to heat treatment was not determined. It is the opinion of the author that the heat-treated seeds that failed to germinate were dead. Years of experience in germination testing of the species has shown that viable seeds of the species will germinate under the conditions maintained in these studies. It is possible, however, that heat treatment alters the seedcoat (e.g. hardening) or the germination mechanism in such a way that the seeds remain viable while requiring some special procedure (e.g., scarification) to stimulate germination.

Conclusions

Dry seeds of alkali sacaton can withstand, without loss of viability, temperatures in excess of 110°C which exceed any likely to occur naturally.

Percent germination of large seeds of alkali sacaton imbibed for 8 hours were reduced by heat treatment of 71°C for 1 hour; percent germination of small seeds imbibed for only 4 hours was reduced by such heating. Both large and small seeds must imbibe for 24 hours before germination percentage is appreciably reduced by heat treatment of 65°C.

Temperatures no higher than those which frequently occur the day following a summer rain prevented germination of imbibed seeds; this could account for the naturally poor field germination of alkali sacaton during the summer.

Literature Cited

Capon, B., and W. Van Asdall.
1967. Heat pretreatment as a means of increasing germination of desert annual seeds. Ecology 48:305-306.

Cartledge, J. L., L. V. Barton, and A. F. Blakeslee.
1936. Heat and moisture as factors in the increased mutation rate from *Datura* seeds. Proc. Am. Phil. Soc. 76:663-685.

Davis, B. M.
1947. The appearance of a balanced lethal situation in the *Oenothera* heterogygote following severe heat treatment of seeds. Genet. 32:185-199.

Knipe, O. D.
1967. Influence of temperature on the germination of some range grasses. J. Range Manage. 20:298-299.

Knipe, O. D.
1969. Factors affecting the germination of alkali sacaton *(Sporobolus airoides)*. Ph.D. Thesis, 82 p. Univ. Ariz., Tucson.

Knipe, O. D.
1970. Large seeds produce more, better alkali sacaton plants. J. Range Manage. 23:369-370.

Knipe, O. D.
1971. Imbibition by alkali sacaton seeds. J. Range Manage. 24:71-73.

Siegel, S. M.
1953. Exposure of seeds to various physical agents. II. Physiological and chemical aspects of heat injury in the red kidney bean embryo. Bot. Gaz. 114:297-312.

Agriculture—CSU, Ft. Collins

July 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-269

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Inexpensive Chest for Conducting Frost-Heaving Experiments

L. J. Heidmann[1]

Laboratory equipment for conducting frost-heaving experiments with soil is expensive. A freezing chest constructed of plywood and styrofoam is described which can be built for approximately $60 (1974 costs). Freezing tests are conducted in 3- by 1.3-inch polyvinylchloride cylinders filled with soil.

Keyword: Frost heaving.

Frost heaving is a major cause of mortality of tree seedlings in many parts of the world. Studies by Larson (1961) and Heidmann (1974), as well as field observations, indicate that frost heaving may be the primary cause of first-year ponderosa pine mortality in Arizona. In spite of this fact, frost heaving has not been studied in detail by foresters or other workers in allied agricultural fields. A great deal of basic research needs to be done both in the laboratory and in the field. Unfortunately, laboratory equipment for conducting heaving experiments is quite expensive.

Numerous authors (Haley 1953; Higashi 1958; Jumikis 1956; Kaplar 1971; Taber 1929, 1930) have described different types of apparatus for conducting laboratory frost-heaving experiments. Most of this equipment is elaborate and expensive. In addition, most of the experiments conducted with these chests utilize cylinders of soil as large as 4 by 10 inches, which means few samples can be studied at one time. I recently concluded a comprehensive study of frost heaving in Arizona in which several experiments were conducted in a simple plywood chest. The frost-heaving characteristics of six soils, as well as methods of controlling heaving, were studied in small cylinders made of polyvinylchloride (PVC) plastic pipe.

Construction of The Chest

The freezing chest, like most others described in the literature, is constructed to simulate an open system. A supply of water which does not freeze is continually available at the bottom of the soil sample, while the freezing occurs from the surface downward. The chest is open on the top and lined on the sides and bottom with styrofoam insulation. Soil cylinders are set in a pan of water in the chest; the water is kept from freezing by a heating tape. The whole apparatus is placed in a chest-type freezer which has been modified by replacing the original thermostat with one calling for warmer temperatures (up to 32° F).

The freezing chest is built of plywood 3/4-inch thick (fig. 1). The inside dimensions are 30 inches long, 18 inches wide, and 10 inches deep. The inside of the chest is lined with a white styrofoam sheet 2 inches thick. A heating tape is countersunk in the styrofoam on the bottom of the chest about 3 inches from the edges of the chest (fig. 1). The tape has a thermostat which is set to come on when the temperature drops

---

[1] *Silviculturist, Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Author is located at Flagstaff in cooperation with Northern Arizona University.*

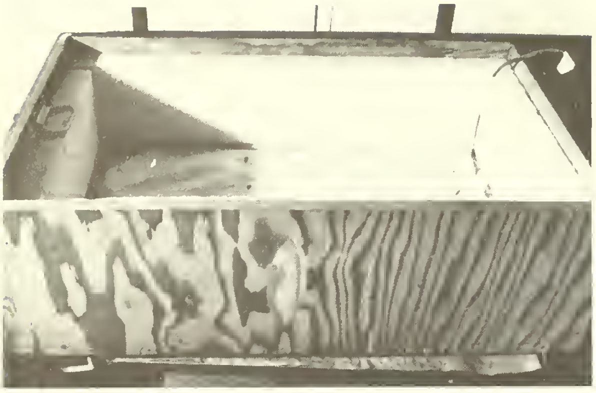


Figure 1.—Freezing chest used in frost-heaving experiments. The wire (top right) leads to a heating tape countersunk in the bottom piece of styrofoam, which is covered with a 1-inch piece of styrofoam with a lattice of holes to allow more heat to reach the water in the pan which rests on the styrofoam.

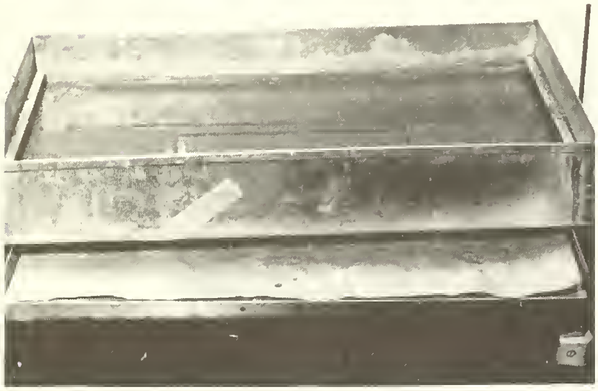


Figure 2.—Sheet metal pan which is placed in freezing chest. Pan is lined on the bottom with 1 inch of coarse sand. Ledges at each end of the pan hold a 2-inch styrofoam block containing soil cylinders.

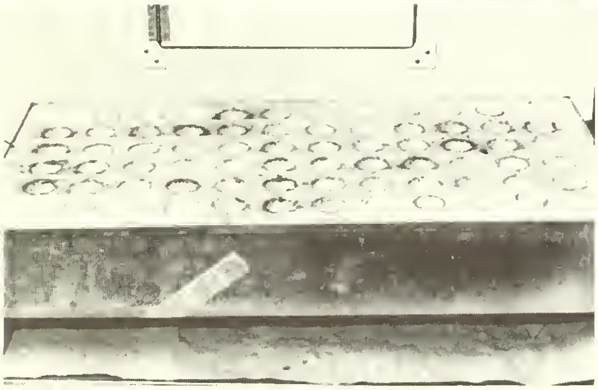


Figure 3.—Sheet metal pan with styrofoam block which holds cylinders containing soil. A total of 72 cylinders can be studied at one time.

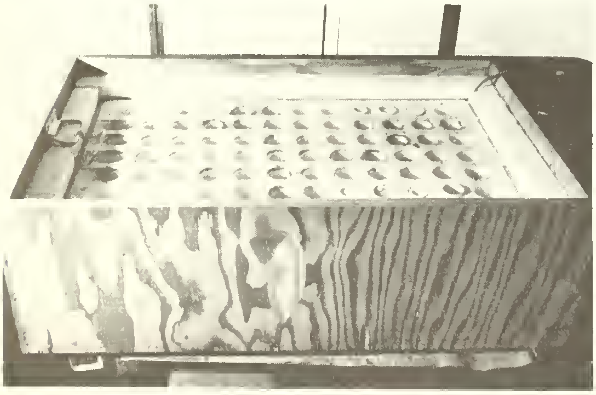


Figure 4.—Freezing box assembled. After soil cylinders are placed in the block, the whole apparatus is placed in a chest-type deep freeze unit.

below 38° F. A 1-inch-thick piece of styrofoam with a lattice of holes, 1-15/16 inches in diameter, 5 inches apart, is placed on top of the bottom piece of styrofoam which contains the heating tape, to allow more heat to flow to the water in the pan.

A pan 26 inches long, 14 inches wide, and 4 inches deep was constructed of sheet metal to hold the soil samples (fig. 2). On the inside of the pan at each end there is a 1/2-inch-wide ledge the width of the pan, 2 inches from the top of the pan. The bottom of the pan is lined with number 16 (coarse) sand to a depth of 1 inch. The sand is covered with approximately 1/2 inch of water (fig. 2). A piece of styrofoam 2 inches thick, 26 inches long, and 14 inches wide is set into the pan and rests on the ledges at the ends so that the top of the styrofoam is flush with the top of the pan. The styrofoam block contains 72 holes 1.3 inches in diameter on 2-inch centers (fig. 3). The holes are made with a piece of PVC plastic pipe which has been sharpened on the inside edge to make a punch.

The pan is placed in the freezing chest (fig. 4) and the chest is placed in a freezer.

Table 1 lists the materials needed to construct the box, and the approximate 1974 costs.

Table 1.--List of materials needed for constructing frost-heaving chest

Item	Amount required	Approx. cost
Plywood, 3/4 in (4 ft x 8 ft)	One-half sheet (4 ft x 4 ft)	$ 6.67
Styrofoam (2 in x 12 in x 30 in)	7 pieces	14.00
White glue (for styrofoam)	1 pt	2.00
Heating tape (9 ft)	One	5.50
Pan, sheet metal	One	25.30
PVC plastic pipe (1-3/16 in, i.d.)	20 ft	4.00
Sand (No. 16)	One sack	2.55
Total		60.02

Conducting the Freezing Tests

The freezing tests are conducted in small cylinders made of PVC pipe of the same diameter as the punch used for making the holes in the styrofoam. The cylinders are 3 inches long with an inside diameter of 1-3/16 inches. The cylinders are filled with oven-dried soil from which all of the material over 2 mm in size has been screened. One end of the cylinder is covered with several layers of cheesecloth held in place by a rubberband to prevent the soil from coming out the bottom. The cloth and rubberband are coated with rubber cement to make them adhere to the cylinders (fig. 5). The inside of each cylinder is coated with silicone applied as an aerosol spray.

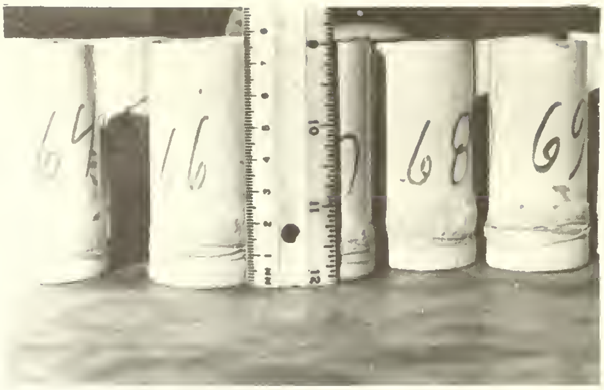


Figure 5.—Cylinders made of PVC plastic pipe are filled with soil and placed in sheet metal pan containing water. The bottom of each cylinder is covered with a piece of cheesecloth held in place by a rubberband and rubber cement.

Heaving is closely related to bulk density, or how much soil is packed into the cylinders. It is therefore necessary to determine the bulk densities desired for each soil to be tested. Calculate the volume of the cylinder to determine the amount of oven-dry soil needed, since the bulk density = mass/volume. The weight of soil needed per cylinder equals the bulk density times the volume, which is 3.4 inches^3.

At lower bulk densities, the soil may be packed into the cylinders dry. At higher bulk densities, it may be necessary to moisten the soil. The soil is packed by adding a small increment at a time to the cylinders and then hand-packing it with a hardwood dowel slightly smaller in diameter than the cylinder. When no more dry soil can be added to the cylinders, they are placed in a pan of water to saturate. After saturation, the packing is finished by adding the remaining dry soil to the cylinders. All soil samples are saturated before freezing tests are begun.

The cylinders with saturated soil are removed from the water and allowed to drain for a few seconds on paper towels to remove excess moisture, after which they are weighed to the nearest 0.1 g.

The weighed cylinders are inserted in the styrofoam block. The cylinders have to be inserted through the bottom of the block due to the cheesecloth and rubberband. The surface of each cylinder is positioned so that it is flush with the styrofoam. After the block is loaded with cylinders, it is placed in the sheet metal pan. With this arrangement, just the surface of each cylinder is exposed to the ambient temperature in the freezer. The bottom of each cylinder rests on the coarse sand in the pan in approximately 1/2 inch of water.

During the first two or three trials, the cylinders fit snugly in the holes in the block. In subsequent trials, the holes become slightly enlarged and some of the cylinders slide out of the holes when attempting to place the block in the pan. This problem is solved by wrapping a piece of paper around the cylinder before inserting it into the hole.

After freezing begins, and the soil has heaved a short distance out of the top of the cylinder, it tends to dry out and crumble because the vapor pressure gradient is from the soil to the freezer, where the humidity runs between 80 and 90 percent. To prevent drying of the frozen soil, the soil surfaces are given a fine mist spray of water at least once a day.

On completion of the experiments, the amount that each soil has heaved out of the tops of the cylinders is measured to the nearest millimeter. When the cylinders are removed from the block, some of the soil cores may have also pushed out of the bottom (fig. 6). A method of holding the cylinder in place during freezing could be devised. Otherwise, the amount of heaving on the bottom is added to the amount of heaving on top to get a total heaving figure.

Figure 6.—Soil cylinders at the conclusion of a 10-day freezing experiment. Note that the soil column has heaved out of the bottom of the cylinders also, especially those on the right.

During all freezing experiments, the air temperature 1 inch above the surface of the block is monitored with a copper-constantan thermocouple. The water temperature is also monitored with a thermocouple and a mercury thermometer. In addition, an indoor-outdoor thermometer is placed in the freezer so that temperature can be determined roughly at a glance.

The ambient temperature 1 inch above the soil surfaces is maintained at approximately 27° F, while the water temperature is kept at about 36° F.

Literature Cited

Haley, James F.
1953. Cold room studies of frost action in soils. A progress report. Highw. Res. Board, Natl. Res. Counc. Rep. 2:246-267.

Heidmann. L. J.
1974. Frost heaving — its cause and prevention. West. For. Conf., [San Jose, Calif., Dec., 1973] Proc. (In press). West. For. and Conserv. Assoc., Portland, Oreg.

Higashi, Akira.
1958. Experimental study of frost heaving. U.S. Army Snow Ice and Permafrost Res. Establ., Corps of Eng., Res. Rep. 45, 20 p. Wilmette, Ill.

Jumikis, A. R.
1956. The soil freezing experiment. Highw. Res. Board, B 135, p. 150-165.

Kaplar, Chester W.
1971. Experiments to simplify frost susceptibility testing of soil. 21 p. U.S. Army Cold Reg. Res. and Eng. Lab., Corps of Eng. Hanover, N.H.

Larson, M. M.
1961. Seed size, germination dates, and survival relationships of ponderosa pine in the Southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 66, 4 p. Fort Collins, Colo.

Taber, S.
1929. Frost heaving. J. Geol. 37:428-461.

Taber, S.
1930. The mechanics of frost heaving. J. Geol. 38:303-317.

Agriculture—CSU, Ft. Collins

July 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-270

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Cultural Control Method for Pinyon Needle Scale

Harold W. Flake, Jr.[1] and Daniel T. Jennings[2]

Describes a simple, inexpensive cultural control method for pinyon needle scale by washing eggs off host trees. Dislodged eggs, litter, and debris are raked, bagged, and destroyed. Control must be timed to coincide with the egg stage before crawler emergence.

Keywords: Cultural control, pinyon needle scale, pinyon, *Matsucoccus acalyptus, Pinus edulis*.

The pinyon needle scale, *Matsucoccus acalyptus* Herbert, is a serious pest of pinyon, *Pinus edulis* Engelm., in the Southwest. Heavily infested trees are characterized by a yellowing or browning of the foliage, reduced needle length, and premature needle drop. Foliage of trees damaged for several years is chlorotic and thin (fig. 1). Pinyons may be killed by repeated infestations of this insect. Also, trees weakened by repeated scale feeding are subject to killing attacks by secondary insects such as bark beetles. Scale damage is of greatest importance in urban and high-use recreational areas where esthetic values are impaired.

Figure 1.—Pinyon defoliated by the pinyon needle scale.

McCambridge and Pierce (1964) determined the life history of the pinyon needle scale in Arizona and Colorado. The life history is summarized as follows: Wingless females emerge in early April from overwintering immobile in-

---

[1] Entomologist, Division of Timber Management, U.S. Forest Service, Southwestern Region, Albuquerque, New Mexico 87103. Present address: Division of State and Private Forestry, U.S. Forest Service, Northern Region, Missoula, Montana 59801.

[2] Research Entomologist, located at Station's Research Work Unit at Albuquerque, in cooperation with the University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.

dividuals on the needles. As the females emerge, they are mated by winged males. Mated females lay eggs in late April in bark fissures and under bark scales of three favored sites on pinyon — (1) around the root collar, (2) in the crotches of larger branches, and (3) along the undersides of large branches (fig. 2). The yellow eggs are deposited in oval clusters held together by white "cottony" webbing. In about 4 weeks, red eye spots are visible in developing eggs under low magnification. The young, mobile crawlers emerge 7 to 10 days after the eye spots appear.

Figure 2.—Cottony egg masses on branches and around root collar.

Figure 3.—Immobile scales on year-old needles.

The crawlers migrate to year-old needles where they become immobile, and start to feed (fig. 3) by inserting stylets into the needle and sucking sap from the needle tissues. The immobile scales secrete a hard, waxy, protective covering. Feeding continues through the summer months, and by fall, mobile males begin to emerge from some of the immobile scales. Male emergence continues during warmer winter periods and in early spring. Female scales remain immobile and spend the winter as second-instar nymphs on the needles. Males emerging in fall and winter crawl down the tree from the needles and spin loose, white silken webs in sheltered places under stones, twigs, or in the litter. Winged males emerge from these webbings in April and mate with emerging females on the needles, thus completing one generation per year.

Only during the egg stage are both male and female scales highly concentrated for a short time, providing a potentially favorable situation for direct control (Pierce et al. 1968). Insecticide tests during egg hatch, and before complete dispersal of crawlers, showed that a water emulsion of 0.5% dimethoate was effective (Pierce et al. 1968). Dimethoate has been successfully used on an operational basis for controlling pinyon needle scale in scenic and recreational areas of the Southwest, and is currently registered for such use. Our Note describes an alternate method for reducing scale populations on individual trees in situations where insecticide use may be prohibited or undesirable.

Methods

We tested our washing method on May 29-30, 1973, when scales were in the egg stage. Five groups of infested trees were selected on the grounds of the Headquarters, Southwest Region, National Park Service, Santa Fe, New Mexico. In each group, three trees of like form and infestation levels were marked. Trees ranged from 5 to 9 ft in height. One of three treatment categories was randomly assigned to each tree in each group. Treatments were: (1) Egg masses were washed from large branches and lower bole of the tree. Litter, egg masses, and debris were then raked and removed from an area equal to the circumference of the tree crown. (2) Same as treatment one, with addition of a 3-inch band of Tanglefoot[3] at the base of the washed tree bole to prevent any crawlers on the ground from climbing into the tree crown. (3) Untreated check.

Egg masses were washed from the trees with a 3/4-inch hose equipped with an adjustable garden-hose nozzle to simulate equipment available to homeowners. Water was supplied by a 250-gal capacity fire pumper tank at 30 to 35 pounds pressure. Twenty to forty gallons of water were used for each tree.

Some low branches had to be pruned so the ground under the trees could be raked in treatments one and two. Litter, egg masses, and other debris raked from under the treated trees were placed in plastic bags and destroyed.

In late July, after egg hatch and crawler dispersal, the test trees were evaluated to determine scale populations on check and treated trees. Twenty-five two-needle fascicles were randomly picked from midcrown levels of each tree, and live scales on each needle were counted under a microscope.

Results

An analysis of variance of the posttreatment scale populations indicated significant differences between treatment and check means. Further analysis with Duncan's (1955) multiple range test showed no significant difference between treatment 1 (without) and treatment 2 (with Tanglefoot band), thus indicating the band was not necessary for effective control. Mean scale populations per 25 two-needle fascicles were 1.64 and 1.90 for treatments 1 and 2, respectively, while check trees had 11.80. Scale populations were thus reduced 86 and 84 percent for treatments 1 and 2, compared to check trees. These reductions were sufficient to protect the appearance of the trees. The Tanglefoot band did not improve the control obtained by washing alone.

Control Procedure

Proper timing of the washing treatment is critical. Washing will be effective only when the insects are in the egg stage, before crawlers emerge and disperse. In the Southwest, the eggs are usually susceptible from the middle of May through the first week of June. The egg stage can readily be detected by the "cottony" webbing around the root collar, in the branch crotches, and on the undersides of large branches (see fig. 2). Small trees (up to 4 ft in height) may not exhibit the "cottony" webbing, but adjacent larger trees are usually good indicators that treatment may be necessary. Needles of small trees devoid of "cottony" webbing should be checked for signs of scale infestations (see fig. 3).

Wash the tree trunk and all branches with a garden hose equipped with an adjustable nozzle (fig. 4). Eggs are easily washed from laying sites with a moderate water stream and pressure. For good control, it is important to thoroughly wash the tree trunk, branch crotches, and undersides

Figure 4.—Washing pinyon branches and trunk to remove eggs.

---

[3] *A sticky material that traps insects as they try to crawl up the tree. Trade, firm, or corporation names are used for the information and convenience of the reader. Such use does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.*

of all branches. Inspect these egg-laying sites to determine if the eggs have been dislodged.

Eggs and other debris must be removed from the tree base and destroyed. The wet litter and eggs at the base may be allowed to dry for 1 or 2 days to facilitate removal, but they must be removed before eggs hatch. Rake all litter from an area around the tree base equal to the circumference of the tree crown. All eggs and debris should be bagged and destroyed to prevent reinfestation of the original or surrounding trees (fig. 5).

The washing and removal-of-debris method is a simple, inexpensive, and effective cultural control procedure that offers an alternative to chemical pesticides.

Acknowledgments

We appreciate the help of Es Lampi, National Park Service, Santa Fe, New Mexico, for arranging the test site and assistance throughout the study.

Literature Cited

Duncan, D. B.
1955. Multiple range and multiple F tests. Biometrics 11:1-42.

McCambridge, W. F., and D. A. Pierce.
1964. Observations on the life history of the pinyon needle scale *Matsucoccus acalyptus* (Homoptera, Coccoidea, Margaroidae). Ann. Entomol. Soc. Am. 57:197-200.

Pierce, D. A., W. F. McCambridge, and G. E. Moore.
1968. Control of pinyon needle scale with dimethoate. J. Econ. Entomol. 61:1697-1698.

Figure 5.—Bagging litter, egg masses, and debris for removal and disposal.

Agriculture—CSU, Ft. Collins

August 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-271

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Velocity-Head Rod and Current Meter Use in Boulder-Strewn Mountain Streams

Burchard H. Heede[1]

The velocity-head rod should not be used in boulder-strewn mountain streams unless the gaged section can be modified to obtain uniform flow. The one-point current-meter method will suffice for most operational purposes.

Keywords: Velocity-head rod, current meter, flow velocities, flow velocity gradient, flow measurement methods, mountain streams.

Land managers concerned with investigations of water quality and yield, as well as other streamflow characteristics, need data on velocities and cross-sectional areas where stream-gaging stations do not exist. Rapidly changing flows in small mountain streams often demand quick surveys. Standard current-meter procedures are time consuming. A fast procedure such as provided by the velocity-head rod is therefore desirable. But questions arise about the accuracy of the rod as compared with that of the current meter in boulder-strewn streams.

The two devices were compared under field conditions on two streams of the Fraser Experimental Forest in central Colorado. Fool Creek was equipped with a San Dimas flume, while Deadhorse Creek had a 120° V-notch weir. The streams, described in detail elsewhere (Heede 1972), are typical of the alpine and subalpine zones of high mountains. The streambeds are armored by gravel and boulders. Flow regimens fluctuate between supercritical-turbulent and subcritical-turbulent. Sediment loads are extremely small in both streams; annual sediment yields vary from 22 to 88 pounds per acre (Leaf 1970).

The objective of this Note is not to discredit the velocity-head rod. The rod has its definite place under conditions different from those of our mountain streams. But it is the objective of this Note to warn the stream gager of pitfalls he may encounter under the stress of time and fund limitations when using either the velocity-head rod or current meter.

Theory of Velocity-Head Rod

Wilm and Storey (1944), working at the San Dimas Experimental Forest, were credited with the development of the velocity-head rod (Linsley et al. 1949). The principle of the rod is based on Bernoulli's theorem that the absolute head of flow at any cross section is equal to the absolute head of flow at a section downstream plus intervening losses of head. After several assumptions, the basic equation becomes:

$$v_t = \sqrt{2gh} = 8.02 \sqrt{h}$$

where v_t is the theoretical velocity, g is the acceleration due to gravity, and h is the static head. This theoretical velocity is computed from the static head when the velocity-head rod is used.

The stream gager selects as solid a footing as possible for the rod, and turns the sharp edge of the rod upstream. Water surface elevation is read on the rod scale for the flow that occurs most frequently at the time of measurement. Then the rod is turned with its broad side upstream. The water impinges on the rod, signifying conversion of the kinetic energy of the flow to potential energy. The rod scale is read again for the most frequent elevation. Subtracting the first reading from the second yields h of the above equation: h is also called the velocity head and is expressed in feet. Tables exist to facilitate the velocity calculations (King 1954).

The computed velocity is, of course, an approximation. Wilm and Storey (1944) warn not to use the rod if velocities are much below 1 ft/s (foot per second) or above 8 ft/s, or if the channel bottom is soft. If velocities are much smaller than 1 ft/s, elevation differences caused by the velocity head may be so small that even approximate readings cannot be obtained. At velocities

---

[1] *Hydraulic Engineer, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins in cooperation with Colorado State University. Research reported here was conducted while the author was assigned to Fort Collins; he is now located at the Station's field unit in Tempe, in cooperation with Arizona State University.*

above 8 ft/s, it is difficult to turn the rod from the edge to broad side upstream without losing the rod location on the streambed. The road location can also be lost easily in a soft stream bottom. The exact location must be kept for both rod readings, otherwise large errors may be introduced. Also if velocities increase above 8 ft/s, the slope of the energy gradient may steepen to such an extent that vertical components of flow may be introduced.

The theory summarized above is valid only for a prismatic channel and conditions of uniform flow so that the water surface is parallel to the channel bottom. As King (1954) proposes, however, the theory can be applied in most cases without material error, except for very steep slopes.

Velocity-Head Rod Measurements

A velocity-head rod, 5 ft high and 3 inches wide, was designed and built from aluminum. The prototype developed by Wilm and Storey (1944) served as the basis of the design. The light weight of the rod proved to be an asset.

We took velocity-head rod measurements when velocities of Fool Creek ranged between 1 and 8 ft/s; the majority were between 3 and 4 ft/s. The survey cross sections were between 3 and 6 ft wide, and the measurements were spaced across the stream at 0.5-ft intervals. Discharge calculations followed the centroid method applied in standard current-meter procedures.

The calculated discharges were compared with the simultaneous recordings of a San Dimas flume which gages the flow of Fool Creek. This flume, used also in other long-term research on the watershed, has a well established rating curve. Ratios between discharges derived from the velocity-head rod measurements and flume recordings were established. The overall mean ratio was 1.65 ± 0.08 with a confidence level of 0.95. It should be emphasized that these results are influenced by the cross sections surveyed, and are not necessarily representative of all mountain streams and situations.

The high losses of discharge between survey sections and flume could not be attributed to channel storage or deep seepage because the cross sections were close to the flume on a thoroughly studied stream. Data based on current-meter measurements, shown later, were on the average much closer to those of the flume.

Current-Meter Measurements

We used a Gurley No. 625 Pygmy current meter, attached to a wading rod, with the centroid method for velocity and discharge determinations. This meter is of the Price type. The vertical sections for point-velocity measurements were spaced 0.5 ft in all cross sections. Point velocities were taken at 0.2 and 0.8 depths wherever possible, otherwise one measurement at 0.6 depth was obtained.

Table 1 compares the discharge rates of Fool Creek, calculated from current meter measurements at five cross sections, with the instantaneous San Dimas flume recordings. Although the ratios of meter to flume data show considerable variation, ranging from 0.58 to 1.77, the majority were between 0.80 and 1.20. The mean ratio of all cross sections is 1.02 ± 0.06, with a confidence level of 0.95. Analysis of variance and multiple range ordering of the individual cross sections showed a significant difference between cross sections C and D only, indicating that one cross section is "out of tune" with others. Since a limited number of cross sections is represented here, the question of validity of results arises. The cross sections were selected to give a wide range of problems facing the stream gager using a head rod or current meter. It can be surmised, therefore, that other locations and cross sections most likely will show less variation.

Table 1.--Ratios of discharges derived from current meter readings to flume recordings, Fool Creek

Cross section	Sample size	Mean ratio	Standard error
A	16	1.18	0.37
B	10	1.01	.19
C	6	.97	.10
D	9	1.27	.15
E	10	.98	.13

Vertical Velocity Gradients

It is well known that, in highly turbulent mountain streams, the vertical velocity gradient does not have logarithmic profile, a characteristic often found in larger channels. But the extensive deviations from the "classic" profile are much less known. These deviations are illustrated by two characteristic profiles of Deadhorse Creek (figs. 1 and 2), based on measurements at depth spacings as close as permitted by the Pygmy current meter. The profiles indicate that nearly any shape of gradient could be found with the exception of two points; the point at zero depth must go through the point of origin and the point at the water surface will always have a velocity greater than zero.

Comparison of Standard Current-Meter Results with Extensively Measured Velocity Profiles

To evaluate the validity of standard current-meter procedures in mountain streams using the one- or two-point measurement techniques, we compared the average velocities obtained from such measurements with those

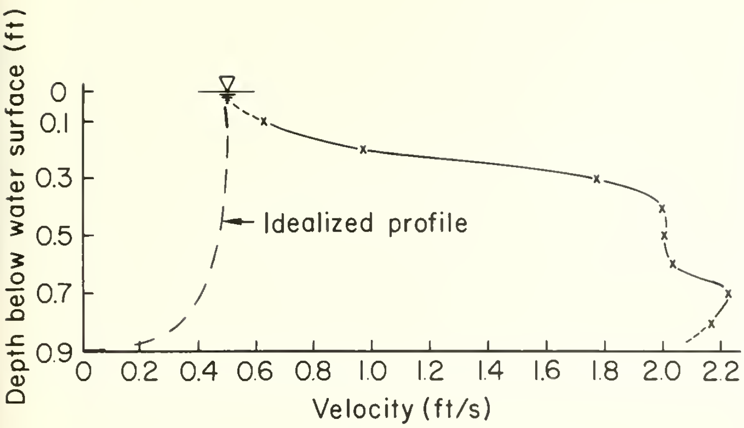


Figure 1. —The vertical velocity profile was measured with a Pygmy current meter during a discharge of 1.32 ft³/s at cross section B of Deadhorse Creek. Distance of vertical section from closest bank is 0.3 ft. The stage is slightly falling. The "classic" velocity distribution in streams is superimposed as an idealized profile.

based on all measured points (table 2). Conventional depths below the water surface were used for the first two methods — 0.6 depth for the one-point and 0.2 and 0.8 depths for the two-point methods. When all measurable point velocities were taken in the vertical section, a very dense distribution was obtained and we felt justified, therefore, to read the 0.6-, 0.2-, and 0.8-point velocities from graphic depth profiles. This procedure eliminated a time lapse between measurements by different methods, and with it any possible changes in flow characteristics such as alterations of flow lines.

Statistical analysis indicated that the cross sections did not behave differently for either method, and the difference between the ratios of one- and two-point methods to all measured points was not significant (0.95 confidence level). This lack of difference is due, of course, to the wide variation in the individual readings (table 2), caused by the high turbulence of flow. Table 2 indicates also that total depth of flow less than 1 ft, such as encountered in this investigation, does not influence the accuracy of either method.

Discussion

Discharge rates calculated from velocity-head rod data were between 115 and 204 percent of those of the flume. It is postulated that, in part, the higher rod values reflect losses of elevation on the streambed when the rod was turned with its broad side upstream. Rounded gravel and boulders on the bed often provided a slippery footing for the rod, and under pressure of the impinging water, the rod moved from a high to a low point. Also, and possibly more influential, were rapidly changing, diverging flow lines (rotational flow) leading to "rooster tails" on each side of the rod, indicating incomplete conversion of velocity head to depth. These flow line changes were caused by channel roughness due to coarse gravel, boulders, and rock outcrops. In our rough channels, cross-sectional areas determined by the centroid method were inaccurate and added to the deviations of the calculated data. Also, a degree of subjectivity is

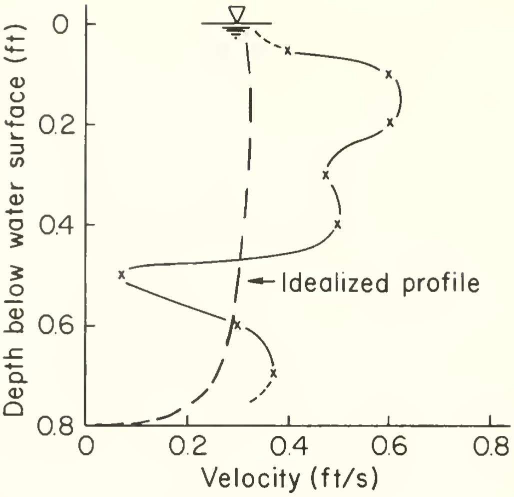


Figure 2.—The vertical velocity profile at cross section C of Deadhorse Creek during a discharge of 1.95 ft³/s. The stage is slightly falling. The vertical section is located 0.7 ft from the closest bank. An idealized profile, representing the "classic" velocity distribution in streams, is superimposed.

Table 2.--Comparison of average velocities of a vertical stream section based on the ratios of 1- and 2-point methods to all measured points, Deadhorse Creek

Distance from nearest bank (Feet)	Total water depth (Feet)	Ratio between: 1-point all points	2-point all points
Cross Section B			
Discharge 1.32 ft³/sec			
0.30	0.90	1.17	0.88
.80	.77	.72	1.13
.90	.70	.59	1.01
.40	.42	.93	.80
Discharge 1.55 ft³/sec			
.30	.84	1.00	.94
.80	.75	.80	1.09
.90	.67	.82	1.24
.40	.42	.98	1.03
Cross Section C			
Discharge 1.95 ft³/sec			
.30	.75	1.55	.86
.80	.75	1.41	1.05
1.30	.90	1.17	1.12
.70	.80	.15	1.19
	Mean:	.94 ±.11	1.03 ±.04

added to the rod readings since determination of the water surface elevation that occurs most frequently during the time of observation is based on judgment.

Past experience has shown that velocity-head rod measurements are reliable within a few percent (Wilm and Storey 1944) if channel bottoms are relatively smooth and cross sections can be determined accurately such as in flumes or concrete channels. Under these conditions, changes of the water surface elevation are not erratic as in our mountain streams and the flow is irrotational. Goodell[2] found good agreement between flow input, as measured by a Venturi meter, to a long, uniform channel in the laboratory and discharge in the channel as measured by velocity-head rod.

Discharge rates obtained from the centroid current-meter method were much closer to those of the flume, and in contrast to the head-rod data, moved between minus and plus values relative to the flume. The current meter deviations are attributed to the impossibility of determining accurate cross sections of flow in a boulder-strewn stream, and to the rapidly changing flow lines (turbulent flow). We used meter periods of 1 minute under more severe conditions. Longer individual meter times would substantially increase the total survey time of a cross section, which in turn could introduce error due to changes in flow occurring within this time span. It took 25 to 30 minutes to survey our small mountain streams by current meter.

The large deviations of the vertical velocity profile from the classic logarithmic distribution are, of course, caused by the high turbulence of flow. Under such conditions, horizontal and vertical flow components may alternate by depth, resulting in drastic changes of velocities in the downstream direction. Velocity is a vector quantity because it possesses both magnitude and direction. Current meters do not respond equally to all directions of flow. The current meter used, with cups rotating around a vertical axis, reflects mainly velocities in the downstream direction, and does not record minus velocities caused by eddies. Yet, the average velocity of a section is the resultant of all individual velocities, regardless of direction. In terms of flow, discharge is the quantity of flow that passes a given cross section in a given period of time, regardless of the angle of passage. It follows that current meters do not record true velocities in turbulent streams (Yarnell and Nagler 1931).

The bizarre profiles of the vertical velocity gradients of flow led to wide variations in average calculations, whether the one-point or two-point method was used. Thus, at the 0.95 confidence level, neither method is superior.

Conclusion

The velocity-head rod should be used if channel bottoms are fairly smooth, channels are approximately prismatic, and cross sections are close to plain geometric figures. The rod is an efficient tool for calibrating or checking calibration changes of a flume, and it could be useful in urban runoff investigations. It should not be used in boulder-strewn mountain streams carrying highly turbulent flows without first modifying the gaged section to obtain uniform flow conditions.

In boulder-strewn mountain streams where cross sections cannot be changed to facilitate velocity-head rod use, velocities should be obtained from current-meter readings. It should be recognized that rotational flow prevails in these streams, water surface elevations fluctuate erratically, and flow lines change rapidly, leading to bizarre vertical velocity profiles. Thus, wide variations in the individual readings are introduced, and it will suffice, therefore, for most operational purposes to use the one-point current meter method to save time. The majority of the individual readings will produce an error in discharge rates within ± 20 percent as compared with the flume, while errors in head-rod readings without channel modification will range between + 15 and + 104 percent. Although in this study the flume was assumed to yield true values, the error at the discharge rates experienced is about ± 5 percent.

Literature Cited

Heede, Burchard H.
  1972. Flow and channel characteristics of two high mountain streams. USDA For. Serv. Res. Pap. RM-96, 12 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

King, Horace Williams.
  1954. Handbook of hydraulics. Ed. 4, rev. by Ernest F. Brater. v.p. McGraw-Hill, N.Y.

Leaf, Charles F.
  1970. Sediment yields from central Colorado snow zone. Proc. Amer. Soc. Civil Eng., J. Hydraul. Div. 96(HY1):87-93; 97(HY2):350-351.

Linsley, Ray K., Max A. Kohler, and Joseph L. H. Paulus.
  1949. Applied hydrology. 689 p. McGraw-Hill, N.Y.

Wilm, H. G., and H. C. Storey.
  1944. Velocity-head rod calibrated for measuring streamflow. Civil Eng. 14:475-476.

Yarnell, David L., and Floyd A. Nagler.
  1931. Effect of turbulence on the registration of current meters. Trans. Am. Soc. Civil Eng. 95:766-860.

---

[2] *Personal communication from Dr. B. C. Goodell, retired, Rocky Mountain Forest and Range Experiment Station.*

Agriculture—CSU, Ft. Collins

ecember 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-272

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Estimating Food Consumption from Twigs Clipped by the Abert Squirrel

David R. Patton[1]

Abert squirrels consume the inner bark of ponderosa pine twigs for food. Mean length, diameter, and dry weight of peeled twigs from a sample of 300 was 88 mm, 5.9 mm, and 1.3 g, respectively. A table gives dry weight of the whole twig, inner bark, and outer bark from dry weight of a peeled twig. Nutrient content of the inner bark is low.

Keywords: Wildlife food plants, *Sciurus aberti aberti, Pinus ponderosa.*

Availability of foods during winter months is probably the single most important factor controlling wild animal populations. Wildlife managers need to determine the quantity of food items consumed by an individual species and how much food will be available in the winter. In this manner the quantity of food needed and amounts available for survival are brought together under the concept of "carrying capacity." This simple principle has been the guiding philosophy in wildlife management for nearly four decades. Now, however, there is a need to understand the total role of animals in an ecosystem. The new direction does not do away with the carrying capacity concept but helps to define it in more precise terms by understanding nutrient cycling and energy flows.

The Abert squirrel *(Sciurus aberti aberti)* occupies a niche in the ponderosa pine *(Pinus ponderosa)* forest and depends on pine for food and cover. Food items of the Abert as they are currently known are composed mainly of seeds, buds, and twigs of ponderosa pine, plus acorns and fungi when they are available.[2] [3] The squirrel's staple winter diet consists mostly of the inner bark of pine twigs during the period from November to April, but this depends on snow cover which inhibits ground foraging.

Clipped and peeled twigs are a sure indication that a squirrel has been feeding, and they are almost always the work of an Abert squirrel. The number of twigs clipped per day is variable, and no one has determined if the number clipped is related to squirrel numbers. However, the number of clipped twigs does indicate some unknown amount of food consumed for a given time. This study was initiated to determine the characteristics of twigs selected for food, to develop a technique for estimating the amount of inner bark consumed from a peeled twig, and to determine the nutrient content of the inner bark.

---

[1] *Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, located at Tempe, in cooperation with Arizona State University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Keith, J. O. 1965. The Abert squirrel and its dependence on ponderosa pine. Ecology 46:150-163.*

[3] *Stephenson, Richard L. 1974. Seasonal food habits of Abert's squirrels, Sciurus aberti. Eighteenth Annu. Meet. [Flagstaff, Ariz., Apr. 1974]. Proc. Suppl., J. Ariz. Acad. Sci. 9:8 (Abstr.)*

Methods

The study was conducted in watershed 8 in the Beaver Creek watersheds on the Coconino National Forest, Arizona. Permanent timber inventory stakes served as plot centers to count clipped twigs that had accumulated on 189 plots (0.01 acre). Clippings were counted in June 1973; 1,219 peeled twigs were removed and dried for measurement.

A random sample of 300 twigs was drawn from the total number to get individual weights, diameters, and lengths. Another sample of 150 live twigs was cut from pine trees in September to duplicate the range in sizes found on the inventory plots (fig. 1). The outer and inner bark was removed and ovendried along with the peeled twig. The inner bark was analyzed for elements, fat, protein, and fiber content.

Results

Sixty-six percent of the peeled twigs were between 61 and 100 mm in length (table 1). The higest percentage (23 percent) were 71 to 80 mm long. Mean length was 88 mm, with a standard error of 1.4 mm and a coefficient of variation of 28 percent.

Diameters from 4 to 8 mm account for 96 percent of the twigs (table 1). Twenty-seven percent were in the 5 mm diameter class. Mean diameter was 5.9 mm, with a standard error of 0.09 mm. Coefficient of variation was 26 percent. Because these figures are for peeled twigs, 2 to 3 mm would have to be added to duplicate the diameter of the twig as it would occur on a tree.

Dry weight of twigs ranged from 0.05 to just over 4 g (grams); 86 percent were less than 2 g (table 1). The mean weight was 1.3 g with a standard error of 0.05 g. Coefficient of variation was quite large at 62 percent.

Figure 1.—Range in size of twigs collected on inventory plots. Scale: 1 block equals 2.54 centimeters (1 inch).

Table 1.--Frequency distribution of length, diameter, and dry weight of twigs clipped by Abert squirrels

LENGTH

Length class (mm)	Number	Percent of total	
41- 50	9	3.0	
51- 60	22	7.3	
61- 70	39	13.0	65.8
71- 80	69	23.0	
81- 90	46	15.4	
91-100	43	14.4	
101-110	21	7.0	
111-120	16	5.3	
121-130	18	6.0	
131-140	7	2.3	
141-150	6	2.0	
151-160	4	1.3	
Total	300	100.0	

DIAMETER

Diameter class (mm)	Number	Percent of total	
1	0	0	
2	0	0	
3	1	.3	
4	58	19.4	96.1
5	81	27.0	
6	62	20.7	
7	57	19.0	
8	30	10.0	
9	4	1.3	
10	5	1.7	
11	1	.3	
12	1	.3	
Total	300	100.0	

DRY WEIGHT

Dry weight class (g)	Number	Percent of total	
<1.0	142	47.4	85.7
1.1-2.0	115	38.3	
2.1-3.0	31	10.3	
3.1-4.0	9	3.0	
4.1>	3	1.0	
Total	300	100.0	

Linear regression equations were computed from the 150-twig secondary sample to estimate weight of inner bark, outer bark, and total weight of peeled twigs to total twig weight (table 2). This sample had been cut from pine to simulate twigs removed by squirrels. All the equations had a correlation coefficient greater than 0.90.

Table 2.--Dry weight (g) of inner and outer bark and total twig weight, estimated from dry weight of peeled twigs

Peeled twig	Inner bark	Outer bark	Whole twig
0.5	0.13	0.69	1.32
.6	.15	.76	1.51
.7	.16	.83	1.69
.8	.18	.90	1.88
.9	.20	.96	2.06
1.0	.21	1.04	2.25
1.1	.23	1.11	2.44
1.2	.25	1.17	2.62
1.3	.26	1.25	2.81
1.4	.28	1.31	2.99
1.5	.30	1.38	3.18
1.6	.31	1.46	3.37
1.7	.33	1.52	3.55
1.8	.35	1.59	3.74
1.9	.36	1.66	3.92
2.0	.38	1.73	4.11
2.1	.39	1.81	4.30
2.2	.41	1.87	4.48
2.3	.43	1.94	4.67
2.4	.44	2.01	4.85
2.5	.46	2.08	5.04
2.6	.48	2.15	5.23
2.7	.49	2.22	5.41
2.8	.51	2.29	5.60
2.9	.53	2.35	5.78
3.0	.54	2.43	5.97
3.1	.56	2.50	6.16
3.2	.58	2.56	6.34
3.3	.59	2.64	6.53
3.4	.61	2.70	6.71
3.5	.63	2.77	6.90
3.6	.64	2.85	7.09
3.7	.66	2.91	7.27
3.8	.68	2.98	7.46
3.9	.69	3.05	7.64
4.0	.71	3.12	7.83

The inner bark from the twigs clipped in September was low in protein (4.6 percent) and fat (7.0 percent), but was high in fiber content (41.7 percent). These figures indicate the inner bark is not very nutritious at least in September. A continuous diet of twigs, without supplemental foods, would put a squirrel in a weak condition susceptible to death from weather extremes. Elements in the inner bark sample, in p/m (parts per million), were:

Nitrogen	6,700
Phosphorus	900
Potassium	4,300
Magnesium	1,620
Calcium	6,300
Sulfur	300
Zinc	42
Manganese	103
Iron	111
Copper	17
Boron	22
Sodium	400

With the data obtained in this study it is possible to estimate the amount of inner bark consumed by the Abert squirrel. The litter that resulted from removing a whole twig can be estimated at the same time. This litter eventually will decay and be returned to the ecosystem as nutrients.

As an example, Keith (1965) estimated that an Abert squirrel can clip 50 twigs a day to get the inner bark. The average weight of a peeled twig from the sample of 300 was 1.3 g. This weight converts to 0.26 g of inner bark and 1.25 g of outer bark. For 50 twigs, the average weights, in g, were:

Inner bark (food)	13.0
Outer bark (litter)	62.5
Peeled twigs (litter)	65.0
Total	140.5

Thus the squirrel actually consumes less than 10 percent of the weight of the twigs it clips.

Agriculture—CSU, Ft. Collins

December 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-273

OREST SERVICE
.S DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Identifying Ponderosa Pines Infested with Mountain Pine Beetles

William F. McCambridge[1]

Trees successfully and unsuccessfully attacked by mountain pine beetles have several symptoms in common, so that proper diagnosis is not always easy. Guidelines presented here enable the observer to correctly distinguish nearly all attacked trees.

Keywords: Scolytidae, *Dendroctonus ponderosae*, *Pinus ponderosa*.

Adult mountain pine beetles attack green trees in late summer. Some trees resist attack and continue to live, while others are overcome, produce brood, and die. The unsuccessfully attacked trees may or may not be reattacked in subsequent years. These trees, while sometimes showing some of the signs of attack, do not show all of them and should not be removed in the course of control work. The task, then, is to properly determine if an attacked tree is infested.

Unfortunately, the needles on most infested trees do not fade until the spring or summer after attack, so that infested and healthy trees superficially look the same for about 10 months following attack. This guide is to help you determine which trees are in fact infested.

Successful Attacks

Trees that are successfully attacked have the following characteristics:

1. Fine, dry frass (sawdustlike) around the base of the tree and in bark crevasses.
2. Brood. You have to cut away pieces of bark to see the cream-colored grubs or pupae. Brown, then black adults will be seen in late June and July.
3. Small (about ¼ inch in diameter) or no pitch tubes. (If you cannot see pitch tubes or fine frass and the tree really is infested, you simply miss spotting it. However, its needles will likely turn straw yellow by June and the tree can still be cut and sprayed before beetles emerge.)
4. Wood under the bark is dull blue due to bluestain fungi carried in by the beetles. If you see only a single narrow strip as high as you can reach, the tree may survive. To be fatal, bluestain has to be well distributed around the tree and accompanied by fine frass or brood. Stain becomes visible in the fall, and by winter is found throughout the sapwood.

---

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

5. Needles fade in June and July. Unfortunately, about 20 percent of infested trees do not fade until after beetles escape. In this case, as in step 3, you just miss the tree, and its brood escapes before the tree finally looks dead. These missed trees are one of the major reasons why bark beetles are hard to control.

Unsuccessful Attacks

Trees that may live, if not reinfested or attacked higher up by other bark beetles, will have the following characteristics:

1. Large pitch tubes (½ inch or more in diameter).
2. Coarse frass.
3. Very sparse or no brood. Frequently the vertical egg gallery is packed with very resinous frass, and the surrounding wood is moist and white.
4. No bluestain wood, or only thin strips of bluestain developed by the following spring.
5. Foliage remains green, not turning yellow. Since some successfully attacked trees do not fade the summer after attack, one or more of the other characteristics must be present.

Please remember when using this guide that its purpose is to prevent removal of uninfested trees. Consequently, one can expect that some trees that were left will die and have to be removed. The risk of spreading or maintaining a beetle infestation from such trees is minimal. Also, keep in mind that attacks can range from a single beetle which cannot harm the tree, to several hundred pairs which assure tree mortality. Somewhere in between are the trees that are difficult to properly identify. If there is any question and the trees are in an active control project area, they should be removed and treated; otherwise, success of the control project is jeopardized.

Agriculture—CSU, Ft. Collins

December 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-274

OREST SERVICE
.S DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Model for Predicting Erosion and Sediment Yield from Secondary Forest Road Construction

Charles F. Leaf[1]

One of the more visible and controversial environmental impacts associated with timber harvesting and development in central Colorado is road construction. Better tools are needed to quantify the effect of soil disturbance on erosion onsite, and the subsequent yield of sediment downstream.

This Note summarizes available data, and from this base, proposes a preliminary model for predicting an index of onsite erosion and downstream sediment yield.

Keywords: Forest roads, erosion, sediment, predictive models.

Effect of Timber Harvesting and Road Construction

Watershed erosion and damage to water quality from road construction and timber harvesting can be significantly reduced through proper planning, construction, and followup maintenance (Packer and Laycock 1969, Megahan 1972a). For example, Leaf (1970-71) showed that on Fool Creek, in the Fraser Experimental Forest, road construction associated with timber harvesting resulted in minimum erosion damage with apparently no reduction in water quality. The 3.3 miles of main access road were carefully located to avoid the stream channel and to minimize erosion. Timber was made accessible by an additional 8.8 miles of spur roads laid out along contours. Spur roads were provided with surface drainage and culverts at stream crossings. After logging was completed, spurs were seeded to grass, and culverts were removed on alternate roads to reduce traffic. Routine followup maintenance is still done on the main haul road.

Annual sediment yields were measured, using a grid of closely spaced cross sections, at the stream gages on Fool Creek and two undisturbed experimental watersheds to determine the effects of harvest cutting and road construction. These yields were based on gross volumes which included leaf litter and related organic material. Dry volumes of mineral matter therefore occupied approximately 75 percent of the total volume of debris. Samples collected from the debris basins indicated that deposited sediments contained a wide range of organic content. Using equations developed by Megahan (1972b), we estimated that organic content varied from 20 percent to less than 1 percent of the total sediment weight. The average computed organic content was approximately 1.5 percent of the total accumulated sediment weight.

---

[1] *Hydraulic Engineer, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University, when research was conducted; Leaf is now self employed as a Consulting Hydrologist, Fort Collins, Colo.*

Sediment yield, including mineral soil and debris, was relatively high immediately following road construction. However, yield decreased rapidly and approached preharvest levels after 6 years despite a persistent increase in runoff caused by logging. Other studies support the time trend results observed on Fool Creek, even though soil and geologic conditions were different (Megahan 1974). It is important to understand that these conclusions apply only to **surface erosion,** and not to **mass erosion,** which can occur through the disturbance of very steep and naturally unstable topography.

Sediment Yield Model

Megahan (1974) has proposed a negative exponential equation with a linear component containing three parameters to describe the time trends in erosion discussed above. The equation can be expressed as:

$$E = \epsilon_n t + S_o(1 - e^{-kt}) \qquad [1]$$

where
E = the cumulative onsite erosion at time (t) after disturbance,
ϵ_n = an estimate of the long-term "normal" erosion rate on the disturbed area,
S_o = an index of the total amount of soil available for erosion due to disturbance, and
k = an index of the rate of decline of erosion following disturbance.

According to Megahan, (ϵ_n) is the long-term erosion "norm" which is reestablished after a site is disturbed. In some areas, this new norm may be higher than the long-term erosion under natural conditions because of irreversible changes in site factors. However, the limited data from Fool Creek and from undisturbed watersheds in the area indicate that the reestablished erosion norm on Fool Creek is essentially the same as before disturbance. Therefore, equation [1] is used to predict erosion time trends—with one modification. In this report, (ϵ_n) is defined as the natural long-term sediment yield.

The logging operation on Fool Creek required disturbance of 35 acres (Goodell 1958); virtually all of this involved construction of roads and landings. Because most of the disturbed area is occupied by roads, it can easily be described in terms of road-design variables (fig. 1). For example, 12.1 miles of road were constructed across slopes which averaged 26 percent. Thus, the 35 acres of road area corresponds to an "effective" cross section having the following characteristics:

"effective width" = 14 ft
cut and fill slopes = 1½:1 (33.7°)
width of disturbed area = 23 ft
area disturbed per mile = 2.8 acres

These results were obtained from the following equations which can be derived from figure 1:

$$D = W + \frac{W/2 \tan \rho}{\tan \Theta_F - \tan \rho} + \frac{W/2 \tan \rho}{\tan \Theta_C - \tan \rho} \qquad [2]$$

when $\Theta_F = \Theta_C = \Theta$,

$$D = W \left[1 + \frac{\tan \rho}{\tan \Theta - \tan \rho}\right] \quad D \geqslant W; \Theta \geqslant \rho \qquad [3]$$

where
D = total disturbed length perpendicular to the centerline in ft,
ρ = steepness of the sideslope in degrees, and
Θ = angle of cut and fill slopes in degrees (Θ_C = angle of cut and Θ_F = angle of fill).

Equation [3] assumes balanced cut and fill (that is, that the centerline bisects the road width). This is not usually the case, since the cross section can vary from total cut to total fill in actual practice. It is assumed, however, that a sufficiently accurate index of the total area disturbed can be obtained by estimating an "effective" width and average cut and fill slopes for the proposed road system. Such estimates require considerable judgment and a knowledge of the topography.

Equation [3] provides a means for expressing the area disturbed in terms of watershed and engineering design parameters. When this expression is used in combination with equation [1] (provided that data are available), it should

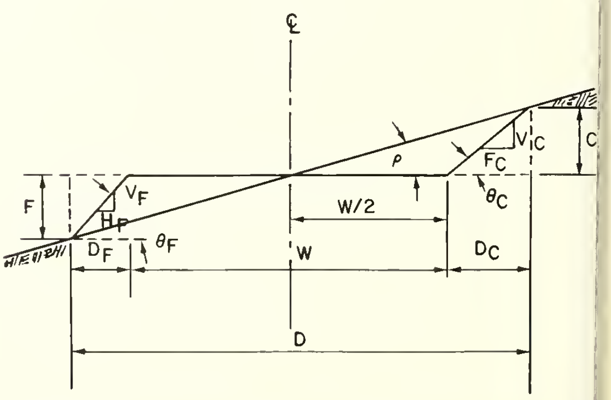


Figure 1.—Simplified cross section, illustrating design variables.

give the land use planner some latitude, subject to the limitations and assumptions discussed below, in predicting the probable erosion hazard for alternative road designs.

Onsite Erosion Versus Sediment Yield Downstream

To fit parameters to equation [1], the sediment yields measured at the gage on Fool Creek were adjusted to unit yields per acre of the area actually disturbed (35 acres). These data (summarized in table 1) represent gross volumes of mineral soil and debris immediately following road construction. It should be emphasized that table 1 summarizes erosion indices and not the actual erosion which took place on-site, since the data were collected in a debris pond at a point downstream. The accumulated erosion data were plotted in figure 2, and [1] was fitted using a nonlinear procedure:

$$E = 0.28t + 401.3(1 - e^{-0.085t}) \qquad [4]$$

E = an index of the cumulative onsite erosion in ft^3/acre at time (t) after road construction on Fool Creek,

ϵ_n = 0.28 ft^3/acre which was determined from (1) average erosion on Fool Creek after the 6th year, and (2) long-term yields from two undisturbed watersheds, and

t = the number of years after the initial disturbance.

Three assumptions were made in order to develop the model for predicting erosion and sediment yields. First, it was assumed that equation [4] provides a better index of erosion than equations based on rainfall-derived erodibility indices. Such indices do not predict time trends, and furthermore, do not account for the effects of snowmelt, which is responsible for much of the sediment yield from the densely forested subalpine zone in Central Colorado. The second assumption was that onsite erosion is proportional to the area disturbed. Finally, it was assumed that the delivery ratio is constant for a given watershed size, regardless of the amount of area disturbed. These assumptions involve complex interactions between the hydrology, geology, and soils, which need to be verified by additional study.

Based on the simplifying assumptions discussed above, equations [2] and [4] were combined in order to predict an index of the cumulative onsite erosion (S), as a function of the width of roadbed (W), average watershed sideslope (ρ), and angle of cut and fill (Θ_C and Θ_F).

Table 1.--Summary of sediment yields from Fool Creek, Fraser Experimental Forest

Year	Sediment yield[1]	Year	Sediment yield[1]	Year	Sediment yield[1]
	Ft^3/acre		*Ft^3/acre*		*Ft^3/acre*
1952	44.9	1958	42.8	1964	([3])
1953	22.6	1959	8.6	1965	25.5
1954	([2] [3])	1960	13.9	1966	5.6
1955	([2] [3])	1961	6.1	1967	6.4
1956	36.7	1962	16.3	1968	11.1
1957	70.1	1963	([3])	1969	13.9
				1970	15.2

[1] Based on 35 acres disturbed; average dry unit weight = 85 lb/ft^3 (range: 16-120 lb/ft^3).

[2] Timber harvest.

[3] Negligible accumulation.

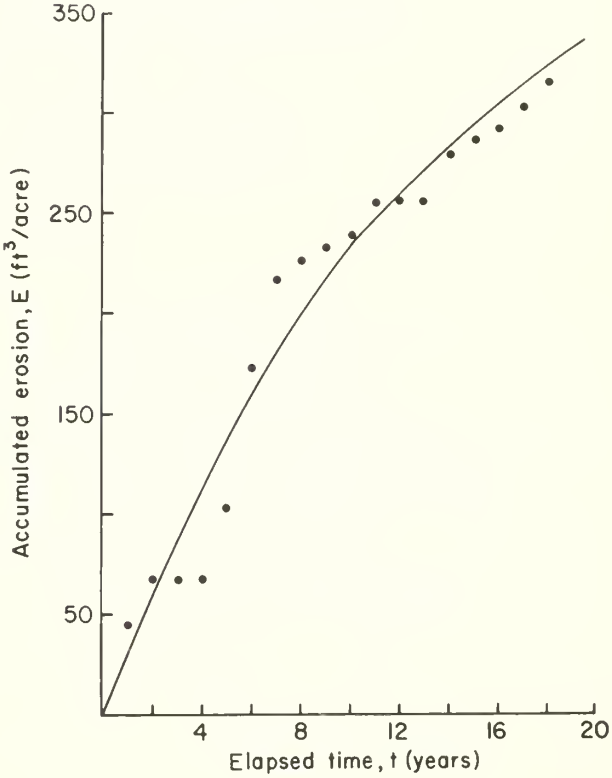


Figure 2.—Accumulated erosion as a function of time on Fool Creek, Fraser Experimental Forest.

Thus
$S = 0.121\ DEn$

Substitution of equation [2] for (D) yields

$$S = 0.121\ WEn\left[1 + \frac{\tan\rho}{2}\left[\frac{1}{\tan\Theta_C - \tan\rho} + \frac{1}{\tan\Theta_F - \tan\rho}\right]\right] \qquad [5]$$

where
S = an index of the cumulative erosion in ft^3,
E = given by equation [4],
t = the number of years after initial disturbance, and
n = the number of miles of road construction.

Because equation [5] is expressed in terms of engineering design variables, its use should provide an indication of the probable erosion impacts of alternative road systems. The yields expressed on a watershed basis are given by the equation

$$Q_S = \frac{S}{A} \qquad [6]$$

where
A = the area of the watershed.

Equation [6] is valid, provided that the upstream drainage area does not exceed 1 mi^2.[2] Sediment yields at downstream points would be less, since delivery ratios are inversely related to watershed area.

Discussion and Conclusions

One of the more significant results from sediment yield studies in mountain watersheds is that most of the erosion impact occurs within a few years after disturbance. This time factor should be considered in land use planning from two standpoints: protection, and long-term effects on hydrologic parameters such as water quality.

Equations which require erodibility indices based on rainfall intensity may be grossly in error when applied to much of the subalpine zone in central Colorado, where much of the sediment yield results from melting snow. Equation [1], proposed by Megahan (1974), appears more appropriate. By describing the disturbed area in terms of watershed slope and engineering design parameters, as given in equation [5], the land use planner has some flexibility, within the limitations discussed above, in evaluating the potential impacts of various road systems.

Because the coefficients in equation [4] were developed from a very limited amount of data, they may not be generally applicable throughout the Rocky Mountain Region.[3] Nevertheless, they are based on the best information available, and should be considered as tentative estimates until more data become available.

The model described in this report is based on data obtained from a carefully constructed road system and a high standard of followup maintenance. Any application of the model should presume similar standards of construction and maintenance.

Literature Cited

Goodell, Bertram C.
1958. A preliminary report on the first year's effects of timber harvesting on water yield from a Colorado watershed. U.S. Dep. Agric. For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 36, 12 p. Fort Collins, Colo.

Leaf, Charles F.
1970-71. Sediment yields from central Colorado snow zone. Am. Soc. Civil Eng., J. Hydraul. Div. 96(HY1):87-93. (Closure in 97(HY2):350-351.)

Megahan, Walter F.
1972a. Logging, erosion, sedimentation—are they dirty words? J. For. 70:403-407.

Megahan, Walter F.
1972b. Volume weight of reservoir sediment in forested areas. Am. Soc. Civil Eng. J. Hydraul. Div. 98(HY8):1335-1342.

Megahan, W. F.
1974. Erosion over time on severely disturbed granitic soils: A model. USDA For. Serv. Res. Pap. INT-156, 14 p.

Packer, Paul E., and W. A. Laycock.
1969. Watershed management in the United States: concepts and principles. Symp. Watershed Manage. [Lincoln College, Aug. 1969] Proc. Lincoln Pap. in Water Resour. 8:1-22.

Retzer, J. L.
1962. Soil survey of Fraser alpine area, Colorado. Soil Surv. Ser. 1956, No. 20, 47 p. U.S. Dep. Agric., For. Serv. and Soil Conserv. Serv., Colo. Agric. Exp. Stn., U.S. Gov. Print. Off.

---

[2] *Equation [4] is based on data collected from a 714-acre experimental watershed, and therefore applies only to drainage areas of approximately 1 mi² in size.*

[3] *It is worth noting here that soils on Fool Creek are uniform and derived from gneiss and schist rocks (Retzer 1962). They are deep, coarse textured, and capable of absorbing virtually all of the water during peak snowmelt.*

Agriculture—CSU, Ft. Collins

December 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-275

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Runoff and Erosion After Brush Suppression on the Natural Drainage Watersheds in Central Arizona

Paul A. Ingebo and Alden R. Hibbert[1]

Brush cover on two small watersheds totaling 26 acres in central Arizona was chemically suppressed in 1954-55. Annual streamflow subsequently increased 22 percent (0.36 area-inch), much less than on other treated chaparral watersheds. Most of the increase in streamflow occurred during the winter season. Annual sediment movement from the treated watersheds was reduced by about 1 ft^3/acre. Grasses, forbs and half-shrubs, which were not sprayed, increased after the chemical treatment.

Keywords: Water yield improvement, brush conversion, erosion.

Chaparral covers nearly 4 million acres of intermediate-elevation watershed land in Arizona; about half is on the National Forests. In recent years these lands have been examined as a possible source of increased water. The four Natural Drainage watersheds, located on the Sierra Ancha Experimental Forest about 40 miles north of Globe, are one of several clusters of watersheds where the water resource of the chaparral is being studied by the Rocky Mountain Forest and Range Experiment Station.

General Description and History of Watersheds

The four Natural Drainage watersheds face southeast on slopes of 15 to 25 percent (figs. 1 and 2). Elevations range from 4,525 to 4,970 ft. The drainages are designated watershed A, 13.4 acres; B, 19.5 acres; C, 12.1 acres, and D, 9.1 acres. Lengths vary from 1,300 to 1,650 ft; widths range from 300 to 500 ft. Although the catchments are small, they are contiguous and their surface boundaries are well-defined ridges. Each area is thought to be hydrologically independent of the others.

Two rock types dominate soil development; diabase on upper portions and quartzite below (fig. 1). Diabase soils cover 42 percent of watershed A, 54 percent of B, 44 percent of C, and 28 percent of D. The diabase soils are deeper and sandier than those derived from quartzite. The fine-textured quartzite-derived brown soils appear to favor grass development.

The dominant vegetation type on the watersheds is marginal chaparral interspersed with occasional juniper and pinyon trees. The cover becomes quite sparse and open on south-facing slopes and on the shallow quartzite soils, where

---

[1] *Hydraulic Engineer and Principal Hydrologist, located at Tempe, Arizona, in cooperation with Arizona State University; central headquarters is maintained at Fort Collins, in cooperation with Colorado State University. Ingebo is now retired.*

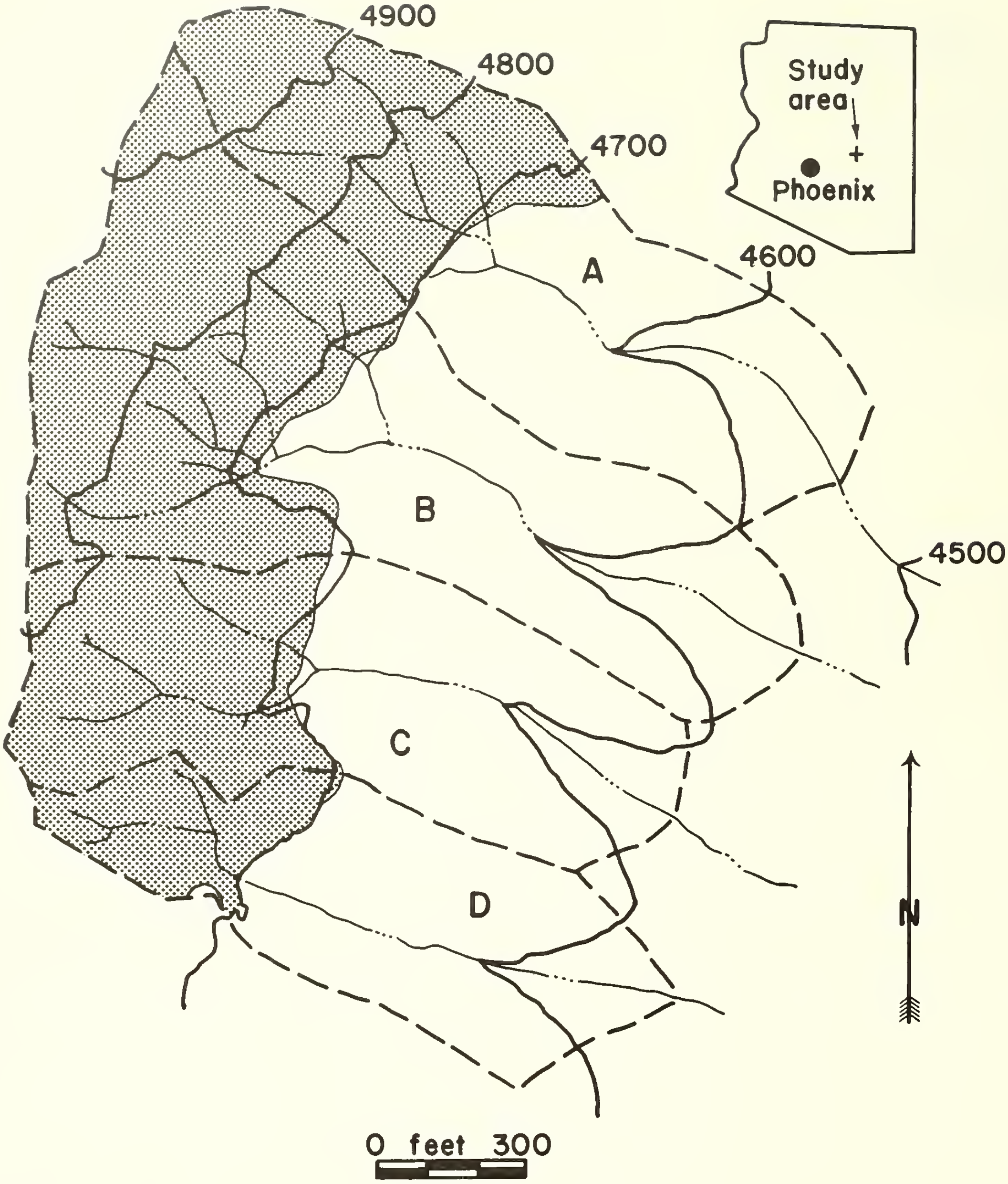


Figure 1.—Natural Drainage watersheds about 40 miles north of Globe, Arizona. Diabase soils (shaded areas) cover upper portions of the watersheds..

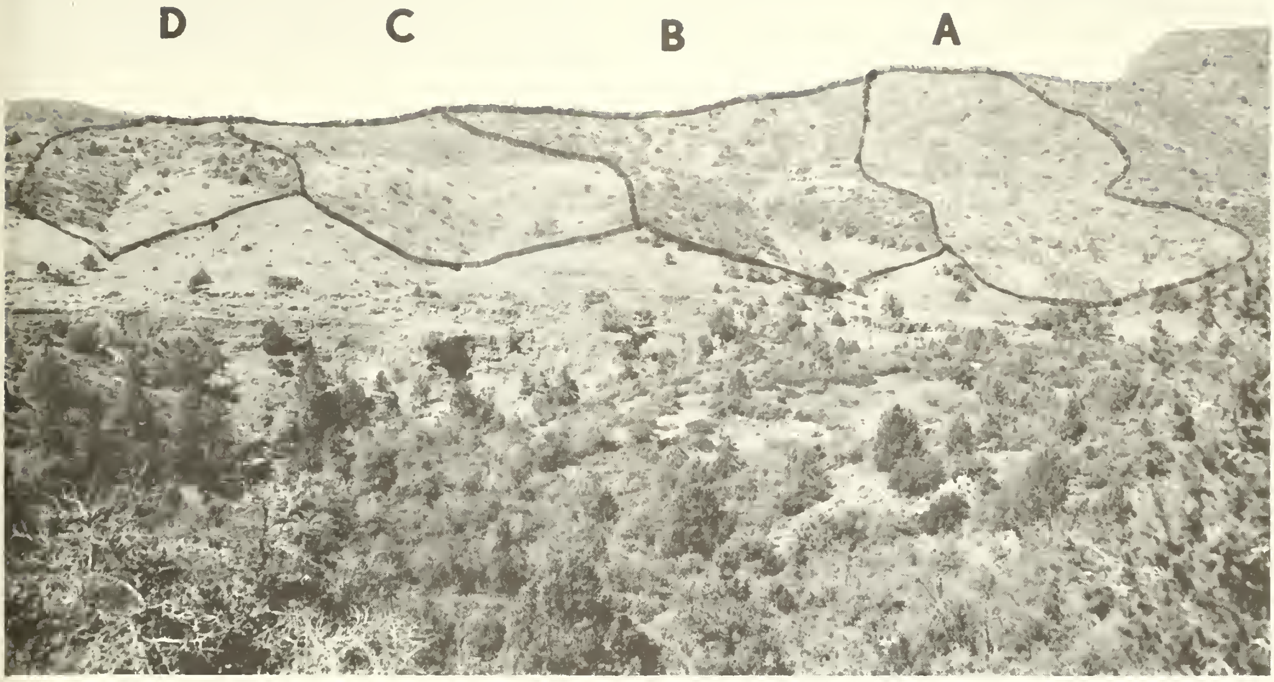


Figure 2.—Natural Drainage watersheds in 1960, 5 years after treatment on watersheds A and C.

it merges into the mesquite-grass type. Cover measurements in 1951, 3 years prior to chemical treatment, indicated total plant cover (vertical crown projection) varied from 32 percent on A to 40 percent on C. Of this, shrub cover averaged between 17 and 22 percent on the catchments. The remainder of the cover consisted of half-shrubs, forbs, and grasses (Rich and Reynolds 1963).

The most abundant shrub was shrub live oak *(Quercus turbinella)*. Other important shrubs included desert ceanothus *(Ceanothus greggii)*, Wright silktassel *(Garrya wrightii)*, hollyleaf buckhorn (*Rhamnus crocea*), and pointleaf manzanita *(Arctostaphylos pungens)*. Half-shrubs (diminutive shrubs or plants which are slightly woody towards the base) included Wright buckwheat *(Eriogonum wrightii)*, false-tarragon *(Artemisia dracunculoides)*, Thurber penstemon *(Penstemon thurberi)*, and rough Menodora (*Menodora scabra*). Perennial grasses were common in all subtypes except on diabase-derived soils. Important species included sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), three-awn (*Aristida* spp.), cane bluestem (*Andropogon barbinoidis*), green sprangletop (*Leptochloa dubia*), and bullgrass (*Muhlenbergia emersleyi*).

Livestock first appeared in the general area in about 1880. Grazing on the watersheds was brought under strict control in 1934 when the drainages were fenced and gages installed for the measurement of precipitation and runoff. Since 1934, grazing has been confined to that in controlled studies. Streamflow was originally metered through flumes and tipping buckets, but in 1936 90° V-notch weirs were installed. All cutoff dams in which the weirs were placed were set on solid quartzite rock so that both surface and subsurface flows were trapped. Sediment from the watersheds was collected and measured in the V-notch weir ponds. Most of the sediment was trapped, but a small proportion passed over the weir blade in suspension.

After a period of calibration ending in 1939 on D and in 1942 on A, the watersheds were used to study the relation of domestic grazing to runoff and erosion. These determinations were completed in 1952 when Rich and Reynolds (1963) found that the intensities of grazing used in the studies had no significant effect on water yields or trapped sediment production. Starting in 1954, chaparral cover was suppressed on two of the watersheds to determine the influence on streamflow. Field work terminated in 1971.

Cover Manipulation with Chemicals

During the summer of 1954, the basal 5 inches of all shrubs and trees on Natural Drainage C was sprayed with a 6.6 percent solution of 2, 4-D and 2, 4, 5-T in diesel oil until the outer bark was saturated. Half-shrubs were not sprayed. Though the first treatment killed most of the sprayed plants, surviving shrubs were resprayed in 1956 and 1958. Shrubs and trees on drainage A were sprayed in similar manner in 1955 and resprayed in 1957. Shrub and tree kill on both watersheds was essentially complete. Drainages B and D were retained as controls.

In 1959 Pond (1964) noted a response in grass, forbs, and half-shrubs to the chemical treatments on watersheds A and C. By 1959 grass cover on the treated quartzite soils was about three times greater than on the untreated areas. Prior to treatment the cover had been similar on all sites. No significant change in grass cover was noted on diabase soils, although crown cover of forbs was greater than on the quartzite soils. Forbs appeared to increase on all treated areas, although these increases were not significant. Half-shrubs gained substantially on both soils, with the greatest increase also on the diabase. Yerba-santa (*Eriodictyon angustifolium*), a rhizomatous-rooted shrub almost unnoticed before treatment, increased on the diabase soils until it became the most prominent plant over much of the upper portions of the treated catchments.

Precipitation at the Natural Drainages

Precipitation has been measured in two standard rain gages at Natural Drainages since 1934. Both are near exterior boundaries, but on opposite sides of the cluster of watersheds. Average difference in their annual catch over the years was about 0.3 inch. The largest annual difference between the two was 1.85 inches in 1944 when about 27 inches of precipitation fell. Because of the small difference in catch by the two gages, distribution of precipitation over the four catchments was considered to be uniform. Precipitation has averaged 19.1 inches per year for the 37-year period ending in 1971 (table 1). Annual and winter disposition before and after treatment was similar, although the first period was wetter.

Runoff from the Natural Drainages

Since Rich and Reynolds (1963) found that the early grazing studies had not significantly affected streamflow, the entire period from 1936 through June 1954 is considered nontreatment or calibration. The remaining years through 1971 constitute the treatment years. Watersheds B and D were used as controls to estimate the volume of streamflow that would have occurred on treated watersheds A and C if the cover had

Table 1.--Annual and winter precipitation for a 37-year period on the Natural Drainage watersheds in Arizona

Period	Annual precipitation (July 1 - June 30)		Winter precipitation (November 1 - April 30)		
	Range	Average	Range	Average	Percent of annual
	- - *Inches* - -		- - *Inches* - -		
Before treatment	14.76 - 40.70	20.18	6.80 - 28.48	11.79	58
After treatment	10.75 - 24.57	17.79	3.42 - 17.11	9.76	55
Total	10.75 - 40.70	19.08	3.42 - 28.48	10.86	57

not been altered. Differences between predicted and actual yield are attributed to treatment. Watershed B was used as the control for A, and D for C. Likewise, B and D were combined and used as a control for A combined with C.

Streamflow from all four watersheds always has been intermittent. The streams normally flow for only a day or two after rain. However, when rains are heavy or prolonged, particularly in winter, flows may persist for several weeks. Much more water is yielded during the winter period than in the warm summer months. Although winter accounts for only slightly more than one-half (57 percent) of annual precipitation, it accounts for 83 percent of the water yielded. Treatment did not alter this seasonal distribution of water yield, although flow periods possibly were prolonged somewhat.

Between watersheds, periods of flow are similar and annual variation in volume within the treated and control groups is consistent. Average annual yields before and after the treatment are given in table 2. Correlation of annual streamflows between control watersheds B and D did not change after treatment. However, the relationship between treated watersheds A and C did change after treatment, suggesting that the two watersheds varied in their response to treatment.

Table 2.--Average annual streamflow and sediment from the Natural Drainage watersheds in Arizona

Watershed and period	Water	Sediment
	Area inches	*Ft^3/acre*
Watershed A:		
Before treatment	1.46	3.3
After treatment	1.35	0.5
Watershed B (control):		
Before treatment	0.94	5.5
After treatment	.71	2.5
Watershed C:		
Before treatment	1.86	1.9
After treatment	2.03	.2
Watershed D (control):		
Before treatment	1.75	.9
After treatment	1.42	.4
Watersheds A + C:		
Before treatment	1.65	2.7
After treatment	1.67	.4
Watersheds B + D (control):		
Before treatment	1.20	4.0
After treatment	.94	1.8

Increases in yield and their 90 percent confidence intervals were:

	Mean annual increase	
	Inches	Percentage
Watershed A	0.19±.16	13±11
Watershed C	.50±.20	27±11
Watershed A+C	.36±.23	22±14

Although no explanation is apparent, it is of interest that the 27 percent increase on C is significantly greater than the 13 percent increase on A. Combined, the two treatments yielded 22 percent or 0.36 inch more water than expected. Presumably, the change resulted from a net reduction in water use on the converted areas.

Sediment from the Natural Drainages

Annual sediment trapped in the four weir ponds from 1937 to 1954 varied from 0 to 14 ft^3/acre. Watershed averages ranged from 0.9 on D to 5.5 ft^3/acre/year on B (table 2). Rich and Reynolds (1963) found no significant difference in annual volumes resulting from the grazing treatments starting in the 1940's and ending in the early 1950's.

Less sediment was measured after treatment on each of the watersheds than before. Sediment declined 55 percent on both control watersheds, possibly because of lower precipitation during this period. The decline was greater on the treated watersheds, however: 85 percent on A, and 89 percent on C. While part of this reduction can be attributed to the same factors affecting erosion on the controls, covariance analysis indicates that a significant portion was due to treatment. By combining the two treated watersheds, the net reduction averaged 72 ± 43 percent (90 percent confidence interval). This reduction, although not particularly large in volume (1.0 ± 0.6 ft^3/acre/year), is attributed to a stabilizing influence on the soil by grasses and forbs which increased after shrubs were eradicated.

Discussion

The 22-percent (0.36-inch) average increase in water yield attributed to treatment on the Natural Drainages is much less than obtained from other chaparral conversions in central Arizona. Onsite increases have averaged 300 to 700 percent (about 3 to 6 inches) on the Three Bar experimental watersheds 20 miles to the west (Hibbert 1971), and about 400 percent (almost 4 inches) following channel-side conversion on 38 acres of brush at Whitespar near Prescott (Ingebo 1972). While a complete explanation for these differences is not assured, we attribute the lower response on the Natural Drainages to the sparse shrub cover, low precipitation, southerly exposure, and shallow soil on the lower portion of each catchment.

The amount of brush cover eradicated by conversion is fundamentally important in reducing evapotranspiration and thereby increasing streamflow. Most of the reduction in evapotranspiration is attributed to a net reduction in transpiration caused by replacing deep-rooted shrubs with shallow-rooted grasses and forbs. Interception loss may also decline after conversion because the grass offers less surface to retain water than brush, but the contribution to water savings from this source is thought to be less than from the reduction in transpiration. Shrub crown cover was less than 25 percent on the Natural Drainages before treatment compared with 50 to 75 percent on Whitespar and Three Bar. With few shrubs to begin with, their removal could not be expected to influence transpiration as much as removal of a dense stand.

Brush density or biomass is largely an expression of the combined influence of precipitation and other climatic and physiographic factors. Water is generally considered the limiting factor in development of brush cover, but the effectiveness of precipitation is modified by site factors such as slope, aspect, elevation, and wind, as well as depth, texture, and permeability of the soil. Integration of these factors into a predictive model could provide a better index of potential increase on a given site than either precipitation or brush density alone, although at present these interrelationships are not quantified.

Slope and aspect, major contributing factors to solar energy input, probably also affect water-yielding characteristics of these watersheds (Lee 1963), although how they respond to treatment is uncertain. Facing southeast, the Natural Drainages receive more energy from the sun than the north-facing Three Bar catchments. The Whitespar watersheds have roughly the same aspect as the Natural Drainages, but their elevation is higher causing them to be cooler. The heavy energy input at the Natural Drainages may contribute to the low response to treatment.

The quartzite-derived soils on the lower portions of the Natural Drainages are finer grained than the granitic soils which cover Three Bar and Whitespar. Though capable of storing more water per inch depth of soil, the lack of depth prevents storage of large amounts of rainfall. Thus, water in this soil is subject to withdrawal (evaporation and transpiration) almost as readily by shallow-rooted grasses and forbs as by deep-rooted shrubs. Removal of the sparse brush cover on these soils likely would have little net effect on evapotranspiration or water yield. Paradoxically, the shallow soils may be the cause of the relatively high ratio of pretreatment runoff to precipitation noted on these catchments (0.08 compared with 0.02 to 0.09 at Three Bar and 0.05 at Whitespar). With limited storage available, heavy rainfall, particularly in winter, cannot be retained and the excess is released to streamflow.

Diabase soils on the upper portions of the Natural Drainage catchments are similar in depth to the granite soils at Three Bar and Whitespar. Removing brush on these soils should result in water savings commensurate with the amount of brush removed, which was sparse. However, these savings may have been reduced by the increase in yerba-santa on the diabase soils after the shrubs were killed. While these shrubs do not root as deeply as the original brush, they probably use more water than grass, thereby reducing water savings attributed to brush removal on these deeper soils.

In light of these distinctive differences between areas, the low response to treatment on the Natural Drainages is not unexpected. Little or no response can be expected from the quartzite soils, and only a limited amount from the diabase soils. Very likely, response to treatment is less than half the amount that otherwise might be obtained under this rainfall regime.

The small but significant decrease in sediment transported to the weir sites on the treated areas is noteworthy because it came during a period when streamflow was being sustained at a slightly higher level than would have occurred without treatment. Minor rilling was observed on the upper slopes of watersheds A, B, and C, which indicates some degree of overland flow. Rilling was not continuous from source to stream channel, however, suggesting that surface runoff was not massive or continuous. Grass and other replacement cover, which increased when the brush was eradicated, retarded the rilling and movement of soil. In watershed C, the filtering effect of grass on streamflow is developing a small meadow from silt brought down in the main channel.

While these results are encouraging, they should not be interpreted to mean that treatment of this type necessarily will reduce erosion. The quartzite soils on which grass increased the most are not typical of chaparral. Therefore, they do not represent the conditions most likely to be encountered when chaparral is converted. On the other hand, there was no evidence of accelerated erosion on the upslope diabase soils, which are more representative of chaparral in Arizona. These results therefore indicate that, if the soil is not disrupted or the protective cover depleted, erosion may not be adversely affected by conversion of brush to grass.

Literature Cited

Hibbert, Alden R.
1971. Increases in streamflow after converting chaparral to grass. Water Resour. Res. 7:71-80.

Ingebo, Paul A.
1972. Converting chaparral to grass to increase streamflow. Proc. 1972 Meet. Ariz. Sect., Am. Water Resour. Assoc. and Hydrol. Sect., Ariz. Acad. Sci, p. 181-192.

Lee, Richard.
1963. Evaluation of solar beam irradiation as a climatic parameter of mountain watersheds. Hydrol. Pap. 2, 50 p. Colo. State Univ., Fort Collins.

Pond, Floyd W.
1964. Response of grasses, forbs, and half-shrubs to chemical control of chaparral in central Arizona. J. Range Manage. 17:200-203.

Rich, Lowell R., and Hudson G. Reynolds.
1963. Grazing in relation to runoff and erosion on some chaparral watersheds of central Arizona. J. Range Manage. 16:322-326.

Agriculture—CSU, Ft. Collins

ecember 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-276

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Formulating Conversion Tables for Stick-Measure of Sacramento Precipitation Storage Gages

Frederic R. Larson[1]

Sacramento precipitation storage gages are usually built to specifications by local sheet metal companies where quality control is limited. This Note presents two mathematical models for estimating precipitation measured in locally constructed gages. A calibration technique is also described.

Keywords: Precipitation, storage gages, rain gage.

Sacramento precipitation storage gages are used in mountainous terrain where precipitation records are needed but visits are infrequent and snowcapping can be a problem (Kidd 1960; U.S. Corps of Engineers 1956; Warnick 1961). This Note presents two mathematical models for estimating amount of precipitation at any measured depth for any size gage and describes a gage calibration technique.

The Sacramento gage is conical in shape, typically having an 8-inch diameter orifice, a 20-inch diameter base, and a sidewall slope of 6:1. The conical gage (fig. 1) has several advantages. It offers a large storage capacity with a small orifice, provides good mixing properties for dissolving snow into an antifreeze-antievaporant solution, and the shape discourages snowcapping (Billones 1963; U.S. Corps of Engineers 1956).

The gages are not fabricated by any particular company, and must be built to specifications (Codd 1947) by local sheet metal companies. Quality control is limited and generalized rating tables are not likely to match the locally constructed gage. However, a set of gages manufactured together are usually consistent, in which case one rating table or curve will be applicable to the set.

Rating curves for the Sacramento storage gage are curvilinear. They reflect both the shape of the gage and the amount of precipitation which may enter a fixed diameter orifice.

Figure 1.—A 100-inch Sacramento storage gage in use on the Beaver Creek watershed, Arizona.

---

[1] *Associate Silviculturist, Rocky Mountain Forest and Range Experiment Station, located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

The two mathematical models for estimating precipitation are:

(1) $P = b_o + b_1d + b_2d^2 + b_3d^3$
(2) $P = b_o + b_1 (t - d)^3$
where
P = estimated precipitation
d = depth of precipitation in the gage
t = total height of a theoretical cone from the base, extending beyond the orifice to an apex

Total height (t) can be calculated by the equation

$$t = hr_b/(r_b - r_o)$$

where
h = the height of the gage
r_b = radius of the base
r_o = radius of the orifice.

Any desired units of depth and precipitation may be used to determine the equation coefficients, since the coefficients reflect the units used. Theoretically, the b_o term should be equal to zero. However, distortion of the gage with added precipitation, drain valves, and other imperfections requires a b_o term to be calculated so that a rating equation may more closely fit the physical situation.

Equation 2 is recommended. Equation 1 is a third degree polynomial, and calculating its coefficients is tedious and time consuming without a computer. Equation 2 only requires a simple transformation of one independent variable, and calculation of its regression coefficients is fairly simple. It is used on the Beaver Creek watersheds in Arizona.

Two sets of gages have been built for Beaver Creek. Each set required a different rating equation. The rating equations were derived by adding known increments of water to four randomly selected gages from each set, and measuring the solution depth after each addition (Garstka et al. 1958).

The set of gages built in 1960 have sidewall slopes of 8.5:1. Their rating equation, for precipitation (P) in inches at any given depth (d) in feet, is:

$$P = 102.97961 - 0.55167 (5.7059 - d)^3$$

The set of gages built in 1972 have sidewall slopes of 7.2:1. Their equation is:

$$P = 110.91541 - 0.70533 (5.3998 - d)^3$$

The r^2 for both equations was 0.9998.

Rating tables used by National Weather Service are based on a sidewall slope of 6:1. Partly because of sideslope differences, applying the National Weather Service tables to the 1960 gages overestimates Beaver Creek precipitation by 20 to 30 percent. Similarly, the equation for the 1960 gages underestimates precipitation measured by the 1970 gages by 10 percent (table 1). Thus it is readily apparent that each set of gages requires its own rating curve.

Table 1.--Precipitation (inches) in Sacramento storage gages for given depths of solution

Depth of solution (ft)	Amount of precipitation		
	National Weather Service	1960 gages	1972 gages
0	0	0.5	-0.1
.5	35.0	25.1	27.9
1.0	63.1	45.5	50.8
1.5	85.1	61.9	69.1
2.0	101.8	74.9	83.2
2.5	113.8	84.8	93.7
3.0	122.0	92.0	101.2

Literature Cited

Billones, Louis.
1963. Operational problems of storage precipitation gages. Proc. West. Snow Conf., 31st Annu. Meet. Yosemite Natl. Park, Calif. Apr. 17-19.

Codd, Ashton R.
1947. Seasonal storage precipitation gages. Amer. Geophys. Union Trans. 28:899-900.

Garstka, W. U., L. D. Love, B. C. Goodell, and F. A. Bertle.
1958. Factors affecting snowmelt and streamflow. A report on the 1946 to 1953 Cooperative Snow Investigations at the Fraser Exp. For., Fraser, Colo. U.S. Dep. Inter., Bur. Reclam., U.S. Dep. Agric., For. Serv., p. 156-158.

Kidd, W. J., Jr.
1960. The advantages of using ethylene glycol in seasonal storage precipitation gages and a method for computing the initial charge. J. For. 58:882-884.

U.S. Corps of Engineers.
1956. Snow hydrology, summary report of the snow investigations North Pacific Div., Corps of Eng., U.S. Army, Portland, Oreg. June 30.

Warnick, C. C.
1961. Year-long precipitation measurement. Proc. Watershed Manage. Study Conf., McCall, Ida. Sept. 11-14.

Agriculture—CSU, Ft. Collin

ember 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-277

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effectiveness of Systemic Insecticides Against the Pine Tip Moth on Ponderosa Pine[1]

Gary D. Sexson[2] and Robert E. Roselle[3]

Carbofuran 10 percent granules and phorate 15 percent granules (10 pounds active ingredient per acre) were superior for protection of nursery stock against the pine tip moth, *Rhyacionia bushnelli.* At 2 ounces per inch of trunk diameter incorporated into the soil at the base of trees, they reduced infestations in ornamental and windbreak trees. Carbofuran wettable powder (0.25 %) or dimethoate emulsifiable concentrate (0.125 %) sprays performed well in nurseries and plantings. Timing of dimethoate applications is critical.

Keywords: Systemic insecticides, *Rhyacionia bushnelli, Pinus ponderosa.*

The pine tip moth, *Rhyacionia bushnelli* Busck (Lepidoptera: Olethreutidae), is an important insect pest of several species of pines in tree nurseries, Christmas tree plantations, and ornamental, field, and farmstead plantings. Tips injured by the larvae are unsightly, and tree growth is severely stunted (fig. 1). Damage has been severe enough to discourage planting of ponderosa pine, a highly desirable tree species in windbreaks.

Residual contact insecticides have not always provided adequate protection from tip moth

Figure 1.—Many years of repeated tip killing by the western pine tip moth has badly deformed and stunted this ponderosa pine.

---

[1] *This investigation was supported in part by a cooperative research grant to the University of Nebraska, from the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Graduate Research Assistant, Department of Entomology, University of Nebraska, Lincoln.*

[3] *Professor, Department of Entomology, University of Nebraska, Lincoln.*

damage. Several treatments each season, carefully timed with the susceptible stages of the pest, were necessary to protect trees. Effective systemic insecticides would provide a longer period of protection so that exact timing of insecticide application would not be essential.

Our earlier study[4] indicated that an application of phorate granules to the soil in the spring protected young ponderosa pine trees in a shelterbelt for two growing seasons. However, a dimethoate spray was effective against only the first generation. The study reported here was conducted to evaluate additional systemics applied to the soil and to the foliage to reduce damage by the pine tip moth on nursery stock, and shelterbelt and ornamental trees.

Methods and Materials

In 1969 and 1970, systemics applied as granules and as sprays were tested at the Bessey Nursery, Nebraska National Forest, at Halsey. Plots, 5 by 20 ft, were laid out in nursery beds containing 4-year-old stock. Each treatment was replicated four times in a randomized block design.

Granular systemics were applied in a 6-inch bank along each side and through the center of the nursery beds (fig. 2) and worked into the soil with a garden rake. The treated and untreated plots were then sprinkler irrigated. In 1959 phorate[5] and carbofuran were applied at the rate of 10 pounds active ingredient (AI) per acre on April 30 and again on July 5. In 1970, these and aldicarb and disulfoton were applied only once at rates of 2.5, 5, and 10 pounds AI per acre on April 25.

Figure 2.—Insecticide applicator, fabricated from
front bicycle forks, two bicycle wheels, and a N
metering device, delivered granules throug
garden hose to the soil surface in a 6-inch-w
band.

---

[4] *Van Haverbeke, David. F., Robert E. Roselle, and Gary D. Sexson. 1971. Western pine moth reduced in ponderosa pine shelterbelts by systemic insecticides. USDA For. Serv. Res. Note RM-194, 8 p. Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.*

[5] *Common and chemical names of insecticides used are listed at the end of this Note.*

Foliar sprays were applied with a knapsack sprayer at a rate of one-half gallon of emulsified chemical per 100 ft^2. The sprays were applied on May 16, and all but two plots were re-treated on June 30. One plot each of dimethoate and carbofuran was not re-treated so that we could determine if one application of these sprays would be sufficient to protect the trees against both generations of tip moth.

Granular systemics were applied in windbreak plantings in December 1969 to determine if early winter applications would provide protection from the tip moth the following season. Carbofuran 10% and phorate 15% were applied at the rate of 2 ounces of formulation per inch of trunk diameter (measured 12 inches above soil surface) in small holes about 6 inches deep at four locations around the drip line. Treatments were applied to 10-tree plots of 9-year-old trees at North Platte, where the treatments were replicated three times in a randomized block design. At Lincoln, the treatments were applied to 10-tree plots of 1-year-old and 6-year-old trees; treatments were replicated three and four times, respectively.

In 1970, tests to determine the effective rates of several granular systemic compounds were installed in windbreak plantings at Greenwood and North Platte. Phorate, aldicarb, and carbofuran were applied April 18 at North Platte, and these plus disulfoton on April 30 at Greenwood. The insecticides, at rates of 0.5, 1, and 2 ounces of formulation per inch of trunk diameter, were incorporated into the soil between the trunk and drip line with a garden rake. Untreated check plots were also established. The treatments were applied to 10-tree plots replicated four times in a randomized block design.

Also in 1970, several foliar sprays were tested on 9-year-old trees at North Platte, and 5-year-old trees at Lincoln. The treatments were applied to 5-tree plots randomly selected in windbreak plantings; each treatment was replicated three times. All sprays were applied with a knapsack sprayer, and each tree was sprayed to the point of runoff.

At North Platte the following foliar spray treatments were applied on May 16 and again on June 30: dimethoate, 0.125%; endosulfan, 0.25%; carbofuran, 0.25%; ENT 27567, 0.125%; and BAY 77488, 0.093%. These treatments and Baygon 0.125%, and BAY 44646, 0.332%, were applied to plots at Lincoln on May 23 and again on July 30. At North Platte, granular phorate was applied for comparison with the sprays on April 10 at the rate of 2 ounces of 15% granules per inch of trunk diameter. It was worked into the soil surface around the tree rom the base to the drip line.

Results

In 1969, treatments of ponderosa pine in nursery beds with carbofuran 10% granules and phorate 15% granules (at 10 lb. AI per acre) reduced the percent of lateral and terminal tips infested by the tip moth better than the other materials tested (table 1). Dimethoate spray

Table 1.--Average percent[1] infestation of lateral and terminal tips of ponderosa pine nursery stock treated with systemic insecticides, Bessey Nursery, Halsey, Nebraska, 1969 and 1970

Treatment	Application rate	Percent infested tips per plot
1969--		
Carbofuran 10%	10 lb AI/acre	0.02 a
Phorate 15%	10 lb AI/acre	.03 a
Dimethoate 0.125%	.5 gal/100 ft^2	.26 ab
Oxydemetonmethyl 0.25%	.5 gal/100 ft^2	.92 bc
DDT 0.25%	.5 gal/100 ft^2	1.39 cd
No insecticide		2.17 d
1970--		
Carbofuran 0.25%	.5 gal/100 ft^2	0.1 a
Carbofuran 0.25%[2]	.5 gal/100 ft^2	.1 ab
Carbofuran 10%	10 lb AI/acre	.6 abc
Dimethoate 0.125%	.5 gal/100 ft^2	.7 abc
BAY 44646 0.332%	.5 gal/100 ft^2	.8 abc
Aldicarb 10%	10 lb AI/acre	.9 abcd
Aldicarb 10%	5 lb AI/acre	1.4 cdefgh
Aldicarb 10%	2.5 lb AI/acre	2.6 jk
Carbofuran 10%	5 lb AI/acre	1.2 cdef
ENT 27567 0.125%	.5 gal/100 ft^2	1.2 cdefg
Endosulfan 0.25%	.5 gal/100 ft^2	1.7 defghi
Phorate 15%	10 lb AI/acre	1.7 efghi
Phorate 15%	5 lb AI/acre	1.7 efghi
Phorate 15%	2.5 lb AI/acre	2.2 hij
Carbofuran 10%	2.5 lb AI/acre	2.0 fghij
Dimethoate 0.125%[2]	.5 gal/100 ft^2	2.1 ghij
Baygon 0.125%	.5 gal/100 ft^2	2.4 ij
Disulfoton 15%	10 lb AI/acre	3.2 kl
Disulfoton 15%	5 lb AI/acre	3.3 kl
Disulfoton 15%	2.5 lb AI/acre	4.4 m
No insecticide		3.7 lm
BAY 77488	.5 gal/100 ft^2	3.7 lm

[1] Percentages followed by a common letter are not significantly different at the 5 percent level of probability.

[2] Only one spray application.

was superior to DDT spray. Sprays of oxydemetonmethyl did not give better protection than DDT and they produced moderate phytotoxicity. In 1970, carbofuran WP gave the best protection against tip moth damage in the nursery (table 1). This formulation applied once was as effective as single applications of carbofuran and aldicarb 10% granules (at 10 lb. AI per acre) and two sprays of dimethoate, Bay 44646, and Diazinon. At Lincoln, carbofuran was more effective than phorate on 6-year-old trees, and both chemicals applied to 1-year-old trees reduced damage compared to no insecticide (table 2). At North Platte, however, neither material reduced damage significantly.

Table 2.--Average percent[1] infestation of lateral and terminal tips of ponderosa pine trees treated in December with granular systemic insecticides,[2] 1970

Treatment	North Platte	Lincoln	
	9-yr-old pines	1-yr-old pines	6-yr-old pines
Carbofuran 10%	47.3 a	37.2 a	31.0 a
Phorate 15%	48.4 a	53.3 a	54.2 b
No insecticide	62.8 a	79.1 b	59.5 b

[1] Percentages followed by a common letter are not significantly different at the 5 percent level of probability.

[2] Applied at the rate of 2 ounces formulation per inch of tree trunk diameter.

At North Platte, carbofuran 10% at 1 or 2 ounces and phorate 15% at 2 ounces per inch of trunk diameter provided the best reduction of tip moth damage (table 3). Aldicarb and disulfoton gave little or no protection.

In the tests of foliar sprays at North Platte and Lincoln, carbofuran WP, ENT 27567, endosulfan, and dimethoate gave generally good results (table 4). BAY 77488, BAY 44646, and Baygon were somewhat less effective.

Trees treated with granules or foliar sprays did not consistently produce average new growth greater than in untreated plots in any test.

Table 3.--Average percent[1] infestation of lateral and terminal tips of ponderosa pine tre treated with granular systemic insecticides, 1970

Treatment	Ounces/inch of trunk diameter	Percent infested tips per plot	
		Greenwood	North Platte
Carbofuran 10%	2	28.9 a	13.5 a
Carbofuran 10%	1	42.6 ab	16.8 a
Carbofuran 10%	0.5	45.4 ab	26.6 a
Phorate 15%	2	40.7 ab	13.9 a
Phorate 15%	1	47.4 abc	18.8 a
Phorate 15%	.5	53.8 bcd	31.3 a
Aldicarb 10%	2	59.8 bcd	20.3 a
Aldicarb 10%	1	68.7 cde	30.9 a
Aldicarb 10%	.5	74.9 de	36.1 b
Disulfoton 15%	2	72.4 de	--
Disulfoton 15%	1	72.5 de	--
Disulfoton 15%	.5	85.1 e	--
No insecticide		73.5 de	73.3 c

[1] Percentages followed by a common letter not significantly different at the 5 percent l of probability.

Table 4.--Average percent[1] infestation of lateral and terminal tips of ponderosa pine tre treated with foliar emulsifiable systemic insecticides, 1970

Treatment	Percent infested tips per plot	
	North Platte	Lincoln
Phorate 15%[2]	5.9 a	--
Carbofuran WP 0.250%	6.7 a	7.4 a
Endosulfan 0.250%	24.2 bc	7.2 a
ENT 27567 0.125%	7.5 a	7.4 a
Dimethoate 0.125%	16.2 ab	8.0 a
BAY 77488 0.093%	32.2 c	10.4 ab
Baygon 0.125%	--	15.2 b
BAY 44646 0.332%	--	15.4 b
No insecticide	69.9 d	46.0 c

[1] Percentages followed by a common letter are not significantly different at the 5 percent level of probability.

[2] Applied at the rate of 2 ounces of granular formulation per inch of trunk diameter.

Conclusions

Although systemic insecticides can greatly reduce tip moth damage, the most effective systemics are not registered for this use (only dimethoate, among those tested, is currently registered for control of pine tip moth). Therefore, most of the following conclusions cannot now be construed to be recommendations for use. Because pesticide registrations are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State extension specialist before using any insecticide.

Ponderosa pine stock in tree nurseries can be protected with carbofuran 10% granules or phorate 15% granules applied in the soil between tree trunk and drip line at the rate of 2 ran WP 0.25% spray applied twice during the season. Dimethoate 0.125% spray applied twice, at the beginning of egg deposition, would also give satisfactory performance. Infestations in individual ornamental or windbreak trees can be reduced with carbofuran 10% granules or phorate 15% granules applied in the soil between tree and trunk drip line at the rate of 2 ounces per inch of trunk diameter. The insecticide should be applied by April 15.

The most effective registered insecticide to protect pine trees in field and farmstead windbreaks is dimethoate spray applied about mid-May and again the first of July. Satisfactory performance of dimethoate requires critical timing of the applications to coincide with egg deposition. Eggs of the first brood are deposited from mid-May until mid-June, and eggs of the second brood from late June until late July. More effective control would be obtained by spraying four times: the third week of May, the first week of June, in early July, and in mid-July.

Insecticides evaluated for protection of ponderosa pine trees
and nursery stock in field test in Nebraska, 1969-70

Common names	Chemical names
Aldicarb	2 methyl-2-(methylthio)propionaldehyde O-methylcarbamoyl oxime
BAY 44646	4-dimethylamino-m-tolylmethylcarbamate
BAY 77488	phenylglyoxylonitrile exime O, O-diethyl phosphorothiate
Baygon (propoxur)	O-isopropoxyphenylmethylcarbamate
Carbofuran	2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate
DDT	1,1,1-trichloro-2,2-bis=(p-chlorophenyl)ethane
Diazinon	O,O-diethyl O-(2-isopropyl-4-methyl-6-pyrimidyl) phosphorothiate
Dimethoate	O,O-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate
Disulfoton	O,O-diethyl S-2 phosphorodithioate
ENT 27567	N'-(4-chloro-O-toyl)-N,N-dimethylformamidine, hydrochloride
Endosulfan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxa=thiepin 3-oxide
Oxydemetonmethyl	S- O,O-dimethyl phosphorothioate
Phorate	O-O-diethyl-S phosphorodithioate

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key — out of the reach of children and animals — and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Agriculture—CSU, Ft. Collins

cember 1974

U S D A FOREST SERVICE
ESEARCH NOTE RM-278

OREST SERVICE
S. DEPARTMENT OF AGRICULTUR

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Five-Year Results of a Ponderosa Pine Provenance Study in the Black Hills

James L. Van Deusen[1]

Survival and height growth data were collected after five field growing seasons from ponderosa pine progeny representing 75 provenances of natural stands in the Great Plains and Northern Rockies. Results showed that trees from no other provenance survived significantly better or grew significantly taller than trees from the Black Hills. Trees from southern Colorado, New Mexico, and western Montana showed significantly poorer survival and height growth.

High mortality evidently resulted from a combination of intense grass competition and root rot.

Keywords: Provenance study, *Pinus ponderosa*.

Ponderosa pine (*Pinus ponderosa*) is so adaptable that it is the most widely distributed pine in North America. The Rocky Mountain, or interior form, *scopulorum*, occupies an extensive range east of the Continental Divide from Montana and North Dakota south into New Mexico.

In the Black Hills of South Dakota and Wyoming, more than 95 percent of the growing stock is ponderosa pine. Reproduction is usually abundant, even without management to encourage it. With thinning to stimulate growth, gross wood production is highly satisfactory. There is a possibility, however, that the evident genetic diversity of the species might endow trees from some other provenances with an inherent potential for more rapid, high quality growth than that of the local stock.

This Note reports early results of the Black Hills phase of a large racial variation study which is intended to identify provenances of ponderosa pine best suited for Plains forestry. The natural forest environment of the Black Hills provides an excellent opportunity to compare the performance of trees representing a large number of nonlocal sources with performance of Black Hills trees.

Methods

Seeds and Seedlings

Seeds were collected from the eastern range of ponderosa pine under the direction of David H. Dawson and Ralph A. Read.[2] Locations of the 75 provenances providing seedlings for the Black Hills trial are shown in figure 1.

Stock for the Black Hills Experimental Forest plantation was grown at the Forest Service's Bessey Nursery, Halsey, Nebraska. Seedlings were outplanted as 2-1 stock in spring 1968; first-year failures were replaced the next spring with 2-1-1 stock of the same source.

---

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

[2] *Present assignment for Dawson is the Institute of Forest Genetics, USDA Forest Service, Rhinelander, Wisconsin; for Read, Rocky Mountain Forest and Range Experiment Station, Lincoln, Nebraska.*

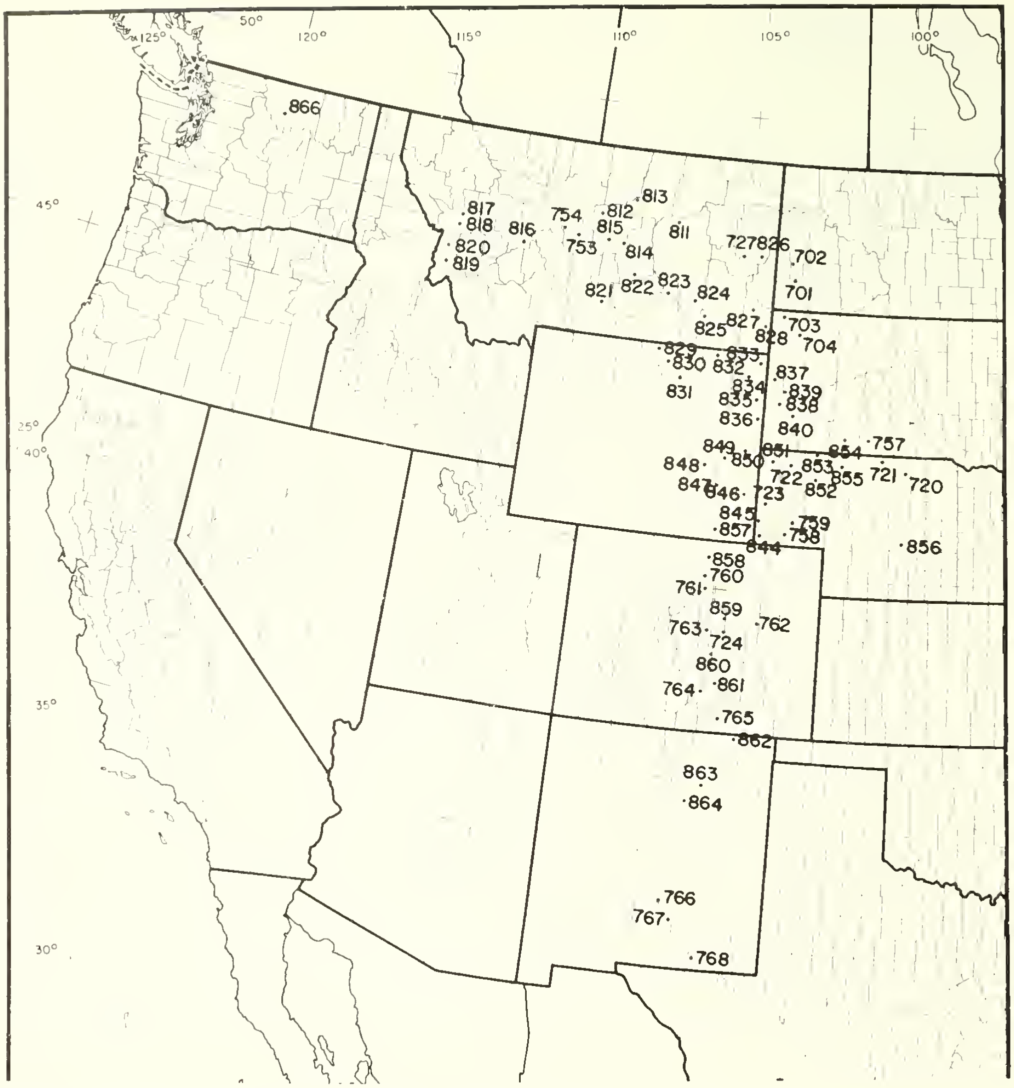


Figure 1.—Location of seed sources for 75 provenances of ponderosa pine being tested on the Black Hills Experimental Forest.

Planting Site

Site index of the relatively level planting area is about 60 (base age 100)—slightly better than average for the central Hills. The site had formerly been occupied by a two-storied stand of ponderosa pine—saplings under sawtimber. A few small patches of aspen (*Populus tremuloides*) were cut from the understory. All trees were cut from the test site during the winter of 1967-68. Pines exceeding minimum merchantable requirements (6.0 inches d.b.h., outside bark) were harvested commercially as roundwood, even though some stems were sawtimber size. Slash and most small stems were chipped and scattered as much as practicable. Material not chipped was piled in windrows between planting rows.

Design and Installation

The 3,000 seedlings in the plantation were hand planted at 8-ft-square spacings in randomized blocks. Each source is represented once in each of 10 blocks (replications) by a 4-tree linear plot. A single row of seedlings from a local source, planted at an 8-ft-spacing, surrounds the plantation as a buffer strip. Approximately 25 ft separates the buffer seedlings from the adjacent natural stand.

Circles about 2 ft in diameter were scalped around each planting spot to reduce vegetative competition. Two more scalping treatments at yearly intervals maintained a nearly competition-free growing condition for each tree during its first 3 years in the field. Repeated scalping is more cultivation than is normally provided, but some site preparation is needed in all Black Hills plantations to keep encroaching vegetation from choking out the trees.

Inspections and Measurements

Survival was determined yearly; heights of all seedlings were measured after 3 and 5 years in the field. Total seedling height and current annual leader growth were measured. During each of the yearly inspections, any damage to seedlings was noted, and cause for mortality was determined whenever possible.

Results and Discussion

After 5 years in the plantation, survival and growth of trees from each provenance were compared with those for provenance SD 839, which originated nearest the Black Hills Experimental Forest. Trees from no other provenance survived significantly better or grew significantly taller on the average than SD 839, while average survival was significantly less for 21 provenances and average heights were significantly shorter for 15 provenances (table 1). Most of the poorer survival and growth came from trees of provenances farthest from the Black Hills. Trees from southern Colorado, New Mexico, and western Montana were the poorest performers. The poor survival and growth of trees from the Bitterroot Valley of western Montana are in contrast to the generally favorable performance achieved in North Dakota reported by Conley, Dawson, and Hill.[3]

Washington provenance 866 is one of the most distant from the Black Hills. Unlike trees from provenances far to the South, those of number 866 survived as well as comparison source 839. Height growth was not as good, however. Height growth, unlike survival, can be improved over time, especially if growth in the early years is affected only by some physical damaging agent.

Survival during the first 3 years in the field was exceptionally good, averaging 86.7 percent:

	Survival	
(Year)	(Number)	(Percent)
1969	2795	93.2
1970	2601	86.7
1971	1820	60.7
1972	1146	38.2

Table 1.--Averages[1] of survival and total seedling height for a plantation of 75 ponderosa pine provenances in the Black Hills, 1969-72

State and source number	Survival				Total height 1972	State and source number	Survival				Total height 1972	State and source number	Survival				Total height 1972
	1969	1970	1971	1972			1969	1970	1971	1972			1969	1970	1971	1972	
	- - - *Percent* - - -				*Ft*		- - - *Percent* - - -				*Ft*		- - - *Percent* - - -				*Ft*
MT815	98	92	82	75	1.7	WY835	100	95	80	42	1.5	CO762	100	98	55	40	1.1*
WY830	100	100	95	70	1.6	MT827	90	88	68	42	1.4	CO859	98	95	50	30	1.1*
NO702	100	92	72	68	2.1	WY836	95	92	78	42	1.3	WY850	90	88	55	30	1.0*
WY831	100	98	85	68	1.6	WY848	95	90	70	42	1.2	MT819	95	78	48*	30	.6*
SD838	100	98	85	65	1.8	CO761	95	90	52	40	1.7	NB844	95	92	48*	28*	1.2
MT754	100	95	90	65	1.5	MT826	85*	85	58	38	1.7	MT817	80*	52*	45*	28*	.8*
SD839	98	92	78	62	1.8	SD840	95	92	58	38	1.6	NB853	95	92	68	25*	1.6
MT813	95	95	78	62	1.4	CO858	90	82	68	38	1.6	NB720	95	92	52	25*	1.6
MT821	98	98	85	60	1.5	MT828	95	95	58	38	1.5	WY846	98	98	68	25*	1.2
MT824	98	92	80	58	1.7	MT727	92	92	65	38	1.4	NB759	95	90	55	25*	1.2
NB851	98	95	70	58	1.2	ND701	80*	80	62	38	1.4	MT820	92	75	38*	25*	.9*
MT811	98	98	80	52	1.9	NB758	80*	75	42*	38	1.2	NB852	98	88	42*	22*	1.8
WY857	100	98	70	52	1.5	WY832	95	92	68	35	1.8	CO861	90	90	50	22*	1.2
WY847	98	92	65	52	1.4	MT812	98	90	70	35	1.6	CO763	100	90	50	20*	1.7
SD837	95	92	75	50	1.9	MT823	82	80	58	35	1.5	NM862	90	80	40*	20*	1.7
MT825	98	92	68	50	1.7	NB855	95	88	60	35	1.5	CO860	82*	75	38*	20*	1.4
SD854	88	85	75	50	1.6	SD757	95	95	48*	35	1.5	NM864	92	78	30*	18*	1.3
SD704	100	100	78	50	1.5	CO760	95	92	62	32	1.4	CO724	95	92	52	18*	.8*
NB723	98	92	75	48	1.6	NB722	92	85	60	32	1.3	NB856	88	82	42*	18*	.9*
MT814	95	92	72	48	1.5	MT822	88	80	55	32	1.2	CO764	92	80	38*	15*	1.4
WY833	92	88	68	45	1.5	NB721	95	90	62	30	2.2	CO765	98	92	45*	12*	1.2
NB845	95	88	65	45	1.5	MT818	70*	58*	40*	30	1.2	NM863	98	88	25*	8*	.3*
WY849	98	95	82	45	1.3	WY834	85*	80	72	58	.9*	NM766	68*	42*	15*	5*	.7*
WY829	100	98	95	45	1.2	MT816	95	88	75	55	1.1*	NM768	78*	32*	8*	5*	.4*
SD703	95	95	78	45	1.2	WA866	95	88	62	48	1.1*	NM767	85*	28*	0*	0*	0*

[1] Averages followed by * are significantly smaller than comparison source SD839 at 95 percent level of probability.

---

[3] Conley, William T., David H. Dawson, and Robert B. Hill. 1965. The performance of eight seed sources of ponderosa pine in the Denbigh Experimental Forest, North Dakota. U.S. For. Serv. Research Note LS-71, 4 p. Lake States For. Exp. Stn., St. Paul, Minn.

Mortality increased sharply during the fourth and fifth years. After the fifth growing season, average survival for the plantation was only 38 percent, while survival for the best provenances was little more than 60 percent. This is lower survival than one would normally expect for trees of local origin, and contrasts with the normal survival pattern in adjacent Great Plains where mortality usually is greatest during the first 2 years, then stabilizes as trees become established.

A number of factors were responsible in varying degrees for seedling mortality throughout the 5-year period. Perhaps the most important factor was competition from ground cover. A large band across the test area, where mortality was heaviest during 1971 and 1972, developed a noticeably heavier cover of grasses, forbs, and aspen sprouts when cultivation was discontinued.

Rodents took a heavy toll of trees at times in localized areas, especially where snow provided a cover for mice to work out into edges of the plantation. Grain treated with zinc phosphide was apparently effective in controlling mice most of the time. Strychnine-treated salt blocks were authorized for use during most of the 5-year period, and when placed in bait boxes scattered throughout the plantation, they effectively controlled porcupines and rabbits.

None of the losses to rodents suggested preferences for trees from certain provenances. Location in the plantation appeared to be more important than origin of the trees.

Shoestring root rot, *Armillaria mellea*, accounted for some mortality, especially in 1972, when inspection showed 66 seedlings killed by the fungus. The root rot has been a nuisance in other experimental forest plantations during the period, killing small numbers of seedlings of Black Hills source. There was no apparent pattern to *Armillaria* mortality in the provenance test block; seedling deaths appeared to be randomly distributed throughout the plantation.

Even, at best, average total height growth has not been especially good. After 5 years in the plantation (total age 8 years), trees from north-central Nebraska provenance 721 were the tallest with an average height of 2.2 ft (table 1). Trees from only one other provenance averaged as much as 2 ft in height after 5 years in the field. Local experience has shown that heights of 4 to 5 ft at total age 10 are not uncommon for Black Hills stock growing on good sites with limited competition.

If provenances outside the Black Hills area are evaluated as seed sources for reforestation in the Hills, better-than-local height growth by those trees might offset survival, which is poorer than for local sources. Initial stocking somewhat more than needed by local trees for later full site occupancy, to allow for the higher early mortality, could capitalize on inherently better growth and still give satisfactory stocking at later ages. Of course, plantation survival cannot be improved over time, except by replanting. Therefore, use of trees from provenances showing poor survival would be risky, even if height growth were comparable to local trees. For example, surviving trees from provenances 852 and 862 have reached heights equal to comparison source 839, but survival is so low that they hold little promise for planting in the Black Hills environment.

Length of the current year's leader, measured in 1970 and 1972, appeared only to supplement data on average total heights. Hence, they will not be reported. There was a predictable, positive relationship between average current annual height growth and average total heights for most provenances.

Conclusions

Results from long-term provenance research have sometimes shown that trees from distant seed sources can outperform local material in one or more respects. Early survival and height growth of ponderosa pine seedlings for a 5-year period from provenances rather far from the Hills in some cases exceeded Black Hills provenances. Other provenances were less noteworthy with little promise of being superior to local strains. Provenance WY 834 had exceptionally good survival but low height growth, and may develop into a more promising seed source later. Others, whose survival has been significantly lower than SD 839, but whose height growth has been comparable, need not be completely rejected, either. In other Black Hills plantations, they might perform better. Sources such as NB 852, CO 763, and NM 862 probably warrant additional trials.

Some sources were unable to cope with Black Hills conditions. New Mexico sources 863, 766, 767 have survived and grown so poorly that they will be of little value in plantations elsewhere in the Hills. Trees from other sources, which have less than 20 percent survival, are probably not worth additional testing in the Black Hills.

The trends of provenance survival and height growth will continue to be evaluated at 5-to 10-year intervals. A few provenances which show better early survival and height growth than Black Hills provenances should be evaluated more intensely, in blocks containing more trees, and for additional traits such as tree form, quality, and volume production.

Agriculture—CSU, Ft. Collins

ember 1974

U S D A FOREST SERVICE
RESEARCH NOTE RM-279

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Snow Accumulation and Melt Along Borders of a Strip Cut in New Mexico

Howard L. Gary[1]

Snowfall amounts were similar along the sunny and shady borders of an east-west oriented clearcut strip. Maximum snow accumulation was greater along both borders than in the adjacent forest. Periodic melting along the sunny border reduced the snowpack, but winter melt losses were somewhat balanced by melt crusts which prevented blowing snow. Snow disappeared 5 to 6 weeks earlier along the sunny border than along the shady border or forest interior. Melt rates along the shady border were 30 to 40 percent greater than those observed in the forest interior, but times of complete melt were the same.

Keywords: Clearcutting, snowmelt, watershed management, water yield improvement.

Most studies in forested snow zones have shown greater quantities of snow in small openings and narrow strip cuttings than under forest cover. Increased snow accumulation is not caused wholly by decreased interception loss, but rather by redistribution of snow and other factors (Anderson and Gleason 1959, Gary 1974, Hoover and Leaf 1967). Thus, the usually greater quantity of snow in clearings must be balanced against the deficit inside the adjacent forest when evaluating the effect of timber cutting practices on snow accumulation. Snow distribution and melt across openings and in clearings are likewise highly variable, and additional information is needed if we are to fully evaluate the effectiveness of strip cutting and/or patchcuts for snowpack management.

This Note reports a 2-year survey of snow accumulation and melt along the sunny and shady borders of an east-west oriented powerline right-of-way through an Engelmann spruce (*Picea engelmanni* Parry) stand. The clearcut strip extended across a south slope, and was generally perpendicular to the hour angles with maximum solar energy. The strip cut, except for length, was similar to the first phase of the proposed wall-and-step forest that would provide the maximum amount of shade over logged areas (Anderson 1956).

Study Area

The study area was about 16 miles northeast of Santa Fe, New Mexico, and one-third mile north of the headquarters of the Santa Fe Basin Winter Sports Area. The general slope aspect was southwesterly, but the study area aspect was south facing. Forest cover was dense Engelmann spruce 55 to 60 feet tall. The study plots were 10,300 feet above m.s.l., one-half mile from an 11,500-foot ridge line. Slopes near the study plots ranged from 15 to 20 percent. Prevailing winds were southwesterly.

Instrumentation and Methods

About 1960, a 60-foot-wide strip (one tree-height wide) was clearcut through the area for a powerline right-of-way. In 1967, six study plots were established along the sunny and shady borders of an east-west segment of the clearcut strip, three along each border. Plots were about 20 feet long with a 10-foot buffer zone between.

---

[1] *Hydrologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters at Fort Collins, in cooperation with Colorado State University. Research reported here was done while the author was located at the Station's Research Work Unit at Albuquerque in cooperation with the University of New Mexico.*

Two rows of 10 snow depth markers were located 8 and 14 feet from the forest borders. Depth markers (5.5-foot metal rods, ¼-inch diameter) were spaced about 2 feet apart, and were color coded at 1-inch intervals. Standard rain-gage cans were located at each end of the study borders on both sides of the clearing, and a recording rain gage was placed in the center of the study area. Instrument shelters housing a recording thermograph were also located on both sides of the clearing. Five depth markers spaced 5 feet apart were placed about 40 feet (about two-thirds tree height) inside the adjacent forest along both borders.

Weekly snow depth and snow water equivalent measurements were begun in December and continued until the end of the melt season for a 2-year period. Rain gages and thermographs were also serviced weekly. Starting in January, during one year, a 1-foot-square by ½-inch-thick board painted white, covered with white flannel and equipped with a depth marker, was placed near the center of each plot. The snowboards provided an additional index of depth and water equivalent of new snowfall during the previous week.

To characterize the borders, amounts of sun and/or shade were estimated weekly during one winter season. An average value for shade along each border was computed after estimating the presence or absence of shade around each of the 60 depth markers, usually at noon and again at 1 p.m. A depth marker was considered as shaded when an imaginary circle (1-foot diameter) around it was more than 50 percent covered by dense or diffuse shade.

Amounts of evaporation from the snow surface along the sunny and shady borders were determined for several 15-hour night and 8-hour day periods during one year from January to April. Five undisturbed snow cores were taken from each border and placed in circular 6-inch-diameter, 5-inch-deep clear plastic pans with false bottoms (West 1962). The pans of snow were weighed before and after varying exposure times at the snow surface, and amount of evaporation was then computed.

Border Climate

The amounts of shade along the borders near solar noon for selected times during 1968 were:

	Sunny border	Shady border
	(Percent	shade)
January 24	2	75
February 21	0	76
March 25	0	60
April 25	0	54

The greatest climatic difference between the plots was apparently the higher amount of direct insolation received along the sunny border (Geiger 1957). During cloudy and overcast days, there was probably little difference in irradiation along the borders. Also, after heat losses during clear nights, both borders probably had similar heat balances by sunrise.

The air temperatures gave a relative measure of the insolation differences (table 1). The monthly maximum air temperatures were 7° to 9°F above freezing along the sunny border, and snow melted periodically through the winter. Ice chunks and lenses and a persistent ice layer at the ground surface were always encountered when measuring water content of the snow along the sunny border, but not along the shady border. Number of days with maximum air temperatures 32°F or above were:

	Sunny border	Shady border
January	22	7
February	23	9
March	25	15

Minimum air temperatures were similar along both borders; they were below freezing every night from January through March.

Table 1.--Mean maximum and minimum air temperatures (°F) for the sunny and shade border plots (1967-68)

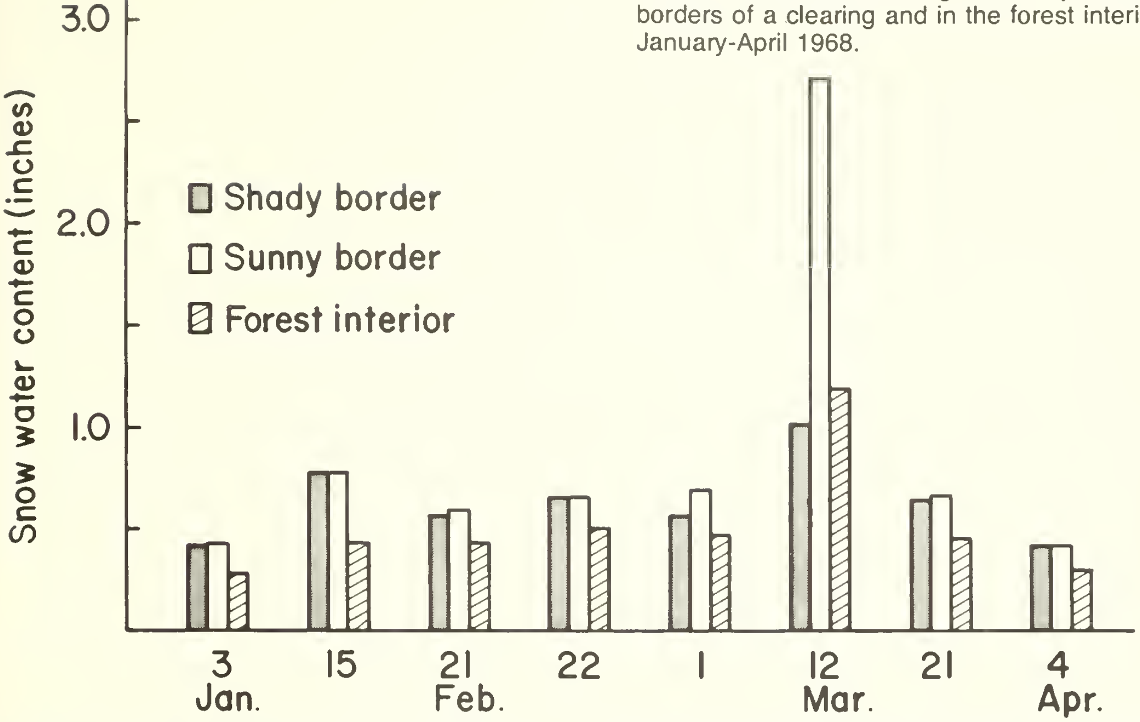
Month	Sunny border		Shady border	
	Maximum	Minimum	Maximum	Minimum
December	30.7	10.7	24.0	10.2
January	36.5	13.6	27.5	13.6
February	37.4	14.8	29.4	15.7
March	38.6	15.2	31.2	15.7
April	40.7	18.8	34.6	18.7
May	52.8	28.1	47.5	28.3

Border Effects on Snow Catch

The weekly snow catch on the snowboards was about the same for the sunny and shady borders (fig. 1). The snowboards apparently measured snowfall more accurately than the rain gages. During big storms, the gages were usually bridged over with snow, and did not measure total snowfall.

Sunny and shady borders were about equally efficient for trapping and holding snow during storms as well as during post-storm periods (fig. 1). The one exception was during the week ending March 12, 1968. A strongly bonded 1-inch ice

Figure 1.—Weekly measurements of average snow catch on snowboards along the sunny and shady borders of a clearing and in the forest interior for January-April 1968.



crust was present along the sunny border on March 12, but not along the shady border where temperatures remained below freezing. Strong winds on March 10 and 11 redistributed much of the uncrusted snow from along the shady border.

During the relatively common windstorms in the spring, when ice crusts are not present, new snow is blown from both the sunny and shady border plots and redistributed into the forest interiors. For practical purposes and under conditions of the study, it was apparent that initial snowfall amounts were similar along the sunny and shady borders.

Border Effects on Snow Evaporation

Weight loss from snow-filled pans was determined once each week for 12 weeks during the period January 8 to April 18, 1969. Average daily snow evaporation amounts were:

	Sunny border	**Shady border**
	(Inches)	
Day	0.0133	0.0065
Night	.0009	.0011

Water loss by evaporation along the sunny border was relatively small during the daylight hours, but averaged twice the amount observed along the shady border. Losses for the night periods were reduced by condensation on the snow-filled pans.

The measured losses were in general agreement with values reported for most snowpack timber zones in the western States. West (1959) reported annual snow-evaporation losses varied between 1.0 and 1.5 inches in a small forest opening about one-half tree height wide, and 0.4 to 1.0 inch in a forest of 70 percent density. Annual evaporation losses along the shady border in the present study area would not likely exceed the values observed in West's small opening.

Evaporation losses in the present study were probably reduced to some minimum value during storm periods. For the 1969 study period, an estimate of cloudy weather based on number of days with snow greater than 0.02 inch water equivalent was:

	Precipitation > 0.02 inch (Days)
January	14
February	11
March	19
April	9

While there may be large relative differences by slope, aspect, size of openings, and density of the forest, evaporation losses appear to be a small percentage of the total snowfall. It is unlikely that evaporation differences between the sunny and shady borders were large enough to account for more than a small fraction of the large difference observed in snow accumulation along the borders of the clearing.

Snow Storage and Melt

The patterns of snow accumulation and melt along the borders of the strip-cut and in the forest interior were nearly identical for the 2 years of study (fig. 2). Through most of the snow accumulation season, the shaded border plots contained 1 to 1.5 inches more snow water content than the sunny border plots. The difference was apparently the result of periodic melting through the winter, since snow catch and evaporation were about the same along both borders. During one week in March in both years, the sunny border plots either equaled or exceeded snow accumulation along the shady border. These anomalies were apparently the result of high winds blowing away uncrusted snow along the shady borders.

Near the time of maximum snow accumulation along the sunny border (about March 12 both years), the border plots on the average contained about 27 percent more snow during 1968 and about 40 percent more during 1969 than the forest interior plots. The clearing apparently affected the distribution of snow, but the total amount of snow was probably unchanged (Hoover and Leaf 1967). It is evident from similar studies that increased quantities of snow in openings and in clearings must be balanced against decreased quantities in the adjacent forest in order to evaluate clearing effects on snow accumulation (Gary 1974).

Spring snowmelt along the sunny border was completed in roughly 1 month (from March 12 to April 17 in 1968 and by April 10 in 1969) (fig. 3). The average melt rate was 0.28 inch per day in 1968, 0.36 inch per day in 1969. The shady border showed some of the characteristics of the forest interior in prolonging snowmelt. When snowmelt was nearly complete along the sunny border (April 4, 1968), the amount of snow remaining along the shady border was 95 percent of the assumed maximum accumulation. In 1969, about 86 percent of the assumed maximum snowpack was present at the time of complete melt (March 26) along the sunny border. Similar results of shading were also observed by Gary and Coltharp (1967) at an elevation of 11,500 feet in the same watershed. They reported that, when snowmelt was completed on a south-facing aspect of a large open burn, 83 percent of the maximum snowpack was present under an adjacent and similarly oriented old-growth spruce-fir forest. On a north-facing aspect, 93 percent of the maximum snowpack was present under the spruce-fir forest at the time of complete melt on the burn.

Complete melt along the shady border and in the forest interior was 5 to 6 weeks later than along the sunny border. The shady border had more snow, but the time of complete melt was about the same for the shady border and forest interior. Average daily snowmelt rates along the shady border and in the forest interior from the time of maximum snowpack were:

Period of melt	Shady border	Forest interior
	(Inches of water)	
April 4 to May 28, 1968	0.188	0.131
April 17 to May 15, 1969	.443	.268

Average daily melt rates along the shaded border ranged from 30 to 40 percent greater than melt rates in the forest interior.

Summary and Conclusions

The sunny and shady borders along a long clearcut strip received similar amounts of snow each storm. Although periodic winter melting along the sunny border reduced the amount of water stored there, the melting loss along the sunny border was eventually balanced by the effect of melt crusts which reduced the amount of blowing snow.

At the time of maximum snowpack, the greatest quantities of snow were along the sunny and shady borders of the clearcut strip. Based on evidence from other studies, the higher snow catch in the clearing was the result of snow redistribution from the adjacent forest interiors. Small patch-cuts no greater than five to eight tree-heights in diameter will probably accumulate maximum quantities of snow (Hoover 1969). Shorter clearings would greatly reduce windspeeds and intensity of blowing snow events.

Melt rates were accelerated along both the sunny and shady borders of the clearing. It is most probable that snowmelt rates in clearings one tree-height wide or larger will be significantly greater than melt rates under surrounding forest cover. The significantly deeper snow along the shady border melted about the same time as the shallower snow in the adjacent forest.

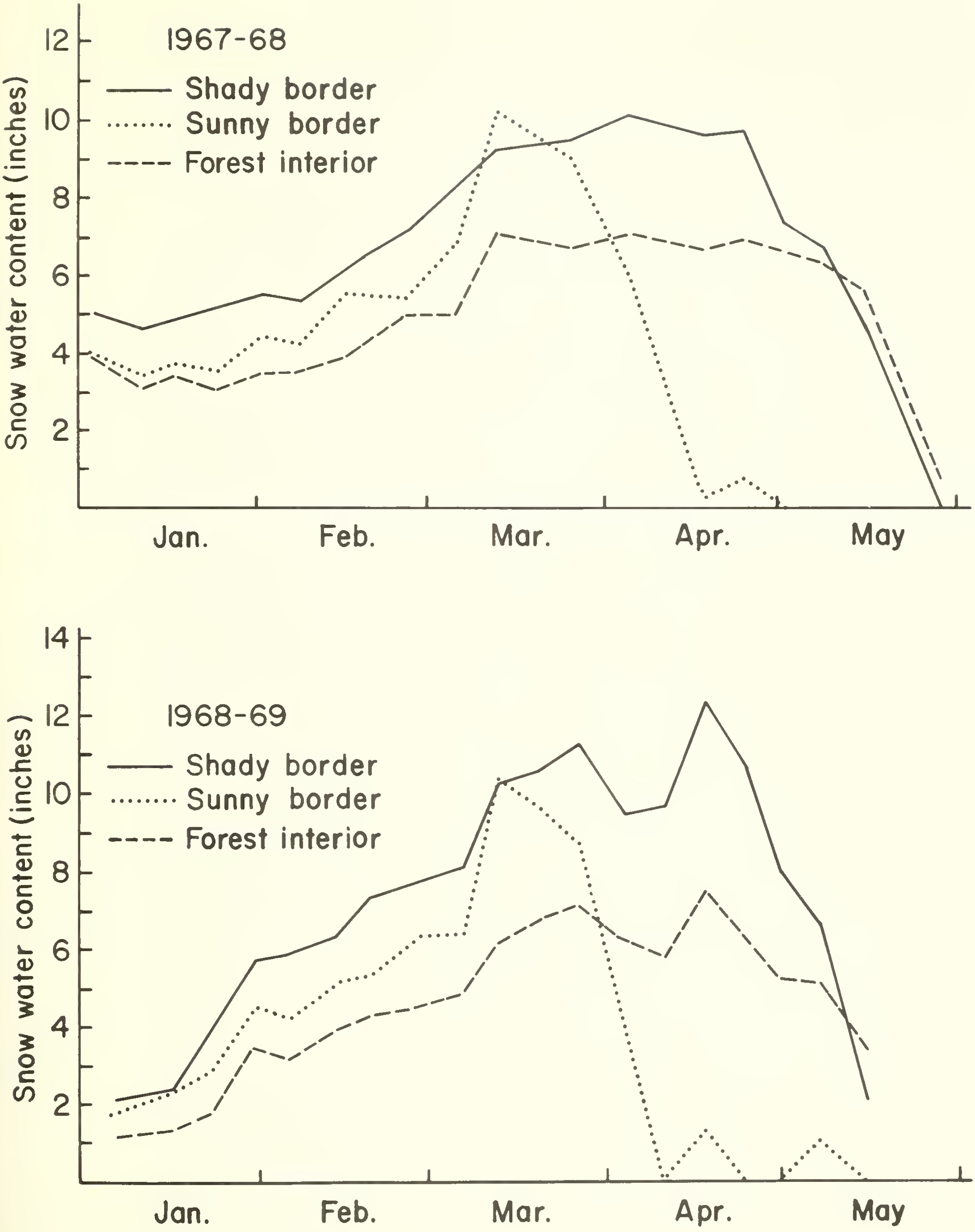


Figure 2.—Snow accumulation and melt along the sunny and shady borders of the clearing and in the adjacent forest interior.

April 17
Sunny

May 1
Sunny

April 17
Shady

May 1
Shady

re 3.—Progress of snowmelt along the sunny and shady borders of the clearcut strip during the spring of 1968.

More and earlier water yield should result from forest harvesting in narrow and short clearcut strips and/or small patch-cuts because of reduced transpiration losses, a greater unit-area concentration of snowmelt water, and a greater year-to-year carryover of soil moisture.

Literature Cited

Anderson, H. W.
1956. Forest cover effects on snowpack accumulation and melt, Central Sierra Snow Laboratory. Am. Geophys. Union Trans. 37:307-312.
Anderson, H.W., and C.H. Gleason.
1959. Logging effects on snow, soil moisture, and water losses. West. Snow Conf. Proc. 27:57-65.
Gary, Howard L.
1974. Snow accumulation and melt as influenced by a small clearing in lodgepole pine forest. Water Resour. Res. 10:348-353.
Gary, Howard L., and George B. Coltharp.
1967. Snow accumulation and disappearance by aspect and vegetation type in the Santa Fe Basin, New Mexico. U.S. For. Serv. Res. Note RM-93, 11 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
Geiger, R.
1957. The climate near the ground. 494 p. McGraw-Hill Book Co., Inc., N.Y.
Hoover, Marvin D.
1969. Vegetation management for water yield. Am. Water Resour. Assoc. Symp. Water Balance North Am. [Banff, Alberta, Can., June 1969] Proc. Ser. 7, p. 191-195.
Hoover, Marvin D., and Charles F. Leaf.
1967. Process and significance of interception in Colorado subalpine forest. p. 213-224, *In* W.E. Sopper and H.W. Lull [ed.] Forest Hydrology. [Int. Symp. For. Hydrol., Univ. Park, Pa., Aug.-Sept. 1965] 813 p., Pergamon Press, N.Y.
West, A.J.
1959. Snow evaporation and condensation. West. Snow Conf. Proc. 27:66-74.
West, A.J.
1962. Snow evaporation from a forested watershed in the Central Sierra Nevada. J. For. 60:481-484.

Agriculture—CSU, Ft. Collins

bruary 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-280

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Rodent Exclosures for the Subalpine Zone in the Central Colorado Rockies

Daniel L. Noble and Robert R. Alexander[1]

Two exclosures established in the subalpine zone of the central Colorado Rockies have effectively excluded rodents from an Engelmann spruce regeneration study. The exclosures have withstood deep snowpacks and required little maintenance during 6 years. Method of construction and recommendations for use are discussed.

Keywords: Regeneration, rodents, *Picea engelmannii*.

Effective rodent control may be necessary for direct seeding in reforestation of conifers (Schubert and Adams 1971). Without some form of control, rodents may consume all the seed. Voles and pocket gophers may be particularly damaging.

Rodents in the subalpine zone in the Front Range of the central Colorado Rockies that damage conifer seed and seedlings include—deer mice (*Peromyscus maniculatus* Wagner), mountain voles (*Microtus montanus* Peale), heather voles (*Phenocomys intermedius* Merriam), red-backed voles (*Clethrionomys gapperi* Vigors), chipmunks (*Eutamias* spp.), northern pocket gophers (*Thomomys talpoides* Richardson), and snowshoe hares (lagomorphs).

A study was begun in 1967-68 on the Fraser Experimental Forest in the central Colorado Rockies to identify major climatic, physiographic, and biotic factors affecting Engelmann spruce (*Picea engelmannii* Parry) regeneration in clearcut openings. The study included artificial seeding. Because rodents and lagomorphs were a potential source of seed and seedling loss, we sought to eliminate them as a variable.

Small cone screens were not used to protect seeds and seedlings from rodents because they tend to alter microsites—temperature, moisture, and radiation. Therefore, two rodent exclosures approximately 100 x 110 ft were established—one on a 10- to 12-percent north-facing slope and the other on a 12- to 15-percent south slope (fig. 1). Both exclosures were at an eleva-

Figure 1.—A finished section of the rodent exclosure fence.

---

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

tion of 10,600 ft. The purpose of this Note is to describe construction of the exclosures, relate their effectiveness, and point out their utility.

Construction

These exclosures, while resembling pocket gopher exclosures described by Keith (1961), have major differences. A creosote-treated wooden post, 6½ ft long and 4 to 6 inches in diameter, was set at each corner and midway between corners. Posts were set 30 inches in the ground with 40 pounds of concrete at the base of each post. The remaining portion of the post hole was filled and tamped with soil. Standard 6-ft metal fence posts were driven into the ground to an approximate depth of 2 ft at roughly 5-ft intervals in the spaces between wooden posts.

A trench, roughly 6 inches deep and 6 inches wide, was dug along the outer perimeter of the exclosure so that the inside wall of the trench was in line with the posts (fig. 2). Hardware cloth was stapled to wooden posts and wired to

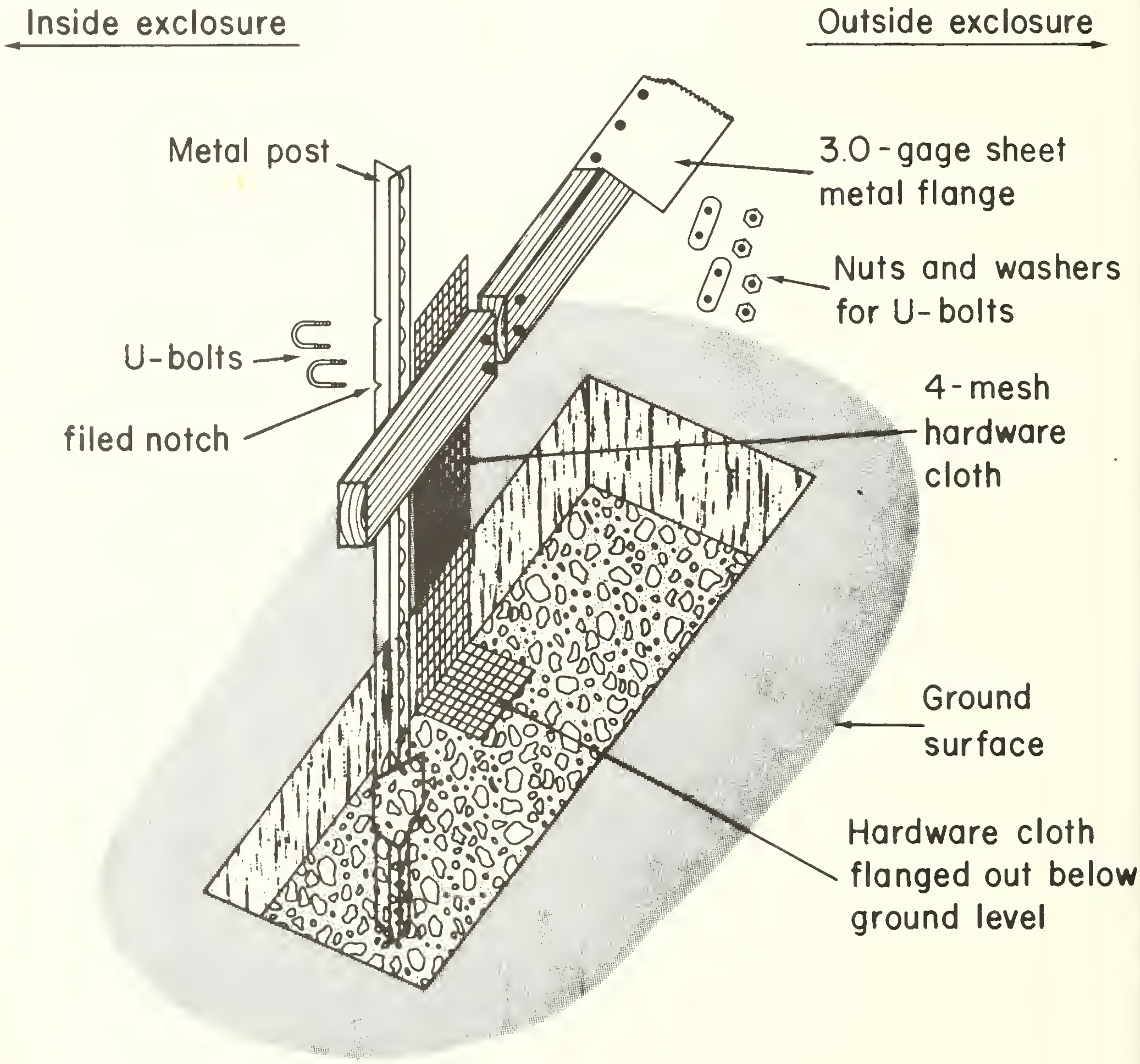


Figure 2.—A schematic diagram of the rodent exclosure fence, illustrating the construction at a rail (2- by 4-inch) joint with a metal post.

metal posts on the sides facing away from the exclosure. The hardware cloth was bent along the long axis at a point 4 inches from the edge to form a right angle which was buried 4 inches in the trench, leaving 28 inches above the ground.

Wooden rails of standard 2- by 4-inch construction lumber approximately 10 ft long were attached to the outside of the posts, 28 inches above the ground, so that the upper edge of the hardware cloth was even with the top of the rails between the posts and the rails (fig. 2). Rails treated with pentachlorophenol to prevent deterioration were nailed to wooden posts and bolted to metal posts with U-bolts ¼ inch in diameter, 2 inches wide, and 4½ inches long. Two U-bolts were used at posts where adjoining rails abutted, whereas only one U-bolt was used to attach rails to posts between joints. To insure more precise construction of the exclosures, wooden rails were cut and drilled for U-bolts on the construction site. Notches in which the U-bolts rested were filed on the inside edge of metal posts to prevent rails from collapsing. The hardware cloth was stapled to the rails at 3- to 4-inch intervals. Thirty-gage sheet-metal strips, 6 inches by 10 ft, were overlapped and nailed to the top edge of the rails with 1¼-inch roofing nails and then bent downward to an approximate 45° angle. The sheet metal was painted black to make the exclosures less conspicuous.

For the exclosures to be effective, all nearby trees and slash from which rodents could climb and jump into the exclosure should be removed. Excluding the time required for removal of such materials, an exclosure can be installed in approximately 6 to 8 weeks by a two-man crew.

Materials and Equipment

Costs and amount of materials have not been included because size of exclosures and costs are both variable.

Treated wood posts—4 to 6 inches by 6½ ft
Steel fence posts—6 ft
Wooden rails, standard construction lumber—2 inches by 4 inches by 12 ft
Hardware cloth, galvanized 4-mesh rolls—100 ft by 36 inches
Steel metal flashing, galvanized —10 ft by 6 inches
U-bolts, ¼ inch in diameter, 2 inches wide by 4½ inches long
Nails, roofing—1¼ inches
Nails, construction—12 penny
Staples—½ inch long
Baling wire—12 gage
Premix, drymix concrete—40-pound sacks
Pentachlorophenol
Special Equipment:
  Portable generator
  Power drill
  Power hand circular saw

Results

The exclosures were successful in excluding rodents, except pocket gophers, from the study areas (Noble and Shepperd 1973). These gophers entered the exclosures either by digging under the buried hardware cloth or tunneling through the snow when the snowpack covered the exclosures. However, these animals were successfully controlled by trapping.

The exclosures have successfully withstood snow conditions for 6 years (1968 to 1974), and annual maintenance has been minimal even though snow depths reached a maximum of 106 inches in 1972.[2] The north exclosure required no maintenance, whereas 4 to 5 man days were needed in June of each year to repair damage to the south exclosure. The north slope was rocky with exposed bedrock in many places, while the south slope was covered with deeper soil containing few rocks. Because the soil was more easily penetrable on the south exclosure, the weight of snow pushed the metal posts with attached rails deeper into the ground—generally 2 to 4 inches each year. Entire sections of fence between wooden posts were often sunken, but rails did not slip down metal posts. Therefore, it was relatively simple to lift sunken fence sections to their original height by loosening U-bolts, jacking up rails, filing new notches for U-bolts, and retightening them. After 4 to 5 years, a few metal posts were pushed so far into the ground that U-bolts could no longer be secured to the posts. Such posts were replaced with wooden posts anchored in concrete, which helped stabilize the fence. Replacement of 2- by 4-inch rails has been limited to those that were defective when installed, and was accomplished without much difficulty using hand tools.

Conclusions and Recommendations

The exclosures were effective, and with minimal alterations could be improved. The problem of pocket gopher entry, for example, can be easily solved by burying the hardware cloth to a depth of 24 inches as recommended by Keith (1961), and extending hardware cloth to a

---

[2] Unpublished data on file at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

height above the rails that would prevent gophers entering the exclosure by tunneling over the top during winter. Also, it would be a simple matter to attach strands of barbed wire above the rails to exclude domestic livestock or deter deer and elk if they were a problem. Similarly, the problem of the fence sinking into deep soil could be reduced, if not eliminated, by placing posts in concrete at 25-ft intervals.

This type of exclosure is recommended for research studies or outplantings from seed-provenance studies when rodents might otherwise destroy the experiment, or for experiments involving concentrations of nursery stock under field conditions.

Literature Cited

Keith, James O.
1961. An efficient and economical pocket gopher exclosure. J. Range Manage. 14:332-334.

Noble, Daniel L., and Wayne D. Shepperd.
1973. Gray-headed juncos—important in first season mortality of Engelmann spruce. J. For. 71:763-765.

Schubert, Gilbert H., and Ronald S. Adams.
1971. Reforestation practices for conifers in California. 359 p. Calif. Div. For., Sacramento.

Agriculture—CSU, Ft. Collins

bruary 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-281

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Nest Use and Home Range of Three Abert Squirrels as Determined by Radio Tracking

David R. Patton[1]

Abert squirrels have and use more than one nest in their home range. Three squirrels used 2, 5, and 6 nests in areas of 30, 10, and 85 acres, respectively.

Keywords: *Pinus ponderosa, Sciurus aberti aberti,* radio tracking.

Documenting animal use of habitat is one of the most difficult problems in wildlife research. As a result of miniaturization of electronic components, however, radio transmitters can now be made for small animals. The radio signal greatly simplifies location of the animal; then, by sight observation, information can be collected on food habits, cover requirements, and behavior activities.

This study was done to document the number of nests and size of home range used by individual Abert squirrels (*Sciurus aberti aberti*). Radio tracking requires competent field assistance and I want to acknowledge graduate students Thomas R. Ratcliff and Kenneth D. Rogers from the University of Arizona, and Richard L. Golightly from Arizona State University for their help in trapping, locating, and observing squirrels.

Methods

The study was done on the Coconino National Forest in the Beaver Creek watersheds near Happy Jack, Arizona. Squirrels were captured in Tomahawk No. 202 live traps baited with unroasted peanuts. After a squirrel was trapped, it was transferred to a holding cone and anesthetized with metofane (methoxyflurane). One squirrel was equipped with a radio attached as a backpack. Two were equipped with radios attached to a collar (fig. 1). After the radio was in place, the squirrel was left to recover in a cage before it was released at the trap site.

Figure 1.—Anesthetized Abert squirrel with a transmitter attached to a collar.

Considerable initial effort was spent in developing and testing the miniature transmitter

---

[1] *Principal Wildlife Biologist, located at Station's Research Work Unit at Tempe, in cooperation with Arizona State University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

and collar.[2] The collar, transmitter, and battery weighed just under 36 grams. This weight did not seem to impede the squirrel's activities.

The location of each nest used and other documented locations of individual squirrels were plotted on a small-scale map referenced to aerial photographs and numbered timber inventory stakes. Lines drawn between squirrel locations delineated the home range boundary.

Results

Squirrel No. 1 was an adult female trapped in September 1972. In 15 days of tracking, she used five different nests but did not stay more than three consecutive nights in the same nest. All of the nests were in live ponderosa pine (*Pinus ponderosa*) trees. The five nests were within a 2-acre area, but observed locations showed her home range to be 10 acres.

From criteria based on tree size and density (Patton 1974), the 10-acre home range was classed as being in optimum squirrel habitat. The area inhabited by this female was partially within a 12-acre trap site where eight adult females and five adult males were trapped from June until November 1972. The squirrel density therefore was approximately one squirrel per acre; there was considerable overlap in their home range. This tagged squirrel was killed by a hunter in October 1972.

Observations of squirrel No. 2, an adult male trapped in January 1974, were limited because he was killed by a hawk while in an open area away from cover 8 days after being released. This squirrel used two different nests in ponderosa pine in the 8-day period. One of the nests had been used by a squirrel tagged in 1973. Home range was determined to be 30 acres.

Squirrel No. 3 was an adult male trapped in February 1974. During a 31-day tracking period, this squirrel used six different nests, one in a hollow Gambel oak (*Quercus gambelii*), one in a ponderosa pine snag, and four nests in live ponderosa pine. The greatest documented consecutive number of nights spent in the same nest was three, but he was not tracked over weekends. One of the nests used was recorded as active in the summer of 1972. Home range for squirrel No. 3 was 86 acres in good habitat.

Discussion

The miniature radios proved to be of great value in documenting the number of nests being used and home range size. Receiving distance varied from 0.5 to 0.7 mile, depending on weather conditions and tree density. By using a whip antenna around the collar and a directional yaga antenna with the receiver, it was possible to go directly to the squirrel at any time.

Nest use varied from two to six per squirrel (table 1). The home range of squirrel No. 1 considerably overlapped that of other squirrels, and more than one squirrel probably used the same nest at the same time. It is also possible that different squirrels used the same nest on a rotation basis. However, neither hypothesis was documented since only one squirrel at a time was tagged with a transmitter.

Table 1.--Home range size and number of nest trees used by three adult Abert squirrels equipped with radio transmitters

Data recorded	Squirrel-- 1	 2	 3
Sex	Female	Male	Male
Month and year trapped	Sept.72	Jan.74	Feb.7
Tracking period (days)	15	8	31
Habitat rating	Optimum	Optimum	Good
Home range (acres)	10	30	85
Nest trees used (number)	5	2	6

Of the six nests used by squirrel No. 3, two were in hollow trees. In the Southwest, pine snags and hollow oak trees are generally removed in timber harvests because they are considered to have no economic value. Because they constitute a cover component for the Abert squirrel, however, their retention should be considered. They are also important for cavity-nesting birds (Scott and Patton 1975).

Home range of squirrel No. 3 (86 acres) was 62 acres larger than the largest reported by Keith (1965) in Arizona, and 32 acres larger than that reported by Farentinos (1972) in Colorado. Both authors indicated home range is influenced by season and mating activity. There are slight indications in this study that home range is also influenced by habitat quality and population density, but more data are needed to document this relationship. Theoretically, squirrels in optimum habitat would have a smaller home range because their life necessities could be met in a smaller area.

---

[2] *Beaty, D. W. Instruction, operation and usage manual for Magnum MK-1 telemetry transmitter series Models M-1 and MM-1. Copyright 1973, 1048 E. Norwood, Mesa, Arizona, 68 p.*

Nest durability has been checked on several areas. Many active nests on the Coconino National Forest were at least 4 years old in 1974. One nest found on the Apache National Forest in 1965 was still in place and in good condition in July 1974.

Literature Cited

Farentinos, R. C.
1972. Social dominance and mating activity in the tassel-eared squirrel (*Sciurus aberti ferreus*). Anim. Behav. 20:316-326.

Keith, J. O.
1965. The Abert squirrel and its dependence on ponderosa pine. Ecology 46:150-163.

Patton, D. R.
1974. Characteristics of ponderosa pine stands selected by Abert's squirrel for cover. Ph.D. Diss. 40 p. Dep. Watershed Manage., Univ. Ariz., Tucson.

Scott, Virgil E., and David R. Patton.
1975. Distribution, nest selection, and food of cavity nesting birds of Arizona and New Mexico. USDA For. Serv. Gen. Tech. Rep. RM-10, [In Press] Rocky Mt.. For. and Range Exp. Stn., Fort Collins, Colo.

Agriculture CSU, Ft Co

bruary 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-282

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Height-Growth Comparisons of Some Quaking Aspen Clones in Arizona

John R. Jones and David P. Trujillo[1]

Height-over-age curves of dominant trees were compared for five pairs of adjacent clones in 70-yr-old aspen stands. Sample trees of a pair occupied a common site. Apparent uniformity or non-uniformity of height was not a criterion in selecting pairs. In the three pairs with significantly different heights, the differences developed in early life. In one pair the difference was large, suggesting possibilities of selecting clonal material for planting. At age 30, all 10 clones would have seriously overestimated aspen site index (base age 80). By age 50, site index estimates would have been reasonably accurate.

Keywords: Clonal differences, height growth, site index, *Populus tremuloides*.

Different bigtooth aspen (*Populus grandidentata* Michx.) clones growing side by side on the same site may differ substantially in height growth (Zahner and Crawford 1965). Presumably such height growth differences result from genetic differences. This explanation seems much more likely than the alternative—that clonal boundaries commonly coincide with large and abrupt but invisible changes in site or history.

Zahner and Crawford did not include quaking aspen (*P. tremuloides* Michx.) in their study. They suggested, however, that genotypic differences in the height growth of quaking aspen clones may be less than between bigtooth aspen clones. In support of that opinion they cited personal communication with J. H. Stoeckeler and R. O. Strothmann, research foresters with extensive experience in the Lake States.

Graham et al. (1963) believed that substantial genotypic differences in the growth of aspen clones in Michigan afford a major opportunity to improve timber yields. Their statement did not differentiate between bigtooth and quaking aspen, nor did they provide support for their experienced judgment.

In the western United States, Cottam (1954) and Egeberg (1963) studied genotypic differences in quaking aspen phenology in Utah and Colorado, respectively. Each paper included a photo showing a clone in leaf standing beside a clone whose buds had not opened. In each case, though the authors did not comment on it, the heights of the adjacent clones were very different.

This Note compares the height growth of some pairs of quaking aspen clones growing side by side in Arizona.

---

[1] *Principal Plant Ecologist and Forest Research Technician, respectively, located at Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

The Study Area

The study area was chosen for accessibility, the abundance of aspen on favorable sites, and because decay was virtually absent from most stands. It is at 8,800 to 9,000 ft (2,680 to 2,740 m) elevation along a 2-mi (3-km) stretch of Forest Road 154, on the Black River District, Apache National Forest, in east-central Arizona (fig. 1).

Figure 1.—Healthy 70-yr-old aspen on the study area.

In 1903 or early 1904, fire burned through the mixed conifer forest of the area. Where the fire was severe enough to kill the conifers, aspen suckers took over, and the present forest is a mosaic of mixed conifer stands and small stands of mature aspen.

The area is on the southern rim of the White Mountains, where they drop rather abruptly southward toward the Basin and Range Province. It is therefore exceptionally moist, receiving approximately 33 inches (850 mm) average annual precipitation, about 45 percent falling as snow from November through March and about 30 percent as July and August rains.[2] This abundant precipitation, in conjunction with silty clay loam and silty loam soils, provides conditions favorable to good aspen growth.

Methods

Study clones were located by driving slowly along the road in late September. The foliage in some clones had turned yellow and in others was still green, making differentiation between clones easier than usual. Other clonal boundaries were first recognized by bark differences or by differences in the tone of green foliage. Each distinguishable clonal boundary along the road was examined. No clonal pair was accepted for sampling unless standing trees were readily assignable to one clone or the other, and unless the site appeared entirely uniform over an area large enough for a full sample. Irregular terrain ruled out a number of pairs. The first five suitable pairs were used. They were taken as they came; apparent contrast or uniformity in height were not criteria.

Within each clone, five dominant trees made up the sample. These were trees at least as tall as any adjacent tree, and taller than most. In an effort to distribute any unseen site dissimilarities as uniformly as possible between the two clonal samples, all sample trees were selected close to the clonal boundary. No tree was chosen, however, which competed directly with the crown of a tree in the other clone. Some of the sample trees in each clone were nearer to sample trees of the other clone than to some in their own.

Sample trees were felled and their heights measured. Cross sections were cut at stump height and at measured intervals up the bole, for ring counts. The cross sections were dried and rings counted in the laboratory

The number of rings for each cross section in a tree was graphed against section height. Section height was the independent (fixed) variable and ring count the dependent variable. If there were 65 rings at 8 ft (2.44 m) above the ground in a 69-yr-old tree, the tree must have passed 8 ft in height sometime during the fifth growing season and was, of necessity, taller than 8 ft, perhaps 9 ft (2.74 m), by the end of the year. To assume that the section height marked the end of a year's height growth would introduce a small but consistent error. Therefore it was assumed that the height-growth rate had been linear between two cross sections, and that each cross section was the midway point in a year's growth. This reduced the error and largely freed it from bias.

---

[2] *Based on precipitation records from similar elevations 5 mi (8 km) northeast and 25 mi (40 km) northwest.*

With these assumptions, estimated height for 1906, 1910, and each subsequent fifth year was graphed, with calendar year treated as the independent variable and height as the dependent variable.

All the stands were the same age. The oldest sample trees in each clone had 70 rings at stump height; almost all the rest had 69 or 68. This age pattern fits the course of aspen stand establishment which sometimes follows fire in mixed conifer forests in the southwest: suckers originating the first summer following fire do not totally occupy the site, and numbers may increase for a few years[3] (Patton and Avant 1970).

The average height of each clone in 1973 was compared statistically with its partner, and their height-over-age curves were compared graphically.

Results

The average heights of clones in 1973 are tabulated below:

Pair	Height		Difference	
	ft	*m*	*ft*	*m*
1	59.6	18.17	9.7±1.2	2.96±0.37
	69.3	21.13		
2	57.9	17.65	4.0±1.7	1.22±0.51
	61.9	18.87		
3	76.4	23.29	Not significant	
	79.1	24.12		
4	84.6	25.79	Not significant	
	86.1	26.25		
5	83.2	25.37	6.5±0.52	1.98±0.16
	89.7	27.35		

For each clonal pair whose heights were significantly different in 1973, the difference developed early in the life of the stand in the sapling stage (fig. 2). Subsequent growth rates in a pair have been rather similar. In clonal pair 3, a moderate difference in early growth was subsequently reversed, and heights have been similar since 1935.

The site index estimates for the site of clonal pair 1 would have differed considerably, depending on which clone was used for the estimate and at what age. Clonal differences in site index at the other sample locations ranged from moderate to trivial, and the estimates again change with age:

Pair	SI_{80} estimated at BH ages—		
	30	50	65
1	76	65	65
	97	80	76
2	74	64	63
	80	68	68
3	107	87	85
	107	89	86
4	120	96	93
	127	97	95
5	122	98	92
	129	102	98

Discussion

This small sample conforms with the impressions of general observation—that quaking aspen clones of the same age on the same site, though sometimes differing considerably in height, usually do not differ very much. However, in any program of collecting roots for production of planting stock, there is an opportunity to collect from clones of superior growing ability.

In collecting, however, one should not ignore other traits which differ from clone to clone and which, for various sites and considerations, may be important. Clonal differences in susceptibility to major decay fungus *Phellinus*

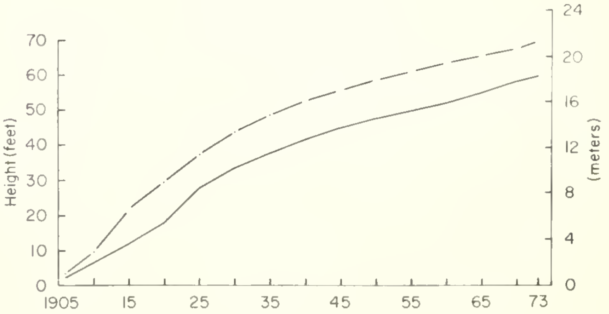


Figure 2.—Height-age curves for clonal pair 1. These two clones differed more in height growth than any other pair studied.

---

[3] *Jones and Trujillo, Manuscript in preparation.*

tremulae (formerly *Fomes igniarius* var. *populinus*) are sometimes suggested by differences in the abundance of conks. Wall (1971) showed that the difference is real. Further, by studying clones occurring together across different kinds of sites, he found that both the growth of different clones and their susceptibility to decay responded differently to site changes. Egeberg (1963) found major differences in clonal susceptibility to frost damage, which may be very important on some sites and not at all on others. Various writers have found differences in field and greenhouse suckering ability of different clones, and in optimum conditions for suckering (Barnes 1969, Farmer 1962, Tew 1970). Barnes (1969) described important differences between clones in stem form and self pruning, differences that the field forester may sometimes notice for himself.

Where natural regeneration is to be relied on, the forester must make the best of the clone on the site. In the West, a single clone often will occupy several acres (Tew et al. 1969). But if, for example, most stems in a given clone are forked, as occasionally happens (Barnes 1969, Jones 1967b, p. 127), regenerating the site by natural suckering may be undesirable. Steneker (1974) has suggested ways of favoring selected clones in regenerating an area naturally, but these are suited only to stands that are a fine mosaic of clones of small area, an exceptional situation in the West.

Every clone in this study seems, at age 30, to have seriously overrepresented site index. The site index table was developed largely from Colorado and New Mexico stem analysis data, and even for that area, site index estimates from 30-yr-old stands were often very inaccurate (Jones 1966, 1967a).

At an age (breast high) of 65, approaching the base age of 80, estimates are almost surely very close, and are approximated well by the estimates at age 50.

Conclusions

Aspen site index estimates from 30-yr-old stands are likely to be very inaccurate.

Although different aspen clones growing on the same site commonly do not differ much in height at maturity, some differ substantially. Any aspen planting program should take advantage of superior growth potentials as well as other inherent clonal differences. Height growth differences between clones at age 30 or younger may sometimes be reversed, however, at least if the difference is not large. Therefore, clonal material for planting should ordinarily be collected from older stands.

Literature Cited

Barnes, B. V.
1969. Natural variation and delineation of clones of *Populus tremuloides* and *P. grandidentata* in northern Lower Michigan. Silvae Genet. 18:130-142.

Cottam, W. P.
1954. Prevernal leafing of aspen in Utah mountains. J. Arnold Arbor. 35:239-250.

Egeberg, R.
1963. Inherent variation in the response of aspen to frost damage. Ecology 44:153-156.

Farmer, R. E., Jr.
1962. Aspen root sucker formation and apical dominance. For. Sci. 8:403-410.

Graham, S. A., R. P. Harrison, Jr., and C. E. Westell, Jr.
1963. Aspen: phoenix trees of the Great Lakes Region. 272 p. Univ. Mich. Press, Ann Arbor.

Jones, John R.
1966. A site index table for aspen in the southern and central Rocky Mountains. U.S. For. Serv. Res. Note RM-68, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Jones, John R.
1967a. Aspen site index in the Rocky Mountains. J. For. 65:820-821.

Jones, John R.
1967b. Environmental coordinates and their relation to aspen height growth in the Southern Rocky Mountains. Ph.D. Diss., 198 p. Colo. State Univ., Fort Collins.

Patton, David R., and Herman D. Avant.
1970. Fire stimulated aspen sprouting in a spruce-fir forest in New Mexico. USDA For. Serv. Res. Note RM-159, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Steneker, G. A.
1974. Factors affecting the suckering of trembling aspen. For. Chron. 50:32-34.

Tew, R. K.
1970. Root carbohydrate reserves in vegetative reproduction of aspen. For. Sci. 16:318-320.

Tew, R. K., N. V. DeByle, and J. D. Schultz.
1969. Intraclonal root connections among quaking aspen trees. Ecology 50:920-921.

Wall, R. E.
1971. Variation in decay in aspen stands as affected by their clonal growth pattern. Can. J. For. Res. 1:141-146.

Zahner, R., and N. A. Crawford.
1965. The clonal concept in aspen site relations, p. 229-243. **In** C. T. Youngberg (ed.) Forest-soil relationships in North America. Ore. State Univ. Press, Corvallis.

Agriculture—CSU, Ft. Collins

ebruary 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-283

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Estimating Breast Height Diameters from Stump Diameters for Black Hills Ponderosa Pine

James L. Van Deusen[1]

Presents tables and equations to estimate diameter at breast height, outside bark, from inside and outside bark diameter of stumps 6 inches and 1 foot high.

Keywords: Diameter estimation, *Pinus ponderosa.*

Ponderosa pine stumps 6 to 12 inches high are commonly left in the Black Hills after roundwood and sawtimber harvests. Breast-height diameters (d.b.h.) of these harvested pines can be estimated from their stump diameters. Four sets of tables and equations are presented to estimate d.b.h.; each set applies to a different combination of stump height and diameter measurements.

If volumes of missing trees should be needed, one can first estimate outside-bark d.b.h. from stump diameter; second, estimate heights of missing trees by determining the relationship between tree height and diameter for trees remaining in the immediate vicinity. The estimated diameters and heights then may be used with locally applicable tables or equations to estimate tree volumes.

Foresters often need to know the sizes of trees removed from cutover stands. If such measurements are lacking, key dimensions of missing trees can be estimated, using aids described in this Note.

---

[1] *Associate Silviculturist located at Station's Research Work Unit at Rapid City, South Dakota, in cooperation with South Dakota School of Mines and Technology; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

The following tables were developed from diameters and stump height measurements of ponderosa pines throughout the Black Hills and Bear Lodge Mountains. Bark thickness of standing trees was the sum of two bark gage measurements, uphill and downhill side, at each stump height.

Example:

Assume a 6-inch-high stump has a diameter of 10.6 inches **outside bark**. In table 3, read across in the 10-inch diameter class, **down** in the .6 column, to intersect at d.b.h. of 8.5 inches.

Table 1.--Tree d.b.h. (diameter at breast height), outside bark, from diameter inside bark at the top of a stump 6 inches high on the uphill side, Black Hills ponderosa pine

Diameter class (Inches)	Stump diameter (i.b.) at 6 inches above ground					Sample trees
	0.0	0.2	0.4	0.6	0.8	
	- - *d.b.h. in inches* - -					*No.*
4	4.2	4.4	4.5	4.7	4.9	2
5	5.1	5.3	5.5	5.7	5.8	20
6	6.0	6.2	6.4	6.6	6.8	12
7	6.9	7.1	7.3	7.5	7.7	22
8	7.9	8.1	8.2	8.4	8.6	15
9	8.8	9.0	9.2	9.3	9.5	13
10	9.7	9.9	10.1	10.3	10.5	14
11	10.6	10.8	11.0	11.2	11.4	25
12	11.6	11.7	11.9	12.1	12.3	23
13	12.5	12.7	12.9	13.0	13.2	14
14	13.4	13.6	13.8	14.0	14.2	22
15	14.3	14.5	14.7	14.9	15.1	14
16	15.3	15.4	15.6	15.8	16.0	4
Total trees						200

Table derived from: d.b.h. = 0.4766 + 0.9240X
Correlation coefficient: r = 0.985
Standard error of estimate: ± 0.53 inch

Table 2.--Tree d.b.h. (diameter at breast height), outside bark, from diameter inside bark at the top of a stump 1 foot high on the uphill side, Black Hills ponderosa pine

Diameter class (Inches)	Stump diameter (i.b.) at 12 inches above ground					Sample trees
	0.0	0.2	0.4	0.6	0.8	
	- - *d.b.h. in inches* - -					*No.*
4	4.5	4.7	4.9	5.1	5.2	5
5	5.4	5.6	5.8	6.0	6.2	19
6	6.4	6.5	6.7	6.9	7.1	22
7	7.3	7.5	7.7	7.8	8.0	16
8	8.2	8.4	8.6	8.8	9.0	14
9	9.1	9.3	9.5	9.7	9.9	24
10	10.1	10.3	10.4	10.6	10.8	24
11	11.0	11.2	11.4	11.6	11.7	46
12	11.9	12.1	12.3	12.5	12.7	27
13	12.8	13.0	13.2	13.4	13.6	37
14	13.8	14.0	14.1	14.3	14.5	35
15	14.7	14.9	15.1	15.3	15.4	21
16	15.6	15.8	16.0	16.2	16.4	24
17	16.6	16.7	16.9	17.1	17.3	17
18	17.5	17.7	17.9	18.0	18.2	23
19	18.4	18.6	18.8	19.0	19.2	11
20	19.3	19.5	19.7	19.9	20.1	11
21	20.3	20.4	20.6	20.8	21.0	16
22	21.2	21.4	21.6	21.7	21.9	14
23	22.1	22.3	22.5	22.7	22.9	10
24	23.0	23.2	23.4	23.6	23.8	11
25	24.0	24.2	24.3	24.5	24.7	15
26	24.9	25.1	25.3	25.5	25.6	12
27	25.8	26.0	26.2	26.4	26.6	13
28	26.7	26.9	27.1	27.3	27.5	6
29	27.7	27.9	28.0	28.2	28.4	4
30	28.6	28.8	29.0	29.2	29.3	11
31	29.5	29.7	29.9	30.1	30.3	5
32	30.5	30.6	30.8	31.0	31.2	6
33	31.4	31.6	31.8	31.9	32.1	2
34	32.3	32.5	32.7	32.9	33.1	0
35	33.2	33.4	33.6	33.8	34.0	1
36	34.2	34.3	34.5	34.7	34.9	1
Total trees						503

Table derived from: d.b.h. = 0.8018 + 0.9267X
Correlation coefficient: r = 0.992
Standard error of estimate: ± 0.85 inch

Table 3.--Tree d.b.h. (diameter at breast height), outside bark, from diameter outside bark at the top of a stump 6 inches high on the uphill side, Black Hills ponderosa pine

Diameter class (Inches)	Stump diameter (o.b.) at 6 inches above ground					Sample trees
	0.0	0.2	0.4	0.6	0.8	
	- - *d.b.h. in inches* - -					*No.*
6	4.6	4.8	5.0	5.1	5.3	9
7	5.5	5.6	5.8	6.0	6.1	5
8	6.3	6.5	6.6	6.8	7.0	14
9	7.1	7.3	7.5	7.6	7.8	8
10	8.0	8.1	8.3	8.5	8.6	5
11	8.8	9.0	9.1	9.3	9.5	13
12	9.6	9.8	10.0	10.1	10.3	9
13	10.5	10.6	10.8	11.0	11.1	7
14	11.3	11.5	11.6	11.8	12.0	15
15	12.1	12.3	12.5	12.6	12.8	9
16	13.0	13.1	13.3	13.5	13.6	5
17	13.8	14.0	14.2	14.3	14.5	8
18	14.7	14.8	15.0	15.2	15.3	6
19	15.5	15.7	15.8	16.0	16.2	0
Total trees						113

Table derived from: d.b.h. = 0.8353X - 0.3838
Correlation coefficient: r = 0.988
Standard error of estimate: ± 0.47 inch

Table 4.--Tree d.b.h. (diameter at breast height), outside bark, from diameter outside bark at the top of a stump 1 foot high on the uphill side, Black Hills ponderosa pine

Diameter class (Inches)	Stump diameter (o.b.) at 12 inches above ground					Sample trees
	0.0	0.2	0.4	0.6	0.8	
	- - *d.b.h. in inches* - -					*No.*
5	4.0	4.2	4.3	4.5	4.7	21
6	4.9	5.1	5.2	5.4	5.6	17
7	5.8	5.9	6.1	6.3	6.5	21
8	6.7	6.8	7.0	7.2	7.4	12
9	7.5	7.7	7.9	8.1	8.3	22
10	8.4	8.6	8.8	9.0	9.1	30
11	9.3	9.5	9.7	9.9	10.0	44
12	10.2	10.4	10.6	10.7	10.9	38
13	11.1	11.3	11.5	11.6	11.8	40
14	12.0	12.2	12.4	12.5	12.7	31
15	12.9	13.1	13.2	13.4	13.6	33
16	13.8	14.0	14.1	14.3	14.5	10
17	14.7	14.8	15.0	15.2	15.4	24
18	15.6	15.7	15.9	16.1	16.3	16
19	16.4	16.6	16.8	17.0	17.2	16
20	17.3	17.5	17.7	17.9	18.0	11
21	18.2	18.4	18.6	18.8	18.9	14
22	19.1	19.3	19.5	19.6	19.8	18
23	20.0	20.2	20.4	20.5	20.7	11
24	20.9	21.1	21.2	21.4	21.6	14
25	21.8	22.0	22.1	22.3	22.5	16
26	22.7	22.8	23.0	23.2	23.4	9
27	23.6	23.7	23.9	24.1	24.3	7
28	24.4	24.6	24.8	25.0	25.2	10
29	25.3	25.5	25.7	25.9	26.0	6
30	26.2	26.4	26.6	26.8	26.9	4
31	27.1	27.3	27.5	27.6	27.8	5
32	28.0	28.2	28.4	28.5	28.7	0
33	28.9	29.1	29.2	29.4	29.6	1
34	29.8	30.0	30.1	30.3	30.5	1
35	30.7	30.8	31.0	31.2	31.4	1
Total trees						503

Table derived from: d.b.h. = 0.8893X - 0.4556
Correlation coefficient: r = 0.994
Standard error of estimate: ± 0.72 inch

Agriculture—CSU, Ft. Collins

February 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM- **284**

REST SERVICE
S. DEPARTMENT OF AGRICULTUR

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Sex-Lure Trap for *Rhyacionia* Tip Moths

Daniel T. Jennings[1]

An inexpensive sex-lure trap is constructed from an ice-cream carton and a board supported on a stake. Caged virgin female moths lure low-flying males to the trap.

Keywords: Pheromones, insect traps, *Rhyacionia* spp.

Insect sex-lure traps are useful for survey purposes, especially in areas with low insect populations. They are also useful for determining seasonal appearance of adults, their flight periods or periods of attraction, mating behavior, and flight response distances. The effectiveness of control measures directed at the adult stage can be tested with sex-lure traps. Traps placed in treated areas following control measures should give an index of the remaining residual populations.

A variety of sex-lure traps have been designed for trapping forest insects. These include board traps, cylindrical cardboard traps, screen-grid traps, and box traps. Basic components are: (1) a trapping surface (board, cylinder, etc.); (2) a sticky substance for ensnaring insects; and (3) a bait or lure. Virgin female insects are often used as bait because they emit odors or pheromones which attract males to the trap. For some forest insects, synthetic lures have recently been developed that duplicate or exceed the attractiveness of natural pheromones. Traps baited with virgin females require an additional component—a cage. Cages should confine the insects but permit the emitted pheromone to escape and disperse. For field placement, traps are usually suspended from branches, nailed to trees, or fastened to self-supporting structures such as rods, stakes, or platforms.

Boards and cylindrical cartons are most commonly used for trapping forest Lepidoptera. Modified board traps, similar to the one described by Coppel et al. (1960), have trapped the eastern spruce budworm, *Choristoneura fumiferana* (Clem.) (Greenbank 1963, Miller and McDougall 1973), the western spruce budworm, *C. occidentalis* Freeman (McKnight 1971), and the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock)(Wray and Farrier 1963, Manley and Farrier 1969). These board traps were either hung from branches or nailed to infested trees.

---

[1] *Research Entomologist, located at the Station's Research Work Unit at Albuquerque, in cooperation with the University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State Universtiy.*

In plantations and natural regeneration areas where only small trees are available, additional supporting structures may be needed. Also, in windy regions, branches may be whipped against traps hung within trees or nailed to tree boles. This Note describes an inexpensive sex-lure trap, independently supported, and suitable for baiting with live virgin female moths. It has been successfully used for trapping males of the southwestern pine tip moth, *Rhyacionia neomexicana* (Dyar), in windy regions near small trees (fig. 1).

Figure 1.—Sex-lure trap baited with one virgin *Rhyacionia neomexicana* female (inside cage). Attracted males are stuck on board.

Description

The trap (fig. 2) consists of a 1 ft² piece of ⅛-inch exterior hardboard mounted on a 2- by 2-inch stake 4 ft long. For ease in recognizing trapped insects, the smooth side is painted with fast-drying white enamel. Two No. 10, 1-inch panhead tapping screws fasten the board to the stake. A small cage for holding virgin female moths is mounted in the center of the board.

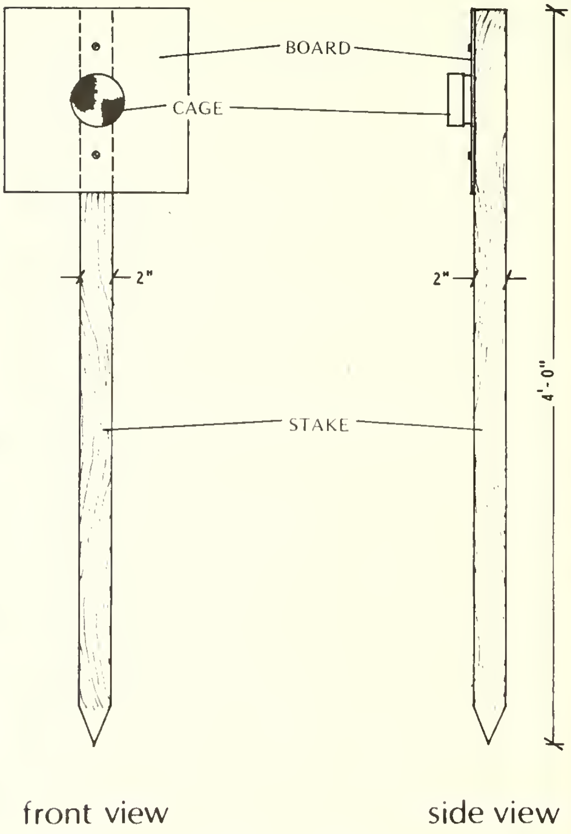


Figure 2.—Construction details for the stake.

The cages are made from cylindrical 1-pint ice-cream cartons cut down to about 1 to 1½ inches in height (fig. 3). The flat center of the carton lid is punched out and replaced with 18- by 16-mesh fiberglass screen glued into the inner rim groove of the lid. The cage base is mounted to the board and stake with one or two No. 6, ½-inch panhead tapping screws.

Some newer ice-cream cartons have a lip around the outer edge of the top. Since this lip is removed when the carton is cut down, the outside diameter of the base section will need to be increased slightly to insure that the screen lid fits snugly. We have successfully used rubber bands; other materials could no doubt also be used.

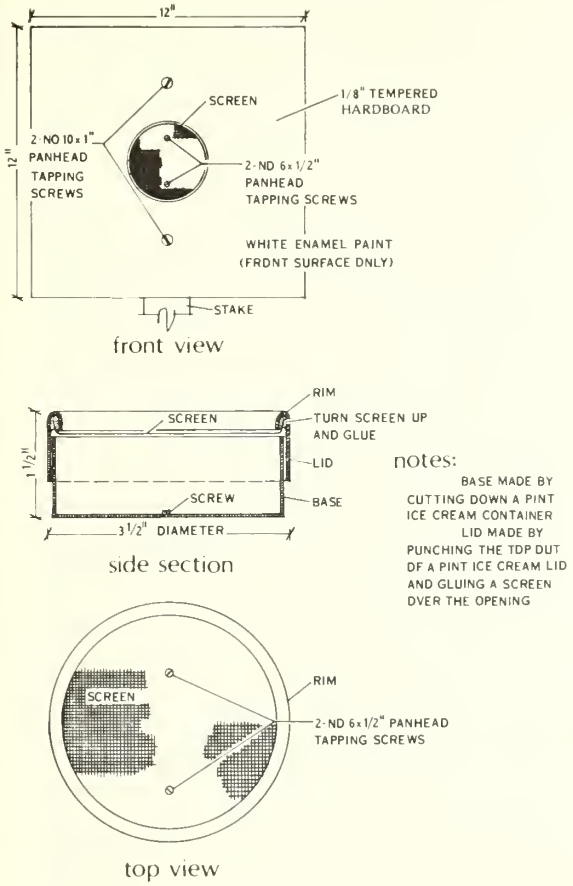


Figure 3. —Construction details for the board and cage.

Materials List

- 1 stake, 2 by 2 inches by 4 ft long, sharpened at one end
- 1 board, 1 ft^2, ⅛ inch exterior hardboard, smooth side painted white
- 1 cylindrical 1-pint ice-cream carton, base cut down to 1 to 1½ inches in height
- 1 fiberglass screen, 4 inches diameter, 18 by 16 mesh
- 2 screws, No. 6, ½-inch panhead tapping
- 2 screws, No. 10, 1-inch panhead tapping
- 1 tube glue, waterproof
- 1 can fast-drying white enamel paint
- 1 can sticky material (Tree Tanglefoot, Stickem Special, Tack Trap, or similar substance)

Materials cost about 50 to 75 cents per trap. After the cutting, painting, and gluing operations, traps can be assembled in a few minutes.

Installation and Field Use

Before installation, stakes are marked 1 ft above the sharpened end. A shovel works best for rapid installation. The trap stake can also be driven with a sledge. But if it is driven into hard, rocky ground, the cage should be removed first to prevent damage.

A thin coating of sticky material is spread on the painted side of the board around the cage. Care must be taken to keep the sticky material away from the fiberglass screen and the cage interior. Scrapers with 3-inch blades are useful for spreading sticky materials.

Cages are baited with live virgin female moths. From one to three tip moths have been placed in each cage, although the cages are large enough to accommodate many more moths without crowding. To make certain only virgin females are used, pupae are sexed by position and configuration of the genital pore (Jennings 1974), and females are reared at room temperature. Emerging females are collected in dry, 2-dram shell vials for transferring to the trap cages.

Traps should be serviced daily or at intervals of not more than 3 to 4 days during peaks in male flight activity. Males can be removed from the sticky material with laboratory teasing needles. If males are to be kept for future reference, they can be placed on strips of paper and then put into vials containing 70 to 80 percent ethanol. Moths can be temporarily stored on 3- by 5-inch cards in file boxes with corrugated cardboard partitioning strips (fig. 4).

Figure 4.—Male moths can be stored temporarily on 3- by 5-inch cards in a file box with corrugated cardboard partitioning.

When the trapping response is heavy, the sticky material becomes coated with moth scales and wing fragments from removed males, plus debris. The sticky material may need to be re-spread or a new coat of material added.

These sex-lure traps have been used in studies to determine the flight behavior and periods of attraction of the southwestern pine tip moth at Chevelon, Arizona. As many as 255 males have been trapped overnight on a single trap. Traps baited with *R. neomexicana* virgin females attract only *R. neomexicana* males. When nearby traps are baited with virgin females of a related new species of *Rhyacionia*, only males of the new species are attracted.

These traps have also been used to study flight behavior and attraction of two sod webworm species inhabiting ponderosa pine forests (Krehoff 1974). Perhaps they will be useful for studying other low-flying forest Lepidoptera.

Literature Cited

Coppel, H. C., J. E. Casida, and W. C. Dauterman.
1960. Evidence for a potent sex attractant in the introduced pine sawfly, *Diprion similis* (Hymenoptera: Diprionidae). Ann. Entomol. Soc. Amer. 53:510-512.

Greenbank, D. O.
1963. The analysis of moth survival and dispersal in the unsprayed area. p. 87-89. **In** Morris, R. F. [ed.] 1963. The dynamics of epidemic spruce budworm populations. Can. Entomol. Soc. Mem. 31, 332 p.

Jennings, Daniel T.
1974. Sexing southwestern pine tip moth pupae, *Rhyacionia neomexicana* (Lepidoptera:Olethreutidae). Ann.Entomol. Soc. Am. 67:142-143.

Krehoff, Raymond C.
1974. Mechanisms of reproductive isolation in two New Mexican sod webworms, including sex pheromone influences. Ann. Entomol. Soc. Am. 67:32-34.

Manley, Curtis, and Maurice H. Farrier.
1969. Attraction of the Nantucket pine tip moth, *Rhyacionia frustrana,* to incandescent light and blacklight, and to virgin females. Ann. Entomol. Soc. Am. 62:443.

McKnight, M. E.
1971. Natural mortality of the western spruce budworm, *Choristoneura occidentalis*, in Colorado. USDA For. Serv. Res. Pap. RM-81, 12 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Miller, C. A., and G. A. McDougall.
1973. Spruce budworm moth trapping using virgin females. Can. J. Zool. 51:853-858.

Wray, Clayton, and Maurice H. Farrier.
1963. Response of the Nantucket pine tip moth to attractants. J. Econ. Entomol. 56:714-715.

Agriculture—CSU, Ft. Collins

May 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-285

REST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Regeneration On An Aspen Clearcut in Arizona

John R. Jones[1]

Approximately 14,000 root suckers per acre sprouted on a 5-acre clearcut. After four growing seasons, about 10,700 per acre were still alive, and mil-acre stocking was 98 percent. The tallest sucker on the average mil-acre plot was 10.5 feet; the tallest on any plot was 17.4 feet. Stocking density was irregular. Thinly stocked spots seemed largely associated with slash concentrations, haul roads, and main skid trails. Browsing by elk was widespread but not generally severe. The suppressive effect of bordering timber was restricted to a trivial strip along the south border.

Keywords: *Populus tremuloides,* clearcutting, root suckers, growth, stand structure, apical dominance.

Foresters, ecologists, and wildlife managers are concerned that the acreage of aspen[2] forest in the western United States may decrease drastically over the decades to come (Beetle 1974, Hinds and Krebill 1975, Jones 1974, Krebill 1972, Patton and Jones 1975). The great preponderance of aspen stands in the West are mature or overmature. Although heavy partial cutting may maintain the type, a satisfactory new stand seems to require something approaching complete removal of the overstory (Baker 1918, 1925; Sampson 1919; Zehngraff 1949). The old source of regeneration, wildfire, seldom burns aspen stands today. In the absence of a well-stocked coniferous understory, aspen forest does not burn readily, and light fire does not kill the overstory (Horton and Hopkins 1965). The holocausts that burned large areas, including aspen stands, in the past are considered too destructive and dangerous to allow.

Clearcutting has successfully regenerated millions of acres of aspen in the Lake States. Its effectiveness has also been demonstrated on a small scale in Utah (Baker 1925, Sampson 1919, Smith et al. 1972).

Aspen clearcutting has been limited in the West, however, by poor markets, especially for small-diameter trees. Thus, even where there has been appreciable logging of aspen, most of it has been market selection, amounting roughly to a diameter-limit cutting. While considerable regeneration often results, it tends to be patchy, with much of it suppressed by the overstory. These irregular stands are then subject to damage and consequent disease as the residual overstory becomes decadent and blows down.

Improving markets are making aspen clearcutting more feasible. At the same time, however, increasing public unhappiness over the esthetic impacts of many

---

[1] *Principal Plant Ecologist, located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Common and scientific names of plants mentioned are listed on page* 8.

past clearcuttings have made managers understandably cautious about further clearcutting.

In May and June 1970, the Alpine Ranger District, Apache National Forest, cut an irregular 5-acre (2-ha) clearing in a well-stocked stand of large aspen. The purpose was to demonstrate that a small clearcutting could be made on a slope facing a highway without adverse esthetic impact. The demonstration was successful. The irregular terrain has a mosaic of naturally different stand conditions, and the trees bordering the downslope edge of the clearing screen the ground from view. The clearcut must be carefully pointed out to be seen from the road.

The area also provided an opportunity to evaluate regeneration following a clearcutting in a southwestern aspen stand.

The Area

The study area, on the headwaters of the San Francisco River, is at 8,400 feet (2,560 m) elevation on a north-facing slope. Associated coniferous stands are a mixture of ponderosa pine, Douglas-fir, white fir, southwestern white pine, and aspen. Gambel oak occurs as scattered individuals and patches.

The weather station at Alpine, Arizona is 2 miles (3.2 km) east in the same valley, and 400 feet (120 m) lower. Precipitation there averages 19.21 inches (487 mm) yearly, 6.97 inches (177 mm) falling as monsoon rains in July and August, and 6.40 inches (162 mm) as snow from November through March. Based on limited records, temperatures average about 63°F (17°C) in July and 28°F (-2°C) in January.

The soils, derived from basic volcanics, are deep and fine textured. In the healthy 70-year-old parent stand, dominants measured from 77 to 96 feet (23 to 29 m) tall at different points around the perimeter of the clearcutting, indicating an excellent aspen site by western standards.

Objectives

The study had three objectives: (1) to describe stocking and height growth four summers after logging; (2) to describe the development of structure and natural thinning in young western stands; and (3) to examine the effects of stand edge on suckering and sucker growth.

Methods

Data were collected late in May 1974. Sampling was of two kinds: (1) Live and dead suckers were counted on mil-acre (4 m^2) quadrats, and height was determined for 1970, 1971, 1972, and 1973 for tl tallest sucker on each quadrat. Bud scars were us to determine how tall the trees had been at the end each summer. These 81 plots were located uniform along systematically spaced lines, and are referred as **line plots.** (2) Tree class (free or overtopped) ar yearly height of all live suckers were recorded on s 1-mil-acre quadrats, and dead suckers were counte These six plots, referred to as **census plots,** we selectively located.

The **line plots** were established along nine tra sects. Each transect extended from within the o growth out into the clearcut. Four transects extende into the clearcut from the south, where the edge the clearcut was shaded throughout the day by tl mature stand. Five others extended from the wes northwest, where the edge of the clearcut w exposed to the sun throughout the morning ar during midday. Other orientations were not us because of scattered old aspen left in parts of tl clearing.

Plots were spaced 20 feet apart on the lines. C each line, the fourth plot was barely within tl clearcut, on a line between two edge trees. Plots 1 were at intervals back into the stand. Plots 5-9 we at increasing distances out into the clearcut.

The **census plots** were located in the clearcut aw from the edge, and avoided the small, lightly stock "gaps" scattered throughout the sucker stand. Th were intended to represent conditions of hea competition.

Results

Edge Effects

Suckers were few and small along the continual shaded south edge of the clearcut. This shaded-ed effect was conspicuous and ended rather abrupt 15-20 feet (4-6 m) into the clearcut (fig. 1). Only tv of the four shaded-edge plots were stocked. The tallest suckers averaged 4.2 feet (128 cm). Away fro the shaded edge, 98 percent were stocked, and the tallest trees average 10.5 feet (3.2 m).

Along the sunny edge of the clearcut, in contras neither restocking nor growth was depressed (fig. 2 In fact, where the sun shone into the edge of tl mature stand throughout the morning, suckers we numerous beneath the canopy, although small ar declining.

The area of affected strip along the shaded edge trivial, and by the time the new stand is mature should be canopied by adjacent trees. Because i representation in our sample is disproportionate large, data from the shaded edge will not be includ in describing the clearcut.

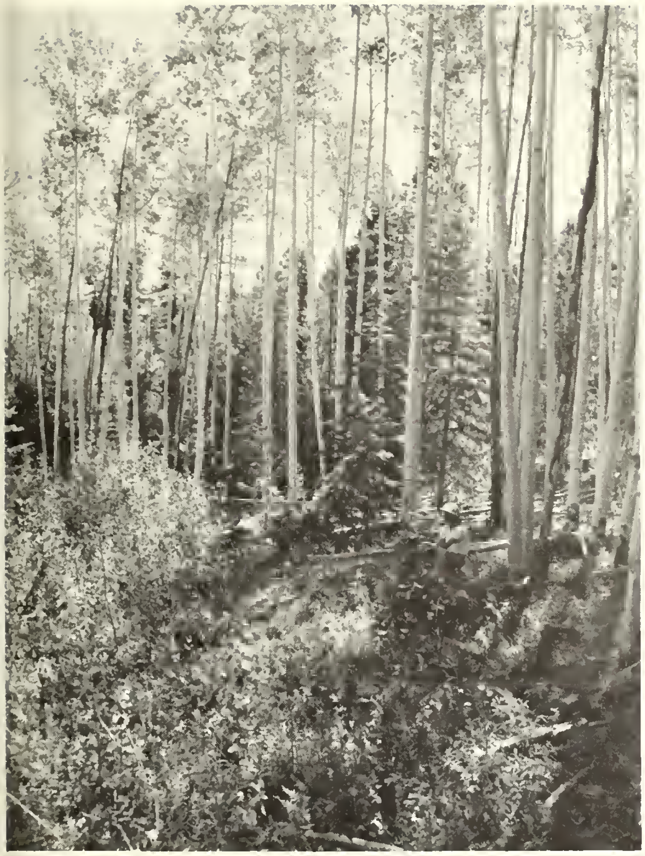


Figure 1.—
Poorly stocked strip along shaded edge, with normal regeneration on left.

Figure 2.—
Sunny edge of clearcut, with normal regeneration.

Stocking

Mil-acre stocking within the clearcut approached 100 percent. Only one of the 50 plots had no live sucker, even though some plots fell within the small "gaps" in the regeneration stand.

The number of suckers tallied, alive and dead, averaged 13,760 ± 1,305 per acre (34,000 ± 3,223 per ha), with 10,660 ± 973 per acre (26,300 ± 2,404 per ha) surviving. Some additional suckers may have sprouted, died, and disappeared. These were probably few, however, as numerous very small dead suckers were readily identified, even though some appeared to have been dead for two summers or more and lay on the ground. Therefore, total suckering since logging probably did not exceed about 14,000 per acre (34,600 per ha).

Some of the small gaps within the sucker stand were associated with slash concentrations (fig. 3), some with truck trails or main skid trails, and some with mounds of decayed wood marking old slumped coniferous windfalls. Still others had no apparent cause. Most gaps are too small to affect mature stocking.

The Dominant Stand

Many of the 10,660 live suckers per acre are overtopped, broken, or seem otherwise likely to die young. The mature canopy will be made up entirely or almost entirely of suckers now in a favorable competitive position—those that are presently tallest and most vigorous. On the average line plot, the tallest tree was 10.5 ± 0.5 feet (3.21 ± 0.14 m) at the end of 1973, with a standard deviation of 3.2 feet (98 cm).

Suckering began in 1970, but most took place later. When the tallest tree on each plot is con-

Figure 3.—Looking across lightly stocked gap where slash lay concentrated. Stocking behind the man is heavier than normal for this clearcut.

sidered, 19 originated in 1970 and 30 in 1971. Most of those starting in 1970 grew less their first season than those which started in 1971: 1.8 feet (54 cm) compared to 3.2 feet (96 cm). Those of 1970 origin average taller, however, because of their earlier start.

The greatest first-year height for any measured sucker was 4.9 feet (149 cm). At the end of 1973 the tallest line-plot tree, four summers old, stood 17.4 feet (5.3 m).

Stand Structure

The six census plots provided a limited picture of developing stand structure where competition is severe. They were located to avoid the lightly stocked gaps, and three were located to sample exceptionally heavy stocking. Stocking with live suckers in May 1974 ranged from 9,000 to 24,000 per acre (22,200 - 59,300 per ha). Most (96 percent) of the live trees had sprouted in 1970 or 1971. One percent pre-dated logging. Three percent did not sprout until 1972, when competition was already severe; they were overtopped when examined.

Growth and structural differentiation is indicated by the numbers of live suckers in different height classes on each census plot (table 1). The large range in heights, combined with the density of stocking, reflects differentiation into crown classes. By May of 1974, 38 percent of all suckers on the census plots had died. In addition, nearly half the live aspen, 42 percent, were overtopped by branches of larger aspen. They can be expected to decline and die during the next decade or so. The mortality and structural differentiation in this stand is consistent with that described by Pollard (1971) for young aspen in eastern Ontario, Canada.

Table 1.--Size class distribution of live suckers on census plots at the end of 1973

English System			Metric System		
Height class	Average per acre ± standard error	Percent	Height class	Average per hectare ± standard error	Percent
ft	*no.*		*m*	*no.*	
0 - 2.0	500 ± 57	3	0 -0.61	1,235 ± 141	3
2.1- 4.0	667 ± 45	4	0.62-1.22	1,648 ± 111	4
4.1- 6.0	2,167 ± 208	14	1.23-1.83	5,355 ± 514	14
6.1- 8.0	3,500 ± 112	22	1.84-2.44	8,649 ± 277	22
8.1-10.0	3,000 ± 105	19	2.45-3.05	7,413 ± 259	19
10.1-12.0	1,667 ± 93	11	3.06-3.66	4,119 ± 230	11
12.1-14.0	2,833 ± 194	18	3.67-4.27	7,000 ± 479	18
14.1 +	1,333 ± 111	9	4.28 +	3,294 ± 274	9
Total	15,667 ± 398	100		38,713 ± 983	100

Damage and Mortality

No effort was made to account for causes of all mortality or severe damage, but many observations were recorded. Numerous dead trees had been girdled by rodents. Many live trees had been partly girdled; many of these had partly callused over and seemed in good health.

Browsing had been widespread and was often associated with breakage. Fairly large shoots had been broken and browsed. Many of these were alive but deformed and overtopped. Elk are known to pull or ride down aspen saplings to browse upon (Beetle 1974). Judging from droppings and the height of some of the browsing, elk, rather than deer or cattle, were largely responsible. Within the uncut stand, most suckers had been browsed. On a well-defined area of about ¼ acre in a corner of the clearcut, mortality from browsing had been substantial and almost all survivors were severely browsed (fig. 4). Other than in this small area, browsing within the clearcut, though appreciable, has not harmed the new stand importantly.

The heavily browsed corner was not sampled.

Discussion

Spring clearcutting in this healthy 70-year-old aspen stand resulted in quick, abundant regeneration by suckering. The resultant large number o suckers per acre, about 13,760 (34,000 per ha), wer nonetheless far fewer than on some exceptional Uta clearcuts tabulated below:

Source	No. of Suckers	
	Per acre	*Per ha*
Baker (1925, p. 22)	110,000	271,800
Sampson (1919)	85,500	211,300
Smith et al. (1972)	59,000	145,800

Barnes (1969) and Tew (1970) found marke differences in sucker production of different quakin aspen clones. This difference seems related, at leas in part, to clonal differences in levels of carbohydrat reserves (Tew 1970, Schier and Johnston 1971). I the West, where single clones frequently cover severa acres, such clonal differences may account for sizabl differences in the density of suckering. However environmental differences probably also can b major factors.

Figure 4.—Severely browsed regeneration, with normal regeneration behind it.

Baker (1925) also found that few additional suckers sprout on aspen clearcuts after the second year. Certainly, in the present study, suckering during the first two growing seasons after cutting seems more than adequate. Furthermore, suckers present by the end of the second summer will apparently constitute the entire mature canopy.

Most published data on sucker growth rates in the West are from Utah, and are averages of all size classes. Sampson (1919) reported that, four growing seasons after spring clearcutting, the average sucker was 3.41 feet (1.04 m) tall. Baker (1925) gave an average height of 4.23 feet (1.29 m) after four growing seasons. Smith et al. (1972) reported 3,529 suckers per acre (8,720 per ha) taller than 5 feet (1.52 m) at the end of four growing seasons, 13 percent of the total stocking on that area. In a northern Arizona study,[3] average heights on a clearcut were 4.9 feet (1.51 m) after four growing seasons, increasing to 10.1 feet (3.08 m) by the end of the seventh. Clearly, early growth on the clearcut in the present study has been better than that reported elsewhere for the West. Stem analyses of much older aspen stands on the Apache National Forest suggest that it is also better than usual for this area. Therefore the growth found here indicates what will sometimes be attained, not what can be expected.

An edge effect had been anticipated. Shade inhibits both suckering and growth, (1) since the ground heating that results when the shading canopy is removed stimulates suckering (Sandberg and Schneider 1953, Maini and Horton 1966) and (2) because aspen is very intolerant of shade. In addition, physiological research has shown that established aspens can impede suckering on connected roots and reduce the growth of new suckers. Two factors seem to contribute to this "apical dominance" effect: a growth regulator produced in the shoot apex and translocated to the roots, and the tendency of stored energy reserves to move toward established energy sinks (Farmer 1962, Maini 1966, Schier 1972).

In a Manitoba sapling stand, Steneker (1974) found that exposure of the ground to full sunlight without breaking apical dominance produced very few suckers, although the ground surface was warmed to temperatures found in clearcuttings. In contrast, breaking apical dominance while leaving the ground shaded produced many suckers. Steneker's work suggests that suckering after logging or fire may be due largely to removal of the apical dominance mechanism rather than to soil warming.

In this study, if roots of uncut border trees had not suckered, or had produced weak suckers, regeneration along the sunlit edge would have been strongly reduced in numbers or vigor; however, neither was reduced. Furthermore, 3-year-old suckers were rather numerous, though weak and declining, within the uncut stand where the adjacent cutting provided increased sunlight. In contrast, suckering and sucker growth were markedly less where the bordering stand continually shaded the clearcut.

Aspen regeneration and sheep are not compatible until the aspen are about 4 feet (1.2 m) tall (Baker 1925, Sampson 1919, Smith et al. 1972). Browsing by deer and elk has also been considered a threat to successful aspen regeneration on burns and clearcuts, especially where the disturbed acreage is small. Jones (1967) reported the elimination of initially numerous aspen suckers by big-game on 98 acres (40 ha) of mixed conifer clearcuts on the Apache National Forest between 1960 and 1964. Smith et al. (1972) indicate that this happens only with exceptional browsing pressures, and populations of both elk and mule deer were very high on the Apache in the early 1960's. Because of its small size, the clearcut in this study had the potential to concentrate browsing quite strongly. Browsing did not seriously affect regeneration, however. The present big-game population in the general area is believed to be moderately below carrying capacity.[4] Also, damage might have been more significant were it not for the speed with which the tops of this particular sucker stand grew out of convenient reach.

Conclusions

Considered in conjunction with findings in other regions, and the known ecology of aspen, this study suggests that clearcutting in southwestern aspen stands is very likely to result in quick and complete regeneration by aspen suckers. On favorable sites, early growth can be very rapid. Inhibition of suckering and sucker growth by the adjacent uncut stand seems likely to be trivial.

Deer and elk are attracted to clearcuts. Where numbers of big-game and cattle are moderate and early growth is exceptional, clearcuts as small as 5 acres (2 ha) may not be seriously damaged. Generally, however, aspen clearcuts should be somewhat larger than 5 acres, or, if small, there should be enough of them in the general area to spread browsing use by big-game.

---

[3] *M. M. Larson. 1958. Aspen regeneration methods in the Southwest. (Office report in the files of the Rocky Mt. For. and Range Exp. Stn., Flagstaff, Ariz.)*

[4] *Personal communication from John K. Adams, Wildlife Biologist, Apache National Forest.*

Literature Cited

Baker, F. S.
1918. Aspen reproduction in relation to management. J. For. 16:389-398.

Baker, F. S.
1925. Aspen in the central Rocky Mountain region. U.S. Dep. Agric. Bull. 1291, 46 p.

Barnes, B. V.
1969. Natural variation and delineation of clones of *Populus tremuloides* and *P. grandidentata* in northern lower Michigan. Silvae Genet. 18:130-142.

Beetle, A. A.
1974. Range Survey in Teton County, Wyoming. Part IV—quaking aspen. 28 p. Univ. Wyo. Agric. Exp. Stn., Laramie.

Farmer, R. E., Jr.
1962. Aspen root sucker formation and apical dominance. For. Sci. 8:403-410.

Hinds, T. E., and R. G. Krebill.
1975. Wounds and canker diseases on western aspen. U.S. Dep. Agric. For. Pest Leafl. 152, [In press.]

Horton, K. W., and E. J. Hopkins.
1965. Influence of fire on aspen suckering. Can. Dep. For. Publ. 1095, 19 p.

Jones, J. R.
1967. Regeneration of mixed conifer clearcuttings on the Apache National Forest, Arizona. U.S. For. Serv. Res. Note RM-79, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Jones, J. R.
1974. Silviculture of southwestern mixed conifers and aspen: the status of our knowledge. USDA For. Serv. Res. Pap. RM-122, 44 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Krebill, R. G.
1972. Mortality of aspen on the Gros Ventre elk winter range. USDA For. Serv. Res. Pap. INT-129, 16 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Maini, J. S.
1966. Apical growth of *Populus* spp. II. Relativ growth potential of apical and lateral buds Can. J. Bot. 44:1581-1590.

Maini, J. S., and K. W. Horton.
1966. Vegetative propagation of *Populus* spp. I Influence of temperature on formation an initial growth of aspen suckers. Can. J. Bot 44:1183-1189.

Patton, D. R., and J. R. Jones.
1975. Management of aspen for big game in th Southwest. Chapter 15, *in* S. Lamb (ed.), Gam range management in the Southwest. [In press.

Pollard, D. F. W.
1971. Mortality and annual changes in distributio of above-ground biomass in an aspen sucke stand. Can. J. For. Res. 1:262-266.

Sampson, A. W.
1919. Effect of grazing upon aspen reproduction U.S. Dep. Agric. Bull. 741, 29 p.

Sandberg, D., and A. E. Schneider.
1953. The regeneration of aspen by suckering Univ. Minn. For. Note 24, 2 p. St. Paul.

Schier, G. A.
1972. Apical dominance in multishoot culture from aspen roots. For. Sci. 18:147-149.

Schier, G. A., and R. S. Johnston.
1971. Clonal variation in total nonstructural car bohydrates of trembling aspen roots in thre Utah areas. Can. J. For. Res. 1:252-255.

Smith, A. D., P. A. Lucas, C. O. Baker, and G. W Scotter.
1972. The effects of deer and domestic livestock o aspen regeneration in Utah. Utah Div. Wildl Resour., Publ. 72-1, 32 p.

Steneker, G. A.
1974. Factors affecting the suckering of tremblin aspen. For. Chron. 50:32-34.

Tew, R. K.
1970. Root carbohydrate reserves in vegetativ reproduction of aspen. For. Sci. 16:318-320.

Zehngraff, P. J.
1949. Aspen as a forest crop in the Lake States J. For. 47:555-565.

Common and Scientific Names of Plants Mentioned

Aspen (quaking)	*Populus tremuloides* Michx.
Douglas-fir (Rocky Mountain)	*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco
Gambel oak	*Quercus gambelii* Nutt.
Ponderosa pine	*Pinus ponderosa* Laws.
Southwestern white pine	*Pinus strobiformis* Engelm.
White fir	*Abies concolor* (Gord. & Glend.) Lindl.

May 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-286

REST SERVICE
. DEPARTMENT OF AGRICULTURE

Y MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Analog Temperature Records from a Linearized Thermistor Network

R. A. Schmidt[1]

To overcome the inherent disadvantage of nonlinear output, a system was developed consisting of a thermistor network and operational amplifiers to produce a linear analog temperature record, either on strip charts or magnetic tape.

Keywords: Temperature measurements, temperature sensors.

Thermistors are used extensively for temperature measurements, primarily because they are highly sensitive and recording equipment is quite inexpensive for routine applications. One feature that offsets these advantages is their inherent nonlinear output. This characteristic is a more noticeable disadvantage when analog records are desired over a temperature range of several tens of degrees (such as meteorological records of air temperature). The system described here uses a thermistor network and operational amplifiers to produce a linear analog record of emperature, either on strip charts or magnetic tape.

A network containing two thermistors and two precision resistors closely approximates the ideal inear sensor. Harruff (1967) predicts a deviation rom linearity of less than ±0.2 percent of the sensor range for the circuit of figure 1. Such networks are commercially available. The one used in this system is manufactured by Yellow Springs Instrument Company.[2] This sensor has a range of -30° to +50°C, with a specified linearity deviation of +0.16°C when input voltage is 3.0 volts or less.

For the circuit in figure 1, the transfer function provided by the manufacturer for this particular sensor is

$$E_{out} = (+0.0067966\ E_i)T + 0.34893\ E_i$$

where T is temperature in degrees C. This relation holds for load resistances greater than 1 megohm at E_o.

Figure 2 shows the circuit designed as an interface between this sensor and an analog tape or strip chart

---

[1] *Hydrologist, Rocky Mountain Forest and Range Experiment Station, with central headquarters maintained t Fort Collins in cooperation with Colorado State Univerity.*

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

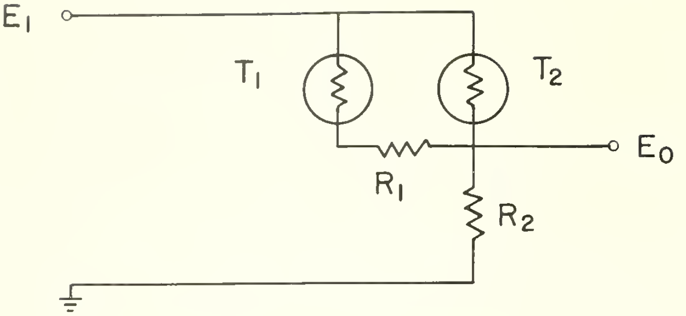


Figure 1.—Dual thermistor network.

recorder. Primary design considerations were: (high input impedance to the sensor, and (convenient outputs for both tape and strip cha recorders. Zener diode D1 and amplifier A1 provi a reference voltage across divider R5 through R The wiper voltage at R6 is buffered by A2, to provi the sensor excitation voltage, E_i. Amplifier A3 fo lows the voltage of the wiper on R6, to yield a ze offset, E_z. Sensor output, E_o, is buffered by A with an input impedance of 10 megohms. Differe tial amplifier A5 subtracts the zero offset volta from the sensor output. This signal is amplified 10 at A6 to provide a signal for magnetic ta recording. The voltage to current converter, A drives a strip chart galvanometer. This design w obtained by applying operational amplifier tec niques described in Tobey et al. (1971).

The probe in figure 3 was designed to protect t dual-thermistor bead and house the sensor comp nents with a minimum increase in response tim Figure 4 presents response curves for two laborato

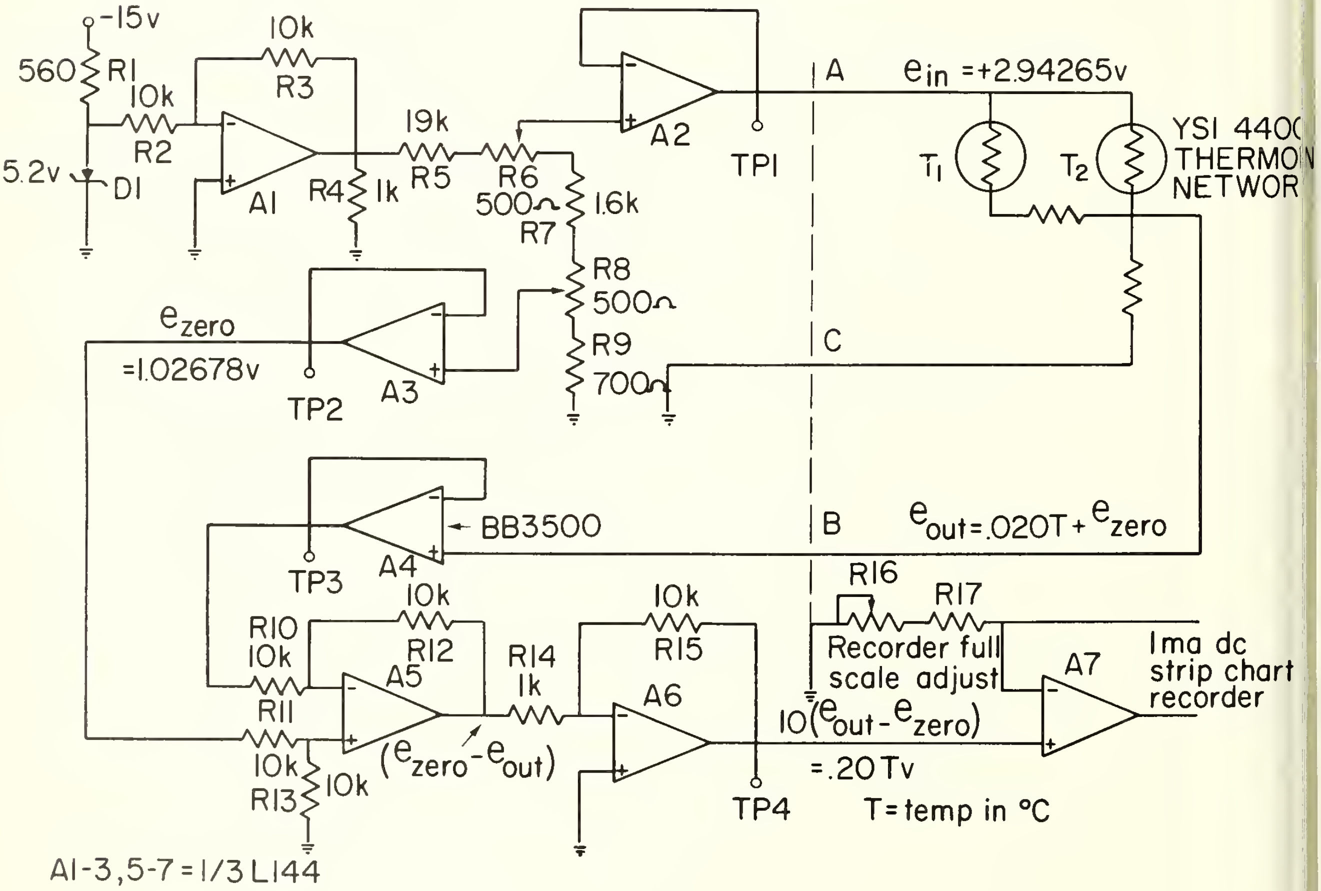
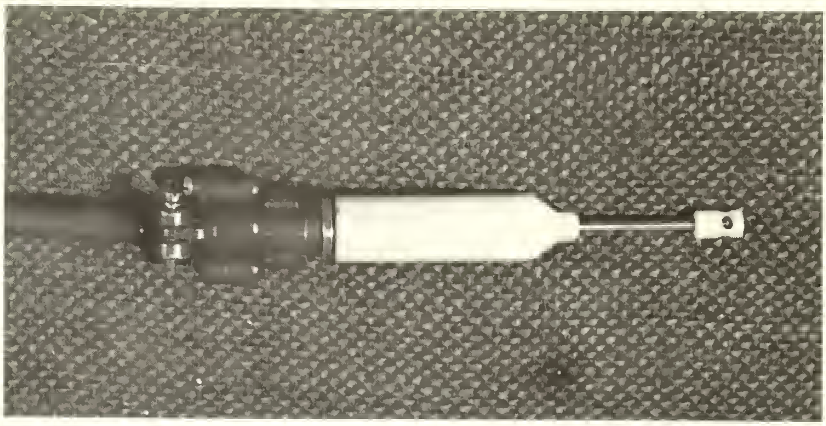


Figure 2.—Interface circuit for the linear temperature recorder.

Figure 3.—

The sensor probe protects the dual-thermistor bead.



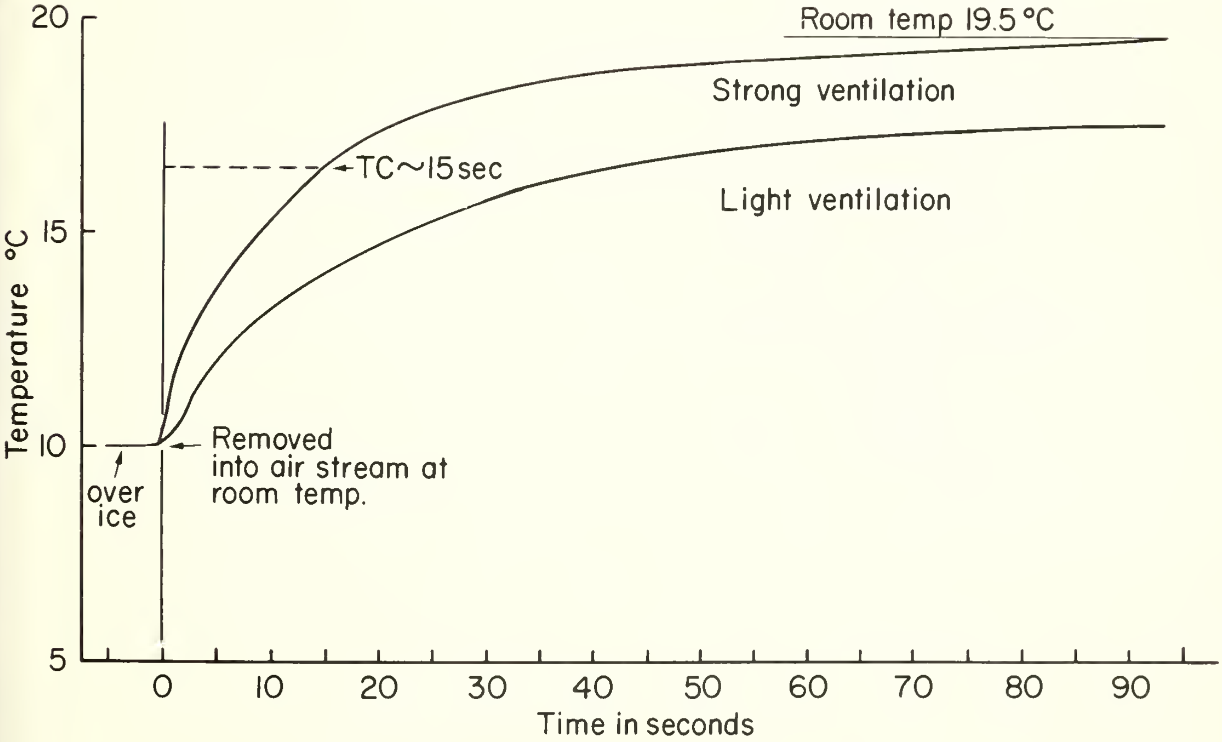


Figure 4.—Response time of the sensor.

situations. Figure 5 shows the printed circuit boar that implements figure 2. This board and on containing a modular ±15-volt power supply ar installed in a case attached to the back of the stri chart recorder.

The strip chart recorder output is adjusted by firs setting the recorder's mechanical adjustment t indicate 0°C when the probe is at thermal equilibrium in an ice bath. The probe is then placed in a environment of known temperature near the value o the extreme to be recorded, and R16 adjusted t obtain the proper indication.

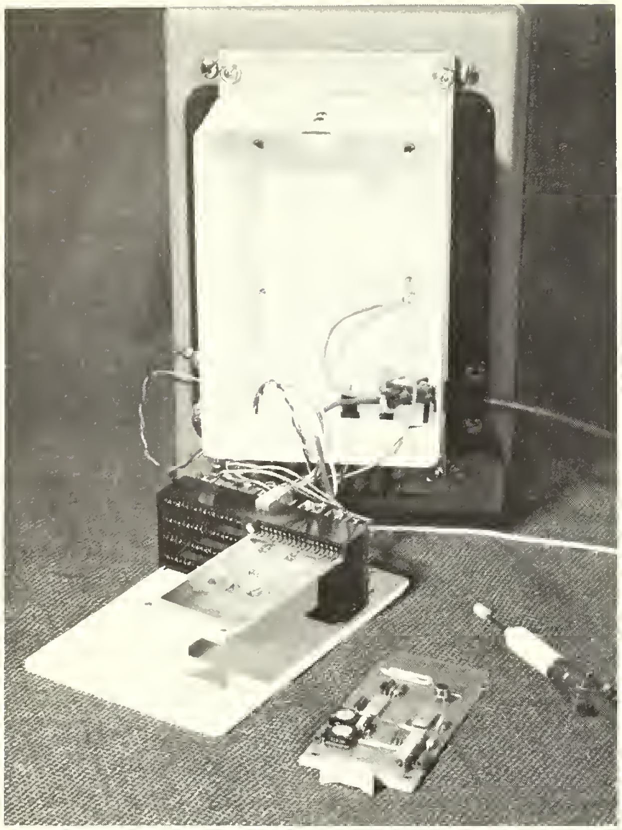


Figure 5.—Printed circuit and housing mounted on a strip chart recorder.

Literature Cited

Harruff, R. W.
1967. Linear temperature scales from thermisto sensors. Instrum. Technol. 14(6):59-61.

Tobery, G. E., J. G. Graizme, and L. P. Huelsman Eds.
1971. Operational amplifiers design and applications. 473 p. McGraw-Hill Book Co., New York

Agriculture—CSU, Ft. Collins

May 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-287

REST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Seasonal Food Habits of Mule Deer in Southeastern Wyoming[1]

Gregory A. Goodwin[2]

Mule deer diets (as determined by fecal analyses) consisted of 87.6 percent browse, 5.6 percent graminoids, and 6.6 percent forbs. Ground cover analysis revealed 16.2 percent browse, 6.5 percent graminoids, 3.2 percent forbs, and 74.1 percent bare ground. The diet varied with seasons. Deer ate as much as 19 percent graminoids in May, 36 percent forbs in June, and 96 percent browse in winter. The most important diet species were big sagebrush, antelope bitterbrush, and true mountainmahogany.

Keywords: *Odocoileus hemionus, Artemisia tridentata, Purshia tridentata, Cercocarpus montanus,* wildlife food habits.

The mule deer (*Odocoileus hemionus*) is an important game species in Wyoming. To plan proper management of any mule deer population, information is needed on food habits as well as food availability under constantly changing conditions.

A particular species may be a preferred food on one range, while a different species may be preferred on another. There are also wide variances in food preferences from one geographical area to another (Kufeld et al. 1973). This study was conducted to determine seasonal food habits of mule deer and vegetation available for food in southeastern Wyoming.

The study area consisted of the entire Pole Mountain District of the Medicine Bow National Forest, located 10 miles east of Laramie, Wyoming. It contains approximately 88 square miles between the elevations of 7,500 and 9,055 feet. The vegetation of the area can be divided into four broad categories: coniferous forest, mixed shrub, grassland, and meadow bottoms. Mule deer feeding sites are located generally in the mixed shrub type dominated by big sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), and true mountainmahogany (*Cercocarpus montanus*).

Methods

Food habits data were obtained using a microtechnique method on fresh fecal material. Samples were collected at 2-week intervals from December 1971 through May 1973.

A total of 328 fecal samples (20 pellets per fecal group) were collected from 21 feeding sites (areas where mule deer were observed feeding more than once). Vegetation analyses, to determine availability, were made on 18 of the feeding sites from June 1972 through May 1973, using a canopy coverage method (Daubenmire 1959). Vegetation was classified as browse, forb, or graminoid. Plant specimens were taken during field measurements to form a reference collection for identifying plant species in the fecal material.

In the laboratory, the fecal samples for each 2-week sample period were placed in a blender and pooled. Subsamples were then drawn and mounted on two microscope slides. Preparation of reference slides and fecal slides is described by Hansen and

---

[1] *Data reported here were used in a thesis presented to the Department of Zoology and Physiology, University of Wyoming, in partial fulfillment of requirements for the degree of Master of Science.*

[2] *Biological Technician, located at Laramie, in cooperation with the University of Wyoming; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Flinders (1969) and Ward (1970). Identification of plant species was based on cell shape and epidermal characteristics following the procedures of Davies (1959), Brusven and Mulkern (1960), and Storr (1961). Only plant fragments that consisted of epidermal tissue were recorded as indicating the presence of a species. Frequency percentages for each species in the diet were determined by examining 50 microscope points at 100X on each of the two slides prepared for each sample period.

Results

Although mule deer consume a variety of vegetation annually, the major part of the diet is composed of only a few browse species (table 1). Deer diets vary considerably from one season to another.

Winter Food Habits

During winter, mule deer fed on dry, rocky, south-facing slopes which support a minimum of vegetation. Feeding sites were generally dominated by either big sagebrush or by true mountainmahogany. During the winter of 1971-72, fecal samples were collected from areas dominated by big sagebrush and antelope bitterbrush. No vegetation analyses were made. The following winter was relatively severe, and as a result fecal samples were collected only from areas dominated by true mountainmahogany. Vegetation analyses for ground-cover estimates on this type of feeding site showed 8 percent browse, 5 percent graminoids, 0.8 percent forbs, and 86.2 percent bare ground (fig. 1).

A total of 154 fecal samples was collected during December, January, and February for 2 consecutive years. Samples collected the winter of 1971-72 from areas dominated by big sagebrush and antelope bitterbrush showed the diet to be made up largely of browse species (fig. 2), with big sagebrush, antelope bitterbrush, and common juniper (*Juniperus communis*) the most important. Creeping barberry (*Berberis repens*) was frequently taken, but only in small amounts. Use of other browse was minor and occasional.

The following winter, samples collected from areas that consisted largely of true mountainmahogany showed true mountainmahogany to account for as much as 60 percent of the diet in January. Big sagebrush made up a large part of the diet, even though it was not readily available.

Forb use during winter was small. Two species, western yarrow (*Achillea lanulosa*) and fringed sagewort (*Artemisia frigida*) were found consistently in the diet. Use of graminoids was also small, amounting to less than 3 percent of the overall diet.

Spring Food Habits

Spring feeding sites were found in a variety of vegetation types. During the second spring, however, winter conditions persisted until May. Deer remained in wintering areas until late spring, resulting in a high-browse low-graminoid utilization for this period. Ground cover of feeding sites was measured in the spring of 1973 only. These sites, of the true mountainmahogany type, consisted of 6.6 percent browse, 3.6 percent graminoids, 0.2 percent forbs, and 89.6 percent bare ground.

Analyses of 61 fecal samples collected during March, April, and May for 2 consecutive years showed an average of 84.5 percent browse in the diet.

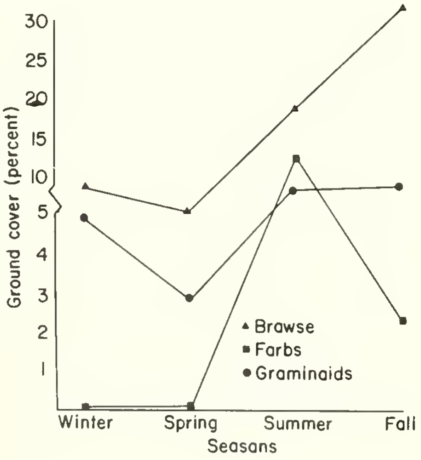


Figure 1.—Seasonal availability (percent ground cover) on mule deer feeding sites in southeastern Wyoming from June 1972 through May 1973.

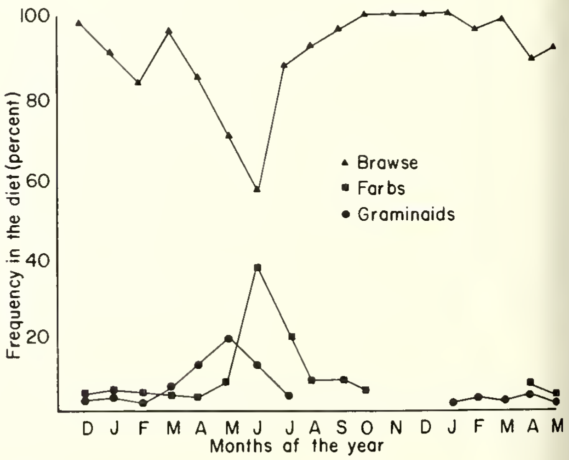


Figure 2.—Total monthly average of forage classes utilized by mule deer in southeastern Wyoming from December 1971 through May 1973, as determined by fecal analyses.

Table 1.—Mule deer food habits, as determined by fecal analyses of 328 samples collected from December 1971 through May 1973 (expressed as percent frequency of occurrence)

Plant species	**Winter**[1]	**Spring**	**Summer**	**Fall**	**Winter**[2]	**Spring**[2]
BROWSE						
Acer glabrum			1.0	1.0		
Amelanchier alnifolia			2.0	1.0	1.0	1.0
Arctostaphylos uva-ursi	3.0	1.0	1.0		1.0	2.0
Artemisia tridentata	33.0	28.0	23.0	28.0	20.0	18.0
Berberis repens	14.0	5.0	2.0		3.0	2.0
Cercocarpus montanus		15.0	13.0	8.0	50.0	46.0
Chrysothamnus sp.	5.0	1.0	1.0	10.0	5.0	4.0
Juniperus communis	7.0	10.0	5.0	8.0	10.0	9.0
Pinus sp.		1.0	1.0		1.0	
Populus tremuloides	1.0	1.0	2.0	1.0		
Purshia tridentata	20.0	10.0	5.0	25.0		2.0
Ribes sp.	2.0	1.0		3.0		
Rosa sp.		1.0	2.0			
Salix sp.	1.0	1.0		3.0		
Shepherdia canadensis		1.0	14.0		1.0	
Symphoricarpos sp.	2.0	1.0				
Vaccinium scoparium			1.0			
Unidentified	5.0	4.0	3.0	4.0	4.0	5.0
Totals	93.0	81.0	76.0	92.0	96.0	89.0
FORBS						
Achillea lanulosa	2.0	1.0	3.0	1.0	2.0	2.0
Antennaria sp.		1.0				
Artemisia frigida	1.0	1.0	2.0	6.0	1.0	2.0
Astragalus sp.			1.0			
Cerastium arvense			1.0			
Descurainia richardsoni			1.0			
Erigeron sp.			2.0			
Lesquerella sp.			2.0			
Melilotus officinalis			2.0			1.0
Mertensia lanceolata		1.0	1.0			
Sedum stenopetalum			1.0			
Senecio sp.				1.0		
Taraxacum officinale			1.0			
Thlaspi alpestre		1.0				
Unidentified			1.0			
Totals	3.0	5.0	18.0	8.0	3.0	5.0
GRAMINOID TOTALS	4.0	15.0	7.0		2.0	6.0

---

[1] Samples collected from areas of predominantly *Artemisia tridentata.*

[2] Samples collected from areas of predominantly *Cercocarpus montanus.*

Big sagebrush, true mountainmahogany, and common juniper made up over half of the total browse consumed.

Forb use remained low. The important species were lanceleaf bluebells (*Mertensia lanceolata*), groundsel (*Senecio* sp.), and field cerastium (*Cerastium arvense*).

Graminoids received their most intensive use during spring. Use amounted to 19 percent in May of 1972, even though this is a period of low availability. This reflects the "green-up" period, and marks the first seasonal change in diet.

Summer Food Habits

Analyses of ground cover on summer feeding sites showed 18 percent browse, 8.3 percent graminoids, 10.6 percent forbs, and 63.1 percent bare ground. These analyses showed that use is concentrated in areas of high browse composition. Forb availability reached its highest level during early summer. Graminoid availability was high, but many plants were mature and usually with seed heads.

Fifty-four fecal samples were collected during June, July, and August. Browse ranked as the most important vegetation group, with big sagebrush contributing the most. Antelope bitterbrush, common juniper, and russet buffaloberry (*Shepherdia canadensis*) were of lesser importance.

Forb utilization was greatest during the summer; forbs represented 36 percent of overall use in June, but dropped significantly in July and August. Fringed sagewort, western yarrow, bladder pod (*Lesquerella* sp.) and yellow sweetclover (*Melilotus officinalis*) made up the largest percentage of summer use. This summer increase was in response to the "greening-up" of forbs in early summer.

Graminoid utilization was still high during early summer, representing 11.5 percent of the diet in June. Use decreased through July, and in August few graminoids were utilized.

Fall Food Habits

Ground-cover analyses of fall mule deer feeding sites showed a return to areas of highest browse availability: 32.5 percent browse, 8.7 percent graminoids, 2.2 percent forbs, and 56.6 percent bare ground. Snow cover in the late fall contributed to low forb availability and relatively high browse availability.

During September, October, and November, 59 fecal samples were collected. Browse use had increased to a level comparable to that of winter. Big sagebrush and antelope bitterbrush were the most important species, representing over half of the total browse use. Antelope bitterbrush was consumed in larger amounts than big sagebrush during early fall while it was still green, but by late fall its use had declined considerably. Common juniper and rabbitbrush (*Chrysothamnus* sp.) were also consumed, but in smaller amounts.

Forb use decreased from that during summer. The major forbs taken during the fall were western yarrow and fringed sagewort. Utilization of graminoids amounted to an average of less than 1 percent.

Conclusions

Food habits data collected over a 17-month period indicates that areas of sagebrush and true mountain-mahogany are essential to mule deer populations. Graminoids and forbs are valuable during certai times of the year; however, shrub species are highl valuable throughout the year, especially during the critical winter period. This study would indicate tha if mule deer populations are to be maintained managers need to practice intensive management o these important areas as competition for land us increases.

Literature Cited

Brusven, M. A., and G. B. Mulkern.
1960. The use of epidermal characteristics for th identification of plants recovered in fragmentar condition from the crops of grasshoppers. No Dak. Agr. Exp. Stn. Res. Rep. 3, 11 p.

Daubenmire, R.
1959. A canopy-coverage method of vegetationa analysis. Northwest Sci. 33:43-64.

Davies, I.
1959. The use of epidermal characteristics for th identification of grasses in the leafy stage. J Brit. Grassl. Soc. 14:7-16.

Hansen, R. M., and J. T. Flinders.
1969. Food habits of North American hares. Sci Ser. No. 1, 18 p. Range Sci. Dep., Colo. Stat Univ., Fort Collins, Colo.

Kufeld, R. C., O. C. Wallmo, and C. Feddema.
1973. Foods of the Rocky Mountain mule dee USDA For. Serv. Res. Pap. RM-111, 31 p Rocky Mt. For. and Range Exp. Stn., Fo Collins, Colo.

Storr, G. M.
1961. Microscopic analysis of faeces, a techniqu for ascertaining the diet of herbivorous mam mals. Aust. J. Biol. Sci. 14(1):157-164.

Ward, A. L.
1970. Stomach content and fecal analysis: Meth ods of forage identification. p. 146-158. I Range and wildlife habitat evaluation — research symposium. U.S. Dep. Agric. Mis Publ. 1147, 220 p.

Agriculture—CSU, Ft. Colli

May 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-288

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Inexpensive Truck-Mounted Ladder for Inspecting Conelet Development and Collecting Cones

W. J. Rietveld[1]

The versatile rig is stable, durable, quickly moved from tree to tree, and easily removed from the truck. Four camper jacks eliminate sway due to the vehicle's suspension. Although designed specifically for making nondestructive inspections of flower and conelet development and cone collection, the platform without ladder is also useful.

Keywords: Truck-mounted ladder, cone collection equipment.

Many devices have been adapted or designed to facilitate various aspects of cone production and collection (Stein et al. 1974). They range from picking platforms or scaffolds mounted on trucks or trailers to tree shakers for collection of cones in quantity (Grinnel and Herridge 1970, Kmecza 1970, Petersen 1962). They also include sectional and rope ladders, climbing steps, and climbing irons for reaching a few valuable cones at the tops of certain trees (Denison et al. 1972, Morandini 1961). A vertical lift with a cantilever-type boom is useful for collecting cones from the periphery of the crown, but has the disadvantages of high cost and restricted use of the vehicle (USDA Forest Service 1968). One thing most of these methods have in common is the relatively high cost of collecting quality seed from specific trees.

We need crown-access apparatus in experimental work for such purposes as nondestructive inspection of conelet development, and for collecting cones from a relatively small number of trees at regular intervals. The apparatus should be safe, functional, inexpensive, highly mobile, have other uses, and be readily removable from the vehicle. The truck-mounted ladder described here was designed to meet these requirements. It is similar in some respects to those described by Johansen and Arline (1958) and Funsch (1971), and is similarly based on a ½-ton four-wheel-drive truck.

Rather than a tall, stationary support framework, the 36-foot magnesium extension ladder is supported

---

[1] Plant Physiologist, located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.

by a platform rack and a pair of support struts mounted near the front of the platform (fig. 1). The support struts were made of 2-inch standard galvanized pipe with ¼-inch steel plate welded to the ends at appropriate angles to connect to the ladder and platform. The base of the ladder and the support struts are attached to brackets mounted on the tailgate and platform, respectively, and are locked into position by steel pins with cotter keys (fig. 2). The support struts and stationary pivot mount on the platform are connected to the ladder by steel rods passed through steel sleeves fitted to the hollow ladder rungs (fig. 3). The ends of the stee rods are threaded and drilled to accept nuts an safety pins. Thus, all stationary and movabl connections are steel against steel to reduce wear an prevent loosening. Sway is minimized by fitting al connections to close tolerances and using ¼-inch thick steel plate reinforcement at the base and pivo mountings (fig. 2 and 3).

Figure 1.—The truck-mounted extension ladder set up beside a 32-foot ponderosa pine. The design utilizes a platform rack and two heavy vertical struts for support. Four camper jacks serve as outriggers to eliminate sway due to the vehicle's suspension, and facilitate removal of the rig from the truck.

Figure 2.—The base of the extension ladder i attached to brackets on the truck tailgate b steel pins. Note reinforcement of ladde above the point of attachment and wid steps on the ladder.

Sway due to the vehicle's suspension is virtuall eliminated by four 3,000-lb-capacity mechanica camper trailer jacks attached to the support posts o the platform rack. The jacks are spaced 1 inch awa from the truck body and fitted with enlarged bases (inches by 8 inches) for added support. The jacks als level the rig on uneven ground, and are used t remove the rig from the truck.

When traveling, the ladder and support struts rest on the 7-foot-high platform (fig. 4). The rear overhang of 4 feet is legal, but should be flagged for added safety. The stabilizing jacks are locked in the raised position to insure adequate clearance when the truck is moved.

Raising the ladder is essentially a two-man operation. One man on the platform lifts the top of the ladder while the second pulls down on the base and inserts the steel pins and cotter keys that connect the base of the ladder to the mountings on the tailgate. The ladder pivots on the stationary mounting at the rear of the platform. With the base of the ladder secure, the support struts are swung along the outside of the platform and connected to their mountings, also by steel pins and cotter keys. When the stabilizing jacks are unlocked, their bases drop to the ground. Then one or two strokes on each jack, using a detachable handle, is sufficient to stabilize the truck. The ladder may then be extended to the desired height. About 10 minutes are required to initially set up the rig. With the extension down, stabilizing jacks up, and one person acting as a spotter, the truck can be driven from tree to tree with the ladder upright. For maximum safety, the extension ladder should not be raised more than half its length—approximately 30 feet, including the height of the tailgate. A ladder-type safety belt and hard hat should be worn when working on the ladder.

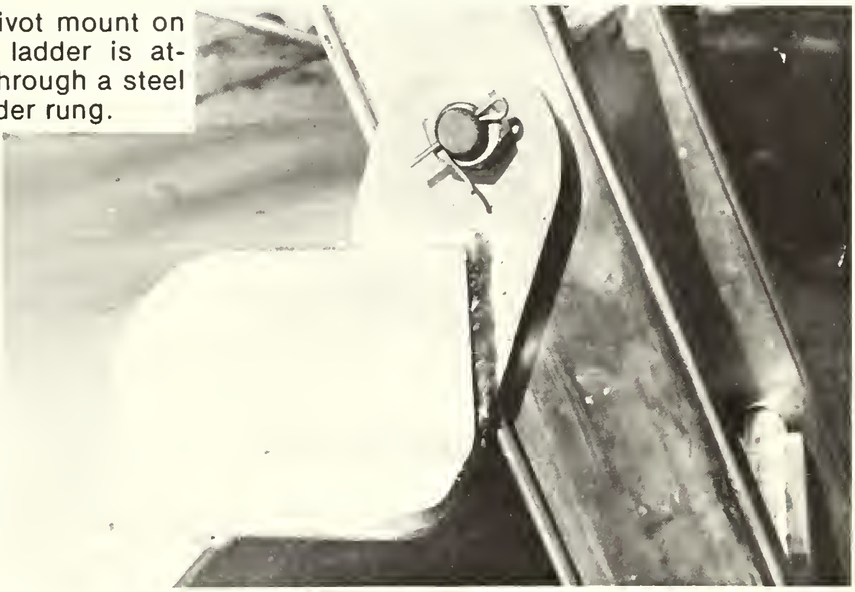


Figure 3.—Detail of stationary pivot mount on the platform. The reinforced ladder is attached by a steel rod passed through a steel sleeve fitted to the hollow ladder rung.

Figure 4.—When disassembled, the extension ladder and support struts pivot down and rest on the platform; the stabilizing jacks are raised and locked to maintain vehicle clearance. Rear overhang is 4 feet.

The platform and ladder rig are easily removed from the truck with the stabilizing jacks. The bolts and backing plates holding the platform to the truck bed are removed. Then the ladder rig is lifted with the jacks until it clears the truck bed. The truck can then be driven away, to be used for other purposes.

The platform by itself was found to be useful for collecting cones with a long aluminum pole tipped with a sharpened hook. The platform surface was coated with fine silica sand for safety. Additionally, the ladder or platform provides a good vantage point for photography.

Material and construction costs for the ladder rig amount to $1,137 (1974 prices). This figure includes $464 in materials and labor for mounting the platform, construction of the support struts and other mountings for the ladder, and attachment of the stabilizing jacks, all by a competent welder. The heavy duty magnesium extension ladder cost $356.

Literature Cited

Denison, William C., Diane M. Tracy, Frederick M. Rhoades, and Martha Sherwood.
  1972. Direct, nondestructive measurement of biomass and structure in living, old-growth Douglas-fir. p. 147-154. *In* Proceedings—Research on Coniferous Forest Ecosystems - A Symposium. Jerry F. Franklin, L. J. Dempster, and Richard H. Waring (eds.). Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Funsch, Robert W.
  1971. Another type of truck-mounted ladder. J. For. 69:805.

Grinnel, H. R., and A. J. Herridge.
  1970. Hydraulic cone-picker. For. Chron. 46:437.

Johansen, R. W., and L. Arline.
  1958. An idea in truck-mounted ladders. J. For. 56:852-853.

Kmecza, N. S.
  1970. Using tree shakers for pine cone collection, Region 8. Tree Plant. Notes 21(1):9-11.

Morandini, R.
  1961. Forest seed handling equipment and procedures. I. Seed production, collection, and production. Unasylva 15:185-199.

Petersen, Donald M.
  1962. Use of portable scaffold in Douglas-fir cone collection. Calif. Div. For. State For. Notes 13, 3 p.

Stein, William I., Paul E. Slabaugh, and A. Perry Plummer.
  1974. Harvesting, processing, and storage of fruits and seeds. p. 95-125. *In* Seeds of Woody Plants in the United States. U.S. Dep. Agric., Agric., Handb. 450.

U.S. Department of Agriculture. Forest Service.
  1968. Equipment to elevate a man to the crown of a tree. Equip. Dev. Test. Rep. 2400-3, 7 p. Equip. Dev. Cent., San Dimas, Calif.

June 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-289

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Fumigate Firewood Infested with Mountain Pine Beetle

William F. McCambridge,[1] John Laut,[2]
and
Ron Gosnell[3]

Beetles in ponderosa pine firewood can be killed by spraying each cord with 2 gallons of ethylene dibromide emulsion then covering and sealing the piles with plastic.

Keywords: *Pinus ponderosa, Dendroctonus ponderosae.*

Mountain pine beetles are killing hundreds of thousands of ponderosa pines annually along the Front Range of the Rocky Mountains. In certain high-value areas, beetles are controlled by cutting infested trees and spraying them with ethylene dibromide (EDB) emulsion. Occasionally, infested trees are cut for firewood, but beetles can mature in this material, and it must be treated. Since firewood can be concentrated, it occurred to us that infested material might be more economically treated in stacks or piles rather than as logs. Also, covering piles with sheet plastic would likely increase the effectiveness of the EDB, which is a fumigant.

The objective of this study was to determine how much EDB is needed to kill beetles in fuelwood piles that are covered with sheet plastic after spraying.

A standard cord of fuelwood, 4 feet by 4 feet by 8 feet, can be made from about five trees similar in size to average Front Range infested ponderosa pines (utilizing the trees to a 4-inch top). If these trees were cut and sprayed individually, a total of about 25 gallons of 4.8 percent EDB emulsion would be needed to kill the beetles.

Methods

We attempted to determine the minimum effective spray volume for treating a similar number of trees, but in piles. We sprayed three 1-cord piles with each of the following: 10, 5, or 2½ gallons of EDB per cord. Also, one pile was sprayed with 1¼ gallons per cord. Two piles received no treatment and one additional pile was covered with plastic but was not sprayed. The EDB was mixed with water to a standard concentration of 4.8 percent actual insecticide (based on labeled contents) and applied either June 17 or July 1, 1974. As soon as the spray was evenly applied, using low-pressure garden sprayers, clear 6-mil plastic was thrown over the pile and all edges covered with soil. Branches and log ends had been carefully trimmed to prevent tearing the plastic.

The piles were made by stacking three rows of 18-inch logs about 4 feet high and 7 feet long. The logs in each pile were then designated as being in one of three zones. Zone 1 logs were on top of the pile and along the upper 2 feet of the outside rows. Zone 2 logs were touching the ground. Zone 3 logs were in the middle of the middle row. The effectiveness of the treatments was then determined by periodically counting live and dead beetles from two 6-inch by 12-inch samples from each of two logs in each zone. The bark samples were taken from the top and bottom of each selected log. Piles that were sprayed with fumigant were not resampled once the plastic was removed. Check piles, un-

---

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

[2] *Staff Forester for insect and disease management, Colorado State Forest Service, Colorado State University, Fort Collins, Colorado.*

[3] *State District Forester, Colorado State Forest Service, Longmont, Colorado.*

sprayed and covered or not covered, were resampled at weekly intervals.

Results and Discussion

All treatments resulted in complete beetle mortality (table 1).

Table 1.--Mountain pine beetle mortality in cordwood piles treated with ethylene dibromide (EDB) and in untreated (control) piles

Treatment	Mortality after--			
	8 days	15 days	22 days	29 days
	- - - - *Percent* - - - -			
TREATED WITH EDB AND PLASTIC COVERED:				
10 gals/cord	100	100	100	--
5 gals/cord	100	100	100	--
2½ gals/cord	100	100	100	--
1¼ gals/cord	--	[1]100	--	--
UNTREATED (CONTROL):				
Plastic only	22	56	77	19
Open pile No. 1	8	11	2	11
Open pile No. 2[2]	--	52	20	--

[1] Brood appeared to have been dead for several days.

[2] Broods in logs in this pile were so sparse they could not be sampled properly on all designated sample dates.

While complete brood mortality can evidently be obtained in early summer with EDB spray at 1¼ gallons per cord (128 cubic feet), 2 gallons give better spray distribution throughout the pile, and the added cost of material and time to apply is insignificant.

Mortality in the control piles is further broken down by zones within the poles. Due to the limited sampling for each period, this mortality for all dates has been averaged. Mountain pine beetle mortality averaged by zones within the untreated piles was as follows:

	Plastic covered	Control (not covered)
	(Percent	*mortality)*
Zone 1		
Top of log	100	52
Bottom of log	84	21
Zone 2		
Top of log	53	20
Bottom of log	21	9
Zone 3		
Top of log	51	23
Bottom of log	24	7

Mortality under plastic is considerably greater than shown here. Beetles that emerge from Zones 2 and 3 die in great numbers under the plastic on sunny sides of the piles. Such mortality is very difficult to measure and no estimate is available.

Ethylene dibromide is a fumigant which soon volatilizes, leaving an inconsequential residue on the firewood.

Spraying and covering cordwood piles for mountain pine beetle control costs about as much as the more conventional cut and spray technique, but the amount of EDB saved is certainly an attractive feature of the method described here.

It is also important that the stack, spray, and seal method eliminates two of the most common causes for control ineffectiveness using the individual tree spraying method. With the fumigation method, it is not necessary to insure complete coverage of each inch of the infested material, and it is not necessary to retreat infested material if it rains shortly after the treatment is completed.

Tests similar to these described here were made in late 1974 to determine the effectiveness of this treatment with an oil carrier applied during the winter months. No satisfactory mortality was obtained after 4 weeks.

Agriculture—CSU, Ft. Collins

1975
U S D A FOREST SERVICE
RESEARCH NOTE RM-290
OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE
KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Nondestructive Method of Whole-Tree Sampling for Spring Cankerworm

John D. Stein and Dennis J. Doran[1]

The use of a backpack mistblower and a pyrethrum compound facilitates whole tree sampling of insects without destroying the trees. This sampling method can be used as a general collecting tool or as a means of determining the density and mathematical distribution of insect populations.

Keywords: whole-tree sampling, *Paleacrita vernata,* insect control.

A convenient method of whole-tree sampling was developed for spring cankerworm (*Paleacrita vernata*) larvae in Siberian elm shelterbelts. This method measured the efficiency of other sampling techniques involving various units of the tree. It was also used to determine density and mathematical distribution of the larvae. A nondestructive technique was necessary because we could not afford to destroy the design or esthetic values of the shelterbelts. Other environmental considerations indicated that we use pyrethrum to take advantage of: (1) rapid knockdown which minimizes collection time, and eliminates interference from birds, small mammals, or turbulent weather; (2) low mammalian toxicity; (3) no phytotoxicity; and (4) no residue problems due to rapid breakdown by sunlight (Thomson 1967).

A number of different chemical knockdown techniques have been reported in the past. Collyer (1951) enclosed fruit trees with polyethylene sheets and applied pyrethrum as a mist. Polles and Payne (1973) found Pyrenone[2] was superior to jarring or using cone-shaped traps for checking pecan weevil, *Curculic caryae* (Horn), populations on the entire tree. Satchell and Mountford (1962) introduced a systemic insecticide through a bark frill on the main trunk. When properly applied, 95 percent of all lepidopterous larvae fell within 4 days of treatment. However, this systemic chemical method was practical only during calm weather when larvae were not blown away.

To evaluate the populations of spring cankerworms, Pyrocide (2 percent active) was utilized to obtain whole-tree samples. The area around selected trees was cleared of weeds and low branches for placement of a vinyl-covered nylon collecting mat. The mat covered an area of 24 m^2 with a slit from the center to the outer edge to encompass the tree trunk. The sample tree was then treated with a backpack mistblower (Stihl SG-17) at the rate of 75 ml per cubic meter of tree crown (fig. 1). The larvae were collected (fig. 2) and preserved in 70 percent alcohol for tabulation at a later date.

---

[1] *Associate Entomologist and Biological Technician, respectively, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Authors are located at Bottineau in cooperation with North Dakota State University-Bottineau Branch.*

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

Figure 1.—

Mistblower application of pyrethrin spray to collect lepidoptera larvae.

The mistblower calibration for time in seconds (Y) required to apply a given volume of spray in ml (X) was

$$Y = -43.7 + 0.0972\ X.$$

Leafy crown volume (not total volume) is expressed as

$$V = 0.15\ DWH\ (2.2 + 0.42n)$$

where

V is crown volume (m^3)
D is depth of crown (m)
W is width of crown (m)
H is height of crown (m), and
n is number of leafy crown sides within the shelterbelt (0, 1, 2).

When the chemical application rate is 75 ml/m^3 of crown volume, then the two equations can be combined to express the time necessary for spraying a given tree as

$$Y = -43.7 + 1.09\ DWH\ (2.2 + 0.42n).$$

The cumulative percent of spring cankerworms that dropped from the tree was plotted against time measured at 10-minute intervals (fig. 3). Sixty-one percent (standard deviation = 3.5) of the cankerworm larvae fell within the first 10 minutes, and 92 percent within 30 minutes of spraying. The final 3 percent of the larvae were jarred from the trees at the end of 50 minutes. Visual examination of the crown verified that all larvae were collected after we jarred the tree.

Figure 2.—

Spring cankerworm larvae on the collection mat.

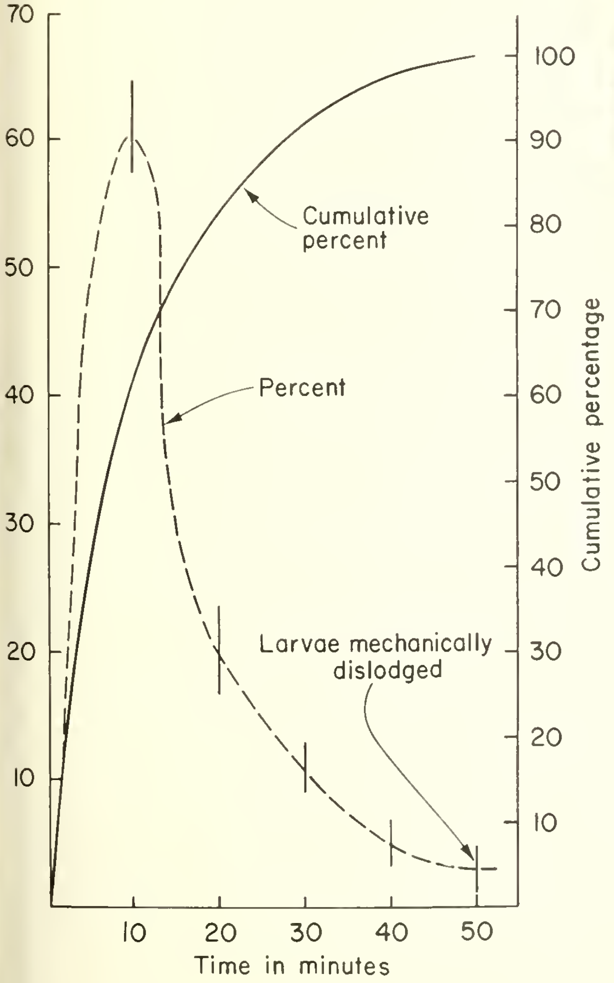


Figure 3.—Time sequence for collection of spring cankerworm larvae from five trees sprayed with Pyrocide. Vertical bars indicate standard deviation.

The procedure as described, is convenient to use on most trees under intensive culture. The same general format can be adapted to a hydraulic sprayer for tree heights in excess of 40 feet. This collection method was also used as a general survey tool. The authors were able to collect adult and immature specimens of Hemiptera, Homoptera, Hymenoptera, Diptera, Neuroptera, Ephimenoptera, Odonata, Orthoptera, Coleoptera, and several families of Araneida.

Literature Cited

Collyer, E.
1951. A method for the estimation of insect populations on fruit trees. East Malling Res. Stn. Annu. Rep. 38:148-151.

Polles, S. G., and J. A. Payne.
1973. Pecan weevil: An improved method of sampling populations in pecan trees. J. Econ. Entomol. 66:519-520.

Satchell, J. E., and M. D. Mountford.
1962. A method of assessing caterpillar populations on large forest trees, using a systemic insecticide. Ann. Appl. Biol. 50:443-450.

Thomson, W. T.
1967. Agricultural chemicals. Book I—Insecticides, Acaracides, and Ovicides. 365 p. Thomson Publ., Davis, Calif.

Agriculture—CSU, Ft. Collin

June 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-291

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

AVALANCHE WARNINGS: Content and Dissemination

Arthur Judson [1]

Snow avalanche warnings are an effective method of alerting the public to unusually dangerous avalanche conditions. An effective warning message conveys a sense of urgency, and should have an official and authoritative source. The message must be simple, clear, and concise. Warnings are transmitted through the National Weather Service's communications network to the media and public. Timely release of bulletins elicits good media coverage.

Keywords: Warnings systems, avalanches, snow.

Minimizing avalanche-related casualties through effective warning is an important goal of snow safety personnel throughout the Western United States. Rising winter recreation use in the mountain West has increased deaths, injury, and property loss due to avalanches despite better control programs, expanded public education efforts, and the initiation of warning programs. Williams (1975) put the average annual death toll from avalanches at seven, with an annual property loss of $250,000.

The objective of the avalanche warning program is to warn the public of unusually dangerous avalanche conditions. Warnings are primarily aimed at persons traveling outside controlled areas, where most serious avalanche accidents happen. The program is a cooperative venture between the National Weather Service (NWS) and the U.S. Forest Service (USFS).

Although informal warning programs have been operated on an intermittent basis in Colorado and Washington for a number of years, formal avalanche warnings first became a reality in November 1973.

In fall 1974, NWS and USFS representatives attended a conference on avalanche warnings sponsored by the Alpine Snow and Avalanche Research Project in Fort Collins, Colorado. Several new avalanche warning programs were initiated as a result of this meeting. The purpose of this Note is to examine one topic of the Fort Collins conference: The avalanche warning message and its dissemination.

Content

Every avalanche warning should convey at least four basic points:

- Area covered.
- Duration of warning.
- Reason for the warning.
- Instructions on what people should do to minimize risk.

---

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

The area covered by the warning must be clearly stated so it can be easily identified by anyone with a standard State road map. Details about elevational limits and specific aspects are better left out, because such information is taken literally and snow stability varies widely from place to place. Warning duration needs to be clearly specified: "This warning is valid through Thursday, April 24, 1975." Heavy snow and high winds, wind-deposited snow, or thaw conditions are the most common reasons given for issuing a warning. Finally, a statement notifying back-country travelers to avoid known avalanche paths, steep slopes, and gullies is needed. The words **back-country travelers** can optionally be changed to **mountain travelers** to indicate a higher degree of hazard.

The message should be simple, clear, and concise; it should avoid use of technical terms and jargon. To be effective, warnings must convey a sense of urgency,[2] and have an official and authoritative source easily identified by the public. Finally, a standard format is needed to insure uniformity and completeness of successive messages. Sample formats of a warning and its termination are given in figures 1 and 2.

Dissemination

Dissemination of warning messages plays a key role in the warning process. The most accurate and carefully worded warning will fail unless it receives wide and timely distribution. The NWS's communications network is an efficient and effective method of getting the warning to the media and public. Avalanche warnings transmitted through NWS facilities reach wire services, radio, television, and major newspapers simultaneously. Further coverage in population centers near the mountains is available through NWS VHF-FM radio broadcasts. These messages are transmitted 24 hours a day on frequencies between 162.40 MHz and 162.55 MHz. Special receivers are available at commercial outlets in a variety of types at reasonable cost. A third method, the Codaphone, also is used to convey messages to the public (see Special Avalanche Statement for January 16, 1975, p. 7).[3]

The media are a key link in the warning system. Lack of response at this level ends the warning process. First of all, avalanche warnings are new. Second, the mass media are based in large cities fa removed from the avalanche problem, so their awareness level is low. Finally, avalanche warnings mus compete with local and national news and sever weather warnings. Some of these, particularly heav snow and high wind warnings, frequently coincid with avalanche warnings. Add related storm news t this, and there is more weather news than tim allows for the weather programs, where most avalanche warnings are aired.

The media-awareness problem can be alleviated b personal contact with key news persons. Such contacts raise interest levels and improve reception o avalanche warnings. Some news personnel will wan to do a feature story on avalanches; this present further opportunity for exposure, and can provid first-hand knowledge through a field trip to an activ avalanche area. The result often gives neede exposure to the public and media alike.

Timing the release of warnings for maximu exposure is important, even with a well-informe media. Warnings released when media staffing level are low seldom reach the public. Best times fo release are: 0530-0600; 1100; 1530-1600; and 200 local standard time. The earliest release time give coverage on morning radio and television. The lat morning spot hits noon news, while the afternoo and evening times are set for evening news. Th largest audience is reached by early morning radio. The second biggest audience is reached by 10 p.m television. Warnings released between 1530 and 160 get double coverage on early evening and 10 p.m news. Unfortunately, rapid development of dangerous avalanche conditions seldom coincides with goo release times. This situation is handled best b releasing the first warning when needed, and rerunning it at the next best time for good new coverage.

When warnings are in effect, media coverage i improved by sending more than one warning per day Best results have been achieved with a morning an late afternoon bulletin each day. These bulletin catch key media personnel on both morning an evening shifts. Successive bulletins, supplying updated information on the number of avalanche reported since issuance of the first warning, appea

---

[2] *Personal communication with Bill Proenza, NWS Central Region Headquarters, Kansas City, Missouri.*

[3] *The U.S. Forest Service codaphone number in Denver, Colorado, is 303-234-4745.*

[4] *Personal communication with Charles Umpenhou KOA Radio and Television, Denver, Colorado.*

AVALANCHE WARNING

ZCZC
AVUS ________ ________________
(*Code*) (*Date-time group*)

. . . AVALANCHE WARNING . . . BULLETIN NUMBER ________
IMMEDIATE BROADCAST REQUESTED

U.S. FOREST SERVICE ________________ ________________
(*Town*) (*State*)

ISSUED ________ AM PM ________ ________________________________
(*Time*) (*Zone*) (*Day, Month, Date, Year*)

____
(*Area covered - general*)

AN AVALANCHE WARNING IS IN EFFECT FOR

____
(*Names of mountain ranges, passes, known landmarks or towns: be specific*)

____
(*Name of State is mandatory*)

THIS WARNING IS VALID UNTIL ________ AM PM
(*Time*)

________________________ ________________________
(*Day, month, date, year*) (*Cause for warning*)

____
(*Precautionary measures*)

____
(*Miscellaneous information*)

____

THE NEXT SCHEDULED UPDATE ON THIS SITUATION WILL BE AT

________ AM PM ________________________________
(*Time*) (*Day, month, date, year*)

OR

THE NEXT AVALANCHE WARNING BULLETIN WILL BE ISSUED ________ AT ________ AM PM
OR EARLIER IF CONDITIONS WARRANT.
(*Day*) (*Time*)

____
(*Name of person(s) issuing bulletin, organization, town, State*)

Figure 1.—Sample format, avalanche warning.

AVALANCHE WARNING TERMINATION

ZCZC
AVUS ________ ________________
(*Code*) (*Date-time group*)

. . . AVALANCHE WARNING TERMINATION . . . BULLETIN NUMBER ________
IMMEDIATE BROADCAST REQUESTED

U.S. FOREST SERVICE ________________ ________________
(*Town*) (*State*)

ISSUED ________ AM/PM ________ ________________________________
(*Time*) (*Zone*) (*Day, month, date, year*)

____
(*Area affected - general*)

THE AVALANCHE WARNING FOR THE ________________________________
(*Area under warning*)

MOUNTAINS HAS BEEN TERMINATED.

POCKETS OF UNSTABLE SNOW REMAIN. ________________________________
(*Type of traveler*)

SHOULD OBSERVE NORMAL PRECAUTIONARY MEASURES.

THIS IS THE LAST BULLETIN ON THIS AVALANCHE SITUATION.

____
(*Name of person(s) issuing bulletin, organization, town, State*)

Figure 2.—Sample format, avalanche warning termination.

to heighten public awareness. Variation in message style improves media acceptance. Important changes in warning area coverage and current mountain weather conditions should be included when appropriate. Bulletins are numbered consecutively for each warning period. The initial bulletin in each series is always number one.

Termination bulletins should be issued whe avalanche danger returns to normal. Random ava lanches may be triggered in certain areas on mo winter days. This is a normal winter condition, and statement in the final bulletin reminding persons this possibility is appropriate. An example of a seri of avalanche warnings follows.

ZCZC
AVUS RWRC 131700

....AVALANCHE WARNING....BULLETIN NUMBER 1
IMMEDIATE BROADCAST REQUESTED
U.S. FOREST SERVICE FORT COLLINS COLORADO
ISSUED 11 AM MDT SUNDAY APRIL 13 1975

SOUTHWESTERN COLORADO MOUNTAINS

AN AVALANCHE WARNING IS IN EFFECT FOR THE SAN JUAN MOUNTAINS OF COLORADO THROUGH MONDAY APRIL 14 1975. HEAVY SNOWFALL HAS CREATED DANGEROUS AVALANCHE CONDITIONS. NUMEROUS AVALANCHES WERE REPORTED THIS MORNING....MORE SNOWSLIDES ARE EXPECTED.

MOUNTAIN TRAVELERS SHOULD AVOID KNOWN AVALANCHE PATHS....STEEP SLOPES....AND GULLIES. BETWEEN 20 AND 40 INCHES OF SNOW FELL IN THE WARNING AREA THIS WEEKEND.

ANOTHER AVALANCHE BULLETIN WILL BE ISSUED LATER TODAY.

JUDSON....USFS. FORT COLLINS COLORADO

ZCZC
AVUS RWRC 140230

....AVALANCHE WARNING....BULLETIN NUMBER 2
IMMEDIATE BROADCAST REQUESTED
U.S. FOREST SERVICE FORT COLLINS COLORADO
ISSUED 830 PM MDT SUNDAY APRIL 13 1975

SOUTHWESTERN COLORADO MOUNTAINS

THE AVALANCHE WARNING FOR THE SAN JUAN MOUNTAINS OF COLORADO REMAINS IN EFFECT THROUGH MONDAY APRIL 14 1975. HEAVY SNOW WHICH FELL IN THE WARNING AREA THIS WEEKEND IS STABILIZING AND DANGER FROM SNOWSLIDES IS MODERATING. THIRTY-SIX AVALANCHES WERE REPORTED SUNDAY AND A FEW MORE ARE EXPECTED.

BACK-COUNTRY TRAVELERS SHOULD AVOID KNOWN AVALANCHE PATHS.... STEEP SLOPES....AND GULLIES. BETWEEN 20 and 40 INCHES OF NEW SNOW FELL IN THE SAN JUANS OVER THE WEEKEND.

THE NEXT AVALANCHE WARNING BULLETIN WILL BE ISSUED MONDAY AT 4 PM OR EARLIER IF CONDITIONS WARRANT.

JUDSON....USFS. FORT COLLINS COLORADO

ZCZC
AVUS RWRC 142210

....AVALANCHE WARNING TERMINATION....BULLETIN NUMBER 3
IMMEDIATE BROADCAST REQUESTED
U.S. FOREST SERVICE FORT COLLINS COLORADO
ISSUED 4PM MDT MONDAY April 14 1975

SOUTHWESTERN COLORADO MOUNTAINS

THE AVALANCHE WARNING FOR THE SAN JUAN MOUNTAINS HAS BEEN TERMINATED. SNOW COVER IN THE WARNING AREA CONTINUES TO STABILIZE. SCATTERED AVALANCHE ACTIVITY OCCURRING TODAY SHOULD CEASE TONIGHT WHEN TEMPERATURES DIP BELOW FREEZING. RANDOM POCKETS OF UNSTABLE SNOW REMAIN.

BACK-COUNTRY TRAVELERS SHOULD USE NORMAL PRECAUTIONARY MEASURES.

THIS IS THE LAST BULLETIN ON THIS AVALANCHE SITUATION.

JUDSON....USFS. FORT COLLINS COLORADO

Special Situations

Situations may develop when avalanche danger fails to meet the criteria for a warning,[5] but avalanche conditions need to be publicized. Routin weekend bulletins may serve this need. Special ava lanche statements are used in Colorado. The state ments have the advantage of covering any situatio when needed. Two statements issued during winte 1974-75 are given as examples:

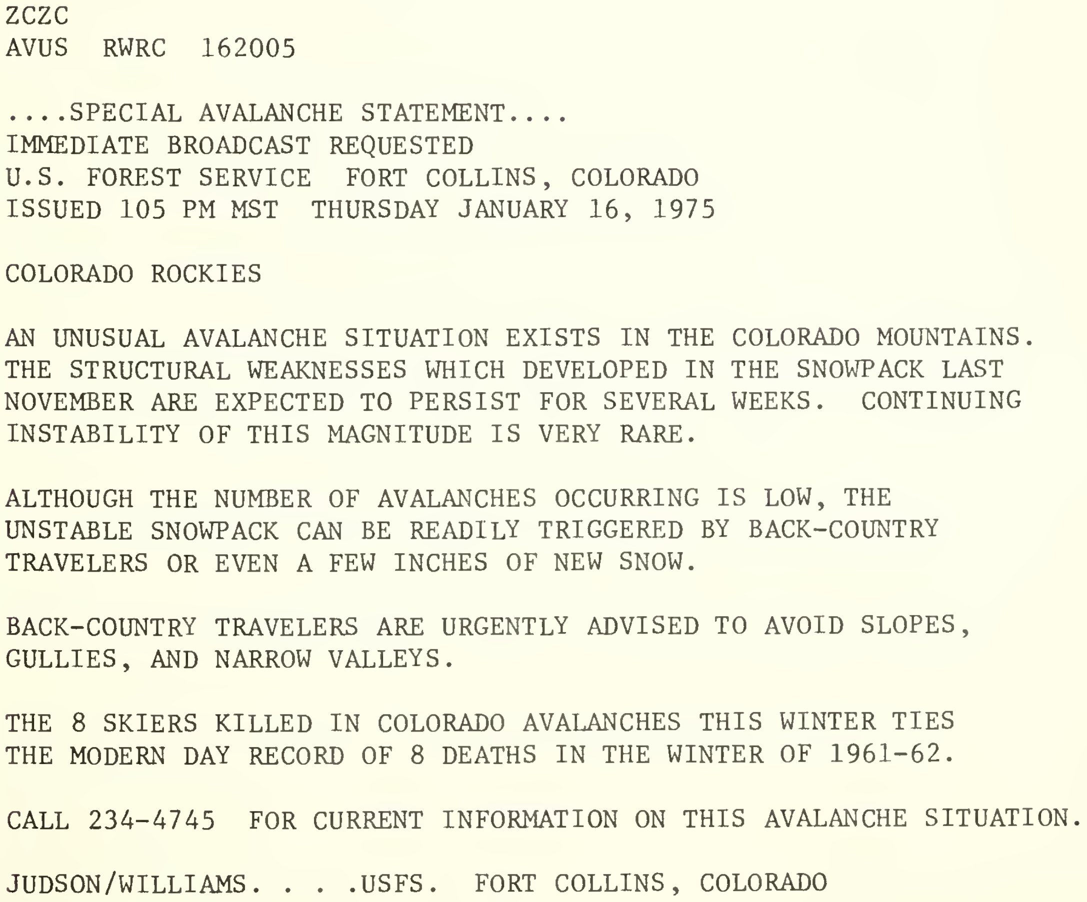
[5] *Warnings in Colorado were issued during the latter part of the 1974-75 season when 10 percent or more of the avalanche paths in a region were expected to run naturally to midtrack or beyond, and/or one-third or more of the paths subject to control were expected to run to the midtrack level or beyond.*

Discussion and Summary

More than 100 avalanche warning bulletins were issued in Colorado during the winters of 1973-74 and 1974-75. Numerous additional bulletins were issued in other western States. Although avalanches claimed 34 lives and caught over 300 persons in the United States during this period, we feel the warnings provide a worthwhile service which should be continued. Content, format, and timely dissemination of avalanche warnings play an important role in public response—the crux of the warning problem.

Personal response to warnings is a complicated process beyond the scope of this Note. Persons issuing avalanche warnings will benefit from McLuckie's (1974) detailed report and Riley's (1971) study on this subject.

In summary, the program objective is to warn the public of unusually dangerous avalanche conditions. The warning message should be simple, clear, and concise. Bulletins should follow a standard format and must have an authoritative source. Good public credibility is maintained by supplying the latest avalanche information in each warning message. The area covered, duration of the warning period, reason for issuance, and instructions for safe conduct in the warning area should be included in every bulletin. Timely release of warning bulletins gives good media coverage. More than one bulletin per day insures



ZCZC
AVUS RWRC 162005

....SPECIAL AVALANCHE STATEMENT....
IMMEDIATE BROADCAST REQUESTED
U.S. FOREST SERVICE FORT COLLINS, COLORADO
ISSUED 105 PM MST THURSDAY JANUARY 16, 1975

COLORADO ROCKIES

AN UNUSUAL AVALANCHE SITUATION EXISTS IN THE COLORADO MOUNTAINS. THE STRUCTURAL WEAKNESSES WHICH DEVELOPED IN THE SNOWPACK LAST NOVEMBER ARE EXPECTED TO PERSIST FOR SEVERAL WEEKS. CONTINUING INSTABILITY OF THIS MAGNITUDE IS VERY RARE.

ALTHOUGH THE NUMBER OF AVALANCHES OCCURRING IS LOW, THE UNSTABLE SNOWPACK CAN BE READILY TRIGGERED BY BACK-COUNTRY TRAVELERS OR EVEN A FEW INCHES OF NEW SNOW.

BACK-COUNTRY TRAVELERS ARE URGENTLY ADVISED TO AVOID SLOPES, GULLIES, AND NARROW VALLEYS.

THE 8 SKIERS KILLED IN COLORADO AVALANCHES THIS WINTER TIES THE MODERN DAY RECORD OF 8 DEATHS IN THE WINTER OF 1961-62.

CALL 234-4745 FOR CURRENT INFORMATION ON THIS AVALANCHE SITUATION.

JUDSON/WILLIAMS. . . .USFS. FORT COLLINS, COLORADO better media response and heightens public awareness.

Acknowledgment

Direct assistance from National Weather Service personnel helped the avalanche warning program off to a good start. Personnel from the Weather Service Forecast Office (WSFO) in Denver put avalanche warnings out quickly. They also helped with wording and format. WSFO forecaster Henry W. Chidley was especially helpful in all phases of the warning program. Bill Proenza, of the NWS Central Region Headquarters, gave valuable assistance in developing message content and format. The format in figure 1 was patterned after NWS Severe Weather Bulletins.

Literature Cited

McLuckie, Benjamin F.
1974. Warning—A call to action. 85 p. U.S. Dep. Commer. NOAA. Natl. Weather Serv., South. Reg., Fort Worth, Tex.

Riley, J. A.
1971. Disaster—Storm ahead. 63 p. Hogg Found. Ment. Health. Univ. Tex. Print. Div., Austin, Tex.

Williams, Knox.
1975. The snowy torrents: Avalanche accidents in the United States 1967-71. USDA For. Serv. Gen. Tech. Rep. RM-8, 190 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

```
ZCZC
AVUS  RWRC  251130

....SPECIAL AVALANCHE STATEMENT....
IMMEDIATE BROADCAST REQUESTED
U.S. FOREST SERVICE  FORT COLLINS, COLORADO
ISSUED 530 AM MDT FRIDAY APRIL 25, 1975

.......AVALANCHE DANGER FROM SPRING SNOWSLIDES IN COLORADO.......

RECENT WARM WEATHER HAS BROUGHT SNOW TEMPERATURES TO THE MELTING
POINT IN SOME AVALANCHE ZONES.  THE MOUNTAIN SNOW COVER IS
BEGINNING TO WEAKEN AND SEVERAL SNOWSLIDES HAVE ALREADY OCCURRED.
DANGER FROM THESE SPRING AVALANCHES WILL CONTINUE INTO JUNE...
BUT THE MOST SERIOUS AVALANCHING SHOULD OCCUR DURING THE NEXT
3 WEEKS.  INTENSITY AND MAGNITUDE OF AVALANCHING WILL DEPEND ON
WEATHER DURING THIS TIME.

LARGE AND POTENTIALLY DESTRUCTIVE AVALANCHES MAY OCCUR IN THE
COLORADO ROCKIES THIS SPRING DUE TO STRUCTURAL WEAKNESS WHICH
FORMED IN THE SNOW LAST NOVEMBER.

BACK-COUNTRY TRAVEL WILL BE SAFEST DURING THE EARLY MORNING HOURS
BEFORE 11 AM.  TRAVEL IN AVALANCHE TERRAIN BETWEEN 11AM AND SUNDOWN
WILL BE VERY DANGEROUS WHEN AIR TEMPERATURES ARE ABOVE FREEZING.
BACK-COUNTRY TRAVELERS SHOULD AVOID KNOWN AVALANCHE SLOPES AND
GULLIES.

ADDITIONAL STATEMENTS AND/OR AVALANCHE WARNINGS WILL BE ISSUED AS
CONDITIONS WARRANT.

JUDSON....USFS.  FORT COLLINS COLORADO
```

Agriculture—CSU, Ft. Collins

June 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-292

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Can Soil Amendments Aid Revegetation of New Mexico Coal Mine Spoils?[1]

Earl F. Aldon, H. W. Springfield, and George Garcia[2]

Adding amendments did not improve seedling emergence in greenhouse tests with mountain rye, fourwing saltbush, and western wheatgrass. Shredded bark depressed herbage yields, especially where no fertilizer was supplied. Fertilizer consistently increased yield. Topsoil was not always a better growth medium than spoil.

Keywords: Rehabilitation, coal mine spoils, mulch, *Secale montanum, Atriplex canescens, Agropyron smithii.*

Soil amendments may be organic or inorganic, or combinations of the two. Straw, manure, sawdust, and bark are common organic amendments. Inorganic amendments include sand, perlite, vermiculite, and a wide variety of chemical fertilizers, particularly nitrogen and phosphorus.

This Note summarizes the results of small-scale greenhouse tests with representative spoils from two coal mines in northern New Mexico. Specifics of each experiment are given separately. The general objective was to determine whether individual or combinations of several amendments would improve germination and growth of native plants grown on mine spoils material. This information would be used as guidelines for field testing and further investigation.

RATON AREA

The Raton coalfield in northeastern New Mexico lies in rough, dissected plateau country, just east of the Sangre de Cristo Mountains. Coking coal has been mined underground in horizontal drifts which are readily accessible from the canyons. The York Canyon Mine coal bed has thin overburden, however, and is currently being developed for strip mining. The mine is located at an elevation of about 2,250

---

[1] *The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements. This work was conducted in cooperation with Pittsburg and Midway Coal Co., and the Kaiser Steel Co. We appreciate the assistance of these companies.*

[2] *Principal Hydrologist, Plant Ecologist, and Forestry Research Technician, respectively, Rocky Mountain Forest and Range Experiment Station, located at Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

meters, in the ponderosa pine (*Pinus ponderosa* Laws.) zone where precipitation ranges from 400 to 580 millimeters.

Shredded pine bark from a nearby sawmill looked like a low-cost, readily available amendment that might be used in reclamation efforts. A study was first set up to test various rates of bark mixed with either spoil or topsoil material, and with or without fertilizer. The mixes included ¼, ½, or ¾ bark. Results showed that levels of ½ and ¾ bark were excessive. Therefore, a followup study was conducted using no more than ¼ bark.

Methods

The experiment was conducted in 1974, using plasticized pots 10 cm in diameter and 15 cm tall. Daily maximum greenhouse temperatures ranged from 22° to 32° C. Shredded ponderosa pine bark, which had been aged in large piles, was mixed with spoils (overburden) or topsoil from the York Canyon Mine.

A 10-5-5 fertilizer was used. Procedures for adding the fertilizer were standardized. The upper half of the mixture in each pot was removed; the proper amount of fertilizer was thoroughly mixed in; then the mixture was returned to the pot. In each pot, 20 seeds of mountain rye (*Secale montanum*) were planted 1.25 cm deep.

Seedlings were counted twice weekly for 3 weeks, after which they were thinned to six seedlings per pot. At the termination of the experiment in 60 days, the maximum height of the seedlings in each pot was measured; then the plants were clipped to soil level, and weighed both green and ovendry.

The following four planting media were used:

Spoil only.
¾ spoil, ¼ bark.
Topsoil only.
¾ topsoil, ¼ bark.

Fertilizer treatments were none, low, and high, as follows:

F_0—no fertilizer.
F_1—0.72 g/pot (800 lb/acre).
F_2—1.44 g/pot (1,600 lb/acre).

Design of the experiment was factorial, with four replications, for a total of 48 pots.

Results

Emergence of mountain rye seedlings generally was higher in spoil than in topsoil (table 1). For example, more than 70 percent of the seeds planted in unfertilized spoil produced seedlings, compared with less than 50 percent in unfertilized topsoil. The overall effects of fertilizer and bark on seedling emergence were negligible. Emergence was nearly the same in spoil and topsoil where bark was added, provided no fertilizer had been applied; but applying fertilizer to a mix of bark and topsoil (1:3 ratio) severely depressed emergence. In contrast, applying fertilizer to a mix of bark and spoil did not depress emergence.

Table 1.--Emergence, growth, and yield of mountain rye in York Canyon mine spoil and topsoil, amended with bark and no, low, and high levels of fertilizer (10-5-5), 60 days after planting, 1974, Raton coalfield area

Planting medium and fertilizer level	Emergence	Leaf length	Ovendry yield
	Percent	*cm*	*g*
Spoil only:			
F_0 (none)	72.50	25.50	0.635
F_1 (low)	41.25	54.00	2.445
F_2 (high)	71.25	39.75	4.332
3/4 spoil, 1/4 bark:			
F_0	70.00	19.75	.265
F_1	73.75	36.25	1.838
F_2	62.50	43.75	3.200
Mean	65.21	36.50	2.119
Topsoil only:			
F_0	48.25	45.25	.978
F_1	55.00	43.75	3.202
F_2	57.50	42.25	4.410
3/4 topsoil, 1/4 bark:			
F_0	71.25	23.75	.215
F_1	30.00	45.00	1.492
F_2	48.75	51.00	3.120
Mean	51.79	41.83	2.236

Leaves generally were longer on plants growing in topsoil than on plants in spoil material. There were, however, several exceptions. As examples, the longest leaves were on plants in spoil only fertilized at the lower level, whereas the next to the shortest leaves were on plants in ¾ topsoil, ¼ bark, unfertilized. Adding bark tended to result in shorter leaves, but the effects were not entirely consistent. When no fertilizer was applied, leaves were substantially shorter where bark was added (fig. 1). Application of fertilizer, especially at the higher rate, usually compensated for the depressing effect of the bark on leaf length. Fertilizer almost always promoted longer leaves; notable exceptions were those plants grown in

Figure 1.—Growth of mountain rye in 60 days:

Left to right—

Spoil, no fertilizer;

Spoil, with fertilizer;

¾ spoil, ¼ bark, no fertilizer;

¾ spoil, ¼ bark, with fertilizer.

topsoil only, where the higher level of fertilizer did not consistently produce longer leaves.

Plants grown in spoil material weighed essentially the same as plants grown in topsoil. Overall, the mean differences in yield were not significant. Adding bark to either the spoils or topsoil reduced the yield of mountain rye. This reduction in yield due to bark was proportionately less where fertilizers had been applied. For spoil, topsoil, and mixes, however, the application of fertilizers consistently increased yields. In all instances, the higher level of fertilization resulted in a higher yield of grass. For spoil only and topsoil only, the yield increases (compared with no fertilizer) were:

	F_1	F_2
	(percent)	
Spoil only	285	582
Topsoil only	227	351

Conclusions

- Seedlings emerged as well (or better) in spoil as in topsoil.
- Adding shredded pine bark or fertilizer did not consistently improve emergence.
- Fertilizer improved leaf length and plant weights in both spoil and topsoil in nearly all treatments.
- Bark depressed plant weights, especially where no fertilizer was used.
- High levels of fertilizer improved yield of mountain rye under all conditions, and was especially effective in spoil and topsoil where no bark was added.

GALLUP AREA

The three spoil materials used for this test were taken from the McKinley Mine of Pittsburg and Midway Coal Company, near Gallup, New Mexico, at an elevation of 2,000-2,100 meters and annual precipitation of 29-39 cm. The planting media for this experiment, all of clay loam texture, (table 2) were:

Old spoil, which resulted from mining in 1968.
Raw Spoil 1, from mining in 1971.
Raw Spoil 2, from mining in 1972.
Topsoil, from a big sagebrush area at the mine site.

Table 2.--Characteristics of planting media from McKinley Mine, near Gallup, New Mexico

Planting media	pH	Electrical conductivity x 10^3	N	P_2O_5	K_2O	Organic matter[1]
			- - *p/m*	- -		*Percent*
Old spoil	7.3	0.96	6.5	8.5	101	6.51
Raw spoil 1	7.3	.79	4	15.5	108.5	4.43
Raw spoil 2	7.3	3.00	18	4.5	68.5	4.84
Topsoil	7.2	5.30	8	18	58	2.27

[1] High due to coal particles.

Methods

Two native forage species—fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.) and western wheatgrass (*Agropyron smithii* Rydb.)—were selected to test plant responses. Both species grow naturally near the McKinley Mine and have a high potential for revegetation. They provide good quality forage for domestic livestock as well as for wildlife, and are important soil stabilizers. Seeds of fourwing saltbush used in the experiment were collected in 1968 at Camp 8, south of Cuba, New Mexico. Seeds of western wheatgrass used were produced at the Soil Conservation Service, Los Lunas Plant Materials Center, and are identified as C-30.

A 10-5-5 fertilizer was tested at two levels:

Low—1.9 g/pot (800 lb/acre).
High—3.8 g/pot (1,600 lb/acre).

Metal pots 16.5 cm in diameter and 21.6 cm in height were filled to within 3.8 cm of the top, with 4,000 g of air-dry material. Large rocks were removed from the spoil material.

Fertilizer was added to the air-dry spoils and topsoil before seeds were planted in 1974. The top 5.0 cm of material was removed from the pot. Then, either 1.9 (low) or 3.8 (high) grams of fertilizer were thoroughly mixed with the material, and the mixture returned to the pot.

The top 1.3 cm of spoil or topsoil was removed from the pot before seeds were planted. Twenty seeds of fourwing saltbush or western wheatgrass were spaced evenly over the surface, then covered with the 1.3 cm of material previously removed.

Pots were watered at 3- or 4-day intervals to maintain moisture near field capacity. The quantity of water added was based on drying curves determined for samples of spoils used in another experiment (Aldon and Springfield 1973), but collected from the same areas as spoils used in this experiment.

The 144 pots were randomly placed on benches in a greenhouse. Air temperatures during the experiment were:

	Range	**Mean**
Daily maximum	27°-36°C	33°C
Daily minimum	13°-18°C	16°C

The experimental design was factorial, with six replications.

Results

Fourwing Saltbush

Maximum emergence of fourwing saltbush seedlings in 90 days was significantly less in Raw Spoil 1 than in the other two spoil materials and Topsoil (table 3). Raw Spoil 1 tended to swell and shrink and crack; consequently it was difficult to maintain moisture near field capacity.

Overall, fertilizer did not significantly influence seedling emergence. The high level of fertilizer, however, depressed emergence of saltbush seedlings in Raw Spoil 2.

At the end of 90 days, plants grown without fertilizer in Topsoil were no taller than those grown without fertilizer in Old or Raw Spoil 2 (fig. 2). Plants grown in pots with fertilizer were significantly taller than in nonfertilized pots. The high level of fertilizer, however, did not produce significantly taller plants than the low level in any material.

Plants grown in Topsoil tended to yield more than those in spoils, particularly if fertilized, but the differences were not always significant. Fertilized plants consistently outyielded unfertilized plants. At the low level of fertilization, plants in Topsoil were heavier than those in Old Spoil; plants in Topsoil and Raw Spoil 2 yielded essentially the same. Plants in Old Spoil and Topsoil weighed significantly more at the high level than at the low level, whereas plants in Raw Spoil 2 weighed the same under the two levels of fertilization. Fourwing saltbush responses to fertilizer agree with the results of Williams and O'Connor (1973) who worked with rangeland soils.

Table 3.--Emergence, height, and yield of fourwing saltbush and western wheatgrass in mine spoils and topsoil, with no, low, and high levels of fertilizer, 90 days after planting, 1974, Gallup coalfield area

Species and planting medium	Emergence, when fertilizer level is--				Height, when fertilizer level is--				Ovendry yield, when fertilizer level is--			
	None	Low	High	Mean	None	Low	High	Mean	None	Low	High	Mean
	- - *Percent* - -				- - - *cm* - - -				- - - - *g* - - - -			
FOURWING SALTBUSH:												
Old Spoil (1968)	41.5	34.7	38.2	38.1	29.2	41.2	48.5	39.6	2.5	5.7	9.1	5.8
Raw Spoil 1 (1971)	2.3	10.0	7.6	6.6	--	--	--	--	--	--	--	--
Raw Spoil 2 (1972)	42.3	41.5	25.2	36.3	32.6	43.4	44.3	40.1	3.1	6.3	6.2	5.2
Topsoil	29.3	37.2	27.9	31.5	25.2	49.1	49.7	41.3	2.2	8.5	11.5	7.4
Mean	28.8	30.8	24.7	28.1	29.0	44.6	47.5	40.3	2.6	6.8	8.9	6.1
WESTERN WHEATGRASS:												
Old Spoil (1968)	96.8	91.3	95.2	94.4	47.7	67.7	76.7	64.0	2.4	10.2	10.2	7.6
Raw Spoil 1 (1971)	29.4	65.5	57.9	50.9	37.7	66.0	65.0	56.2	.7	5.7	6.8	4.4
Raw Spoil 2 (1972)	83.8	89.3	80.6	84.6	53.0	70.1	71.9	65.0	3.5	8.3	10.2	7.3
Topsoil	90.6	94.7	95.3	93.5	46.9	62.1	69.2	59.4	2.4	8.7	11.6	7.6
Mean	75.2	85.2	82.2	80.8	46.3	66.5	70.7	61.2	2.2	8.2	9.7	6.7

Western Wheatgrass

Emergence of western wheatgrass seedlings was much higher than for fourwing saltbush (table 3). As with saltbush, however, emergence of wheatgrass was significantly less in Raw Spoil 1. Wheatgrass seedlings emerged exceptionally well in unfertilized Old Spoil.

The effect of fertilizer on emergence varied according to spoil material. Adding fertilizer to Topsoil or Raw Spoil 1 improved emergence. On the other hand, the high level of fertilizer depressed emergence somewhat, compared to the low level, in both Raw Spoils. (The interaction between spoils and fertilizer was significant at the 0.05 level.)

During the 90 days of this experiment, western wheatgrass grew well in all spoils except Raw Spoil 1, which produced the smallest plants. The average height and weight of the grass plants were practically the same in Raw Spoil 2, Old Spoil, and Topsoil.

Plants were consistently taller and heavier where fertilizer had been applied. For example, in the Old Spoil material, fertilized plants were at least 40 percent taller and four times heavier than unfertilized plants.

Doubling the amount of fertilizer generally affected yield much more than height. Plants grown in Old Spoil weighed the same, however, whether fertilized at the high or low level.

Conclusions

- Fertilizer does not improve emergence of fourwing saltbush or western wheatgrass measured after 90 days.
- Fertilizer does significantly improve height and yield of plants.
- The high level of fertilizer did not improve height of these plants, and produced only small additional gains in the yield of western wheatgrass.
- Topsoil was not significantly better as a growth medium than either a 5-year-old spoil material or a recently mined spoil material.
- One sample of recently mined spoil material did reduce emergence and growth of both species. This reduction was related to watering difficulties due to physical properties of the spoil.

LITERATURE CITED

Aldon, Earl F., and H. W. Springfield.
1973. Revegetating coal mine spoils in New Mexico: a laboratory study. USDA For. Serv. Res. Note RM-245, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Williams, Stephen E. and George A. O'Connor.
1973. Chemical fertilization of fourwing saltbush. J. Range Manage. 26:379-380.

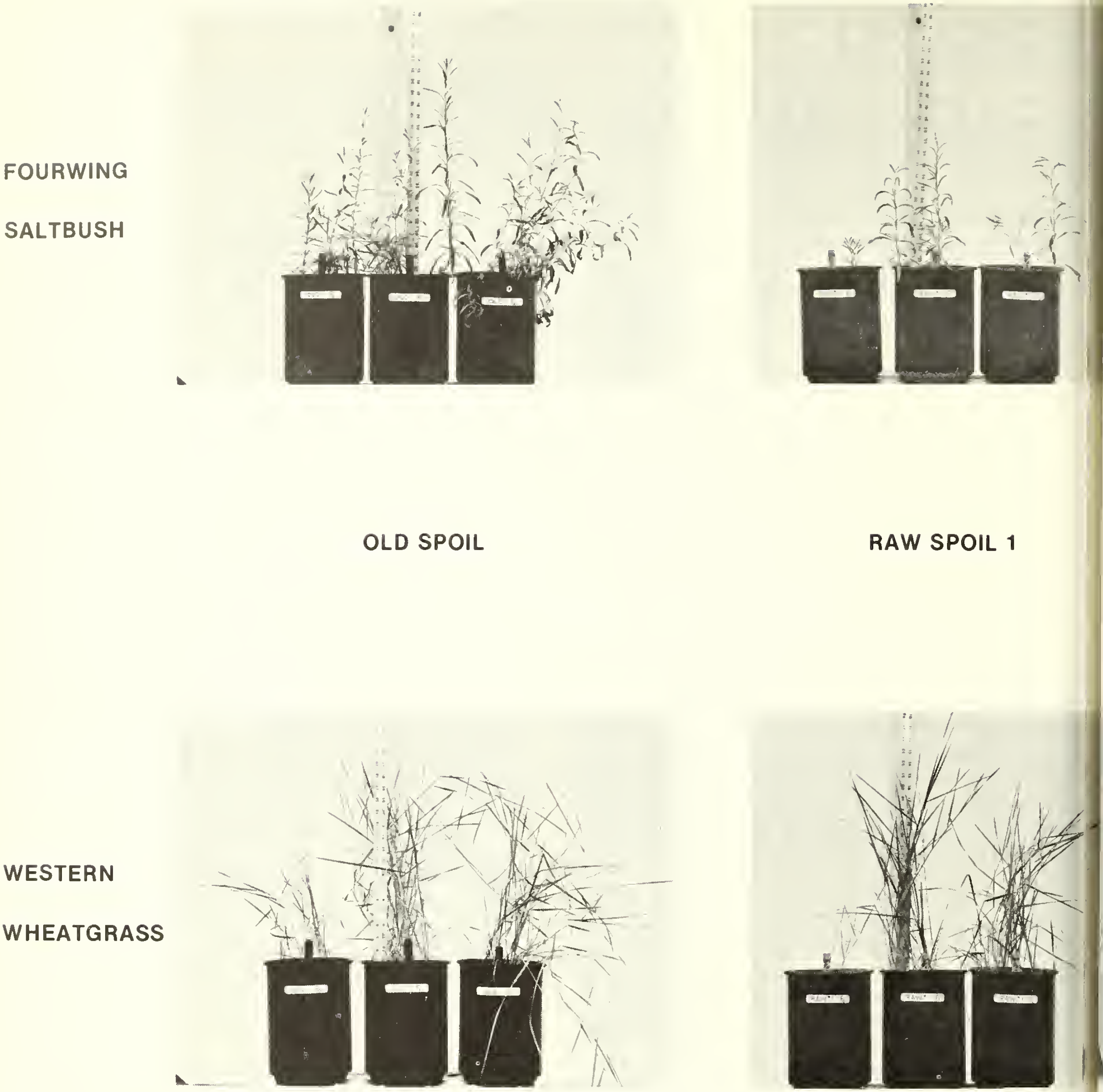


Figure 2.—Growth of fourwing saltbush and western wheatgrass in 90 days: Left to right—no fertilizer; low-level fertilizer; high-level fertilizer.

RAW SPOIL 2

TOPSOIL

July 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-293

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Effect of Bulk Density on Frost Heaving of Six Soils in Arizona

L. J. Heidmann[1] and David B. Thorud[2]

For all soils and depths, frost heaving increased with bulk density. All soils had essentially the same water content when they started to freeze, which indicates that, as bulk densities decreased, percentage of pores filled with air increased. At higher bulk densities, capillary flow is probably improved.

Keywords: Frost heaving, soil bulk density, tree seedling mortality.

Frost heaving of tree seedlings is a serious problem in many parts of the world. Areas subject to frost heaving are characterized by below-freezing temperatures, adequate soil water, and susceptible soils. In northern Arizona, frost heaving is a leading cause of ponderosa pine seedling mortality (Larson 1961). Heaving of first-year seedlings is usually more severe than for nursery transplants (Haasis 1923, Schramm 1958).

In 1971 a comprehensive study of frost heaving was begun at Flagstaff to identify susceptible soils and develop control measures. Preliminary field and laboratory observations indicated that frost heaving was related to soil bulk density (fig. 1). As a result, the following study relating frost heaving to bulk density was begun in December 1972.

Figure 1.—Example of the relationship between bulk density and frost heaving. Left to right, the bulk densities are: 0.9, 1.0, 1.1, 1.2, and 1.25. Note that the soil has pushed out of the bottom of the cylinders, especially those on the right.

Methods

Soil Collection and Preparation

A review of the literature[3] indicated that frost heaving is closely correlated with soil particle size. As a result, six soils of varying texture were selected for study; all were collected within a 40-mile radius of Flagstaff, at elevations ranging from 3,800 to 7,400 feet elevation (table 1).

Five of the soils were collected from the ponderosa pine zone, while one was collected from a desert-grassland site. At each location four soil samples were collected from each of three soil depths. Depths sampled were: 0-2.5 cm, 2.5-7.6 cm, and 7.6-15.2

---

[1] Silviculturist, located at Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University. Information reported here is based on Heidmann's Ph.D. Dissertation, submitted to the University of Arizona, Tucson.

[2] Director, School of Renewable Natural Resources, University of Arizona, Tucson.

[3] Heidmann, L. J. Forst heaving of tree seedlings: A literature review of causes and possible control. (Manuscript in preparation at Rocky Mt. For. and Range Exp. Stn., Flagstaff, Ariz.)

Table 1.--Bulk density and textural classification[1] for six soils from northern Arizona at three depths

Location and soil depth *(cm)*	Elevation	Bulk density	Sand	Silt	Clay	Organic matter	Textural classification (USDA system)
	Feet		- - - *Percent* - - -				
Tie Park (TP)	7,400						
0 - 2.5		1.21	0	66	34	4.33	Silty clay loam
2.5 - 7.6		1.08	1	66	33	1.93	Silty clay loam
7.6 - 15.2		1.27	0	62	38	1.90	Silty clay loam
Beaverhead Flat (BF)	3,800						
0 - 2.5		1.56	60	30	10	.33	Sandy loam
2.5 - 7.6		1.79	52	34	14	.20	Sandy loam
7.6 - 15.2		1.75	51	32	17	.20	Loam
Fort Valley Experimental Forest--							
S-3 West (S-3W)	7,300						
0 - 2.5		.93	15	68	17	2.27	Silt loam
2.5 - 7.6		.97	13	66	21	3.43	Silt loam
7.6 - 15.2		1.07	9	66	25	1.87	Silt loam
S-3 East (S-3E)	7,300						
0 - 2.5		1.14	16	64	20	2.47	Silt loam
2.5 - 7.6		1.09	15	67	18	1.47	Silt loam
7.6 - 15.2		1.20	10	66	24	.77	Silt loam
Beaver Creek Watershed 14 (W-14)	7,400						
0 - 2.5		1.04	10	61	29	5.20	Silty clay loam
2.5 - 7.6		1.24	3	66	31	6.83	Silty clay loam
7.6 - 15.2		1.32	5	66	29	2.57	Silty clay loam
Kelly Tank (Kelly)	7,200						
0 - 2.5		1.08	63	24	13	2.57	Sandy loam
2.5 - 7.6		1.34	61	26	13	3.73	Sandy loam
7.6 - 15.2		1.50	57	28	15	3.20	Sandy loam

[1] As determined by the hydrometer method.

cm. The four soil samples from each depth and location were mixed together and dried for several weeks. Each soil was then sifted through a 2 mm mesh soil sieve and ovendried at 105° C until a constant weight was reached.

Particle size for each soil and depth was determined by the hydrometer method. Soil bulk densities were determined in the field using the sand cone method (Black 1965).

To determine the minimum bulk density, three cylinders (described under "freezing tests") were filled loosely with soil for each location and depth. The cylinders were agitated slightly to settle the soil, but an effort was made not to compact the soil. The amount of dry soil necessary to fill the cylinders was determined to the nearest 0.1 g. In determining the maximum bulk density, soil cylinders were filled with a small amount of soil at a time. After a small increment of soil had been added to a cylinder, it was tamped with a hardwood dowel. Then another increment of soil was added to the cylinder and tamped. This procedure was repeated until the cylinder was full. The cylinders were soaked in water, after which soil was again added until the maximum amount they could hold was reached. The soil in each cylinder was then ovendried. The ovendry weights of soil for the minimum and maximum bulk densities were calculated to the nearest 0.1 g and averaged to find the amount of soil needed for the mean bulk density.

Freezing Tests

Freezing tests for each soil and depth were conducted at minimum, mean, and maximum bulk densities in a specially constructed plywood freezing chest (Heidmann 1974).

The chest is designed to simulate an open system. Polyvinylchloride (PVC) cylinders 3.3 by 7.6 cm are filled with soil and placed in water until a constant weight is reached. The cylinders are then placed in a pan of water in the freezing chest. The freezing chest is insulated on the bottom and sides with styrofoam. The water is kept from freezing by a heating tape below the pan. The whole chest is placed in a freezer. Since only the surfaces of the soil samples are exposed, freezing occurs from the surface downward.

After all the soil cylinders had been packed for the various bulk density levels, they were placed in pans of water to soak until a constant weight was reached, about 24 hours. The cylinders were removed from the water, allowed to drain for a few minutes, and weighed to the nearest 0.1 g to determine their water content. The soil cylinders were placed in the freezing chest, which was then put in the freezer. Each freezing test lasted 10 days. The ambient temperature in the freezer at 2.5 cm above the soil surface was maintained at approximately -3° C. The samples were checked every 8 hours to determine onset of freezing. At the conclusion of the test, each cylinder was removed and the amount of frost heaving was measured to the nearest millimeter. The depth of frozen soil was also recorded for each cylinder.

The bulk density freezing tests were replicated four times in randomized blocks, a procedure requiring 216 cylinders. The freezing chest has space for 72 cylinders; consequently four separate trials with 54 cylinders were run.

Results

The soils studied varied considerably (table 1). Field bulk densities ranged from less than 1.00 to 1.79. Sand content ranged from zero to over 60 percent. None of the soils had a high clay content, but all contained a considerable amount of silt. Organic matter content also was quite varied.

The data relating frost heaving (table 2) to bulk density were analyzed by covariance analysis. The

Table 2.--Results of tests on six soils from northern Arizona, by location, depth, and bulk density

Soil depth, and location of soil sample	Frost heaving when bulk density is--			Mean frost heaving for soil depth	Moisture content after soaking when bulk density is--			Moisture, dry weight basis, when bulk density is--			Depth frozen, when bulk density is--		
	Minimum	Mean	Maximum		Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum
		mm/day				*g*			*Percent*			*mm*	
<u>0 - 2.5 cm</u>:													
TP	1.24	1.52	2.03	1.60	23.0	23.9	22.7	48	43	36	48	52	54
BF	.46	.86	1.12	.81	19.3	17.6	16.4	26	22	19	42	36	42
S-3W	.53	.81	1.70	1.01	29.2	28.6	26.3	70	59	47	50	54	52
S-3E	.72	.76	1.69	1.06	27.1	26.9	25.5	60	52	44	45	47	54
W-14	.76	.68	1.44	.96	24.6	27.0	24.9	60	54	52	47	48	55
Kelly	.56	.79	1.06	.80	23.4	22.3	20.0	40	34	28	45	38	46
<u>2.5 - 7.6 cm</u>:													
TP	.85	.80	2.16	1.27	25.0	24.5	22.3	54	45	35	46	44	54
BF	.66	.94	1.36	.99	20.0	18.9	18.1	30	26	22	44	46	48
S-3W	.58	.80	1.98	1.12	27.2	27.2	25.4	64	54	43	43	48	55
S-3E	.56	.76	1.56	.96	25.1	25.6	23.8	57	47	37	43	46	51
W-14	1.16	.98	1.63	1.26	22.9	24.8	24.2	54	48	40	48	48	55
Kelly	.38	.77	.77	.64	22.1	21.3	20.1	38	33	28	38	38	44
<u>7.6 - 15.2 cm</u>:													
TP	1.06	1.42	1.24	1.24	20.0	21.9	22.3	44	41	37	47	49	46
BF	1.04	1.10	1.78	1.31	21.4	20.6	19.4	34	29	25	46	49	48
S-3W	.74	.84	2.58	1.39	23.2	25.1	23.8	51	46	37	46	46	58
S-3E	.72	.82	2.13	1.22	23.4	23.4	23.0	48	40	34	49	50	59
W-14	.99	1.10	1.61	1.23	22.0	24.9	23.6	50	47	38	48	47	48
Kelly	.48	.83	1.84	1.05	22.3	20.9	18.8	41	32	24	41	35	52
<u>Interaction means</u>:													
TP	1.05	1.25	1.81	1.37									
BF	.72	.97	1.42	1.04									
S-3W	.62	.82	2.09	1.17									
S-3E	.67	.78	1.79	1.08									
W-14	.97	.92	1.56	1.15									
Kelly	.47	.80	1.22	.83									

main effect of bulk density was significant at the 0.01 level. Soil types were significantly different (0.01 level) with the main difference due to Kelly and TP (0.83 mm vs 1.37 mm) (table 2). None of the interactions were large. The interaction between depth and bulk density was not significant. The largest interaction was between bulk density and soil type (0.05 level) (fig. 2).

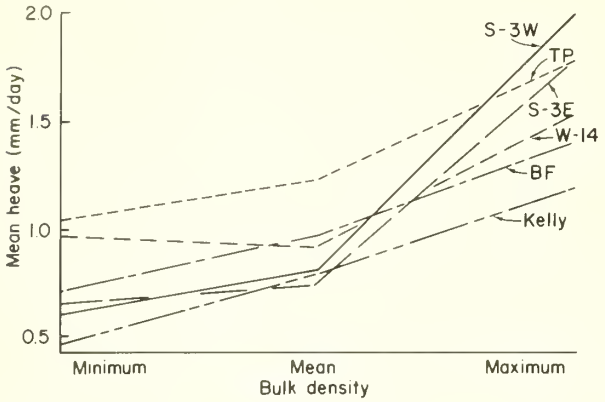


Figure 2.—Interaction diagram showing the relation of soils and bulk density to mean frost heaving per day for six soils in northern Arizona.

The general trend was the same for all soils. Bulk density was dominant in its effect on frost heaving, and this dominance was mainly due to the highest bulk density level.

The total water content in each soil sample before freezing was essentially the same (table 2), which indicates that some of the pores in samples at the lower density levels are filled with air, possibly due to lower capillarity. The soil frost depth was greater at the maximum bulk density levels (table 2).

Discussion

Frost heaving results from the flow of water through the soil to a freezing front where layers of ice are formed (Taber 1929). This movement of water is sometimes referred to as segregation, and is related to negative water pressure (or tension) and permeability. In a heavy clay soil, permeability rates are generally low and water tensions can be high. In a coarse sand, permeability rates are high but soil water tension does not usually develop. According to Penner (1958), a silt soil is ideally suited to frost heaving because soil water tension can be developed and the soil is relatively permeable.

The six soils in this study had fairly high silt contents but were low in clay. In every case when the soils were compacted, frost heaving increased. Compaction most likely improved water flow to the freezing front. Since the total water content of all soils at each bulk density level was essentially the same, soils at the lowest bulk density must have had a considerable amount of pore space filled with air. As a result, capillary flow was restricted and frost heaving was minimal. At mean bulk density levels there were fewer air-filled pores, and capillary flow increased as did frost heaving. At the highest bulk density, the air-filled pores were at a minimum and frost heaving increased greatly. The greater frozen depth in the compacted soils was probably due to a higher rate of heat conduction to the surface. Thorud and Anderson (1969) reported similar findings.

Literature Cited

Black, Charles A. (Ed.)
1965. Methods of soil analysis: Physical and mineralogical properties, including statistics of measurement and sampling. Agron. Ser. Monogr. 9, Part 1, 770 p. Am. Soc. Agron. Madison, Wis.

Haasis, F. W.
1923. Frost heaving of western yellow pine seedlings. Ecology 4:378-390.

Heidmann, L. J.
1974. An inexpensive chest for conducting frost heaving experiments. USDA For. Serv. Res. Note RM-269, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Larson, M. M.
1961. Seed size, germination dates, and survival relationships of ponderosa pine in the Southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn. Res. Note 66, 4 p. Fort Collins, Colo.

Penner, E.
1958. The nature of frost action. Proc. 38th Convention Canad. Good Roads Assoc. Tech. Pap. 53, p. 234-253.

Schramm, J. R.
1958. The mechanism of frost heaving of tree seedlings. Am. Philos. Soc. Proc. 102(4):333-350.

Taber, S.
1929. Frost heaving. J. Geol. 37:428-461.

Thorud, David B., and David A. Anderson.
1969. Freezing in forest soil as influenced by soil properties, litter and snow. Water Resour. Res. Center, Univ. of Minn. Graduate School, Bull. 10, 41 p.

Agriculture—CSU, Ft. Collins

U S D A FOREST SERVICE
RESEARCH NOTE RM-294

OREST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Endomycorrhizae Enhance Survival and Growth of Fourwing Saltbush on Coal Mine Spoils[1]

Earl F. Aldon[2]

Fourwing saltbush (*Atriplex canescens*) is a valuable shrub that provides forage for domestic livestock, food and cover for wildlife, and protects soil from wind and water erosion in semiarid areas. These features are beneficial for coal mine spoil reclamation efforts in areas receiving less than 250 mm of precipitation. Inoculation of saltbush seedlings with *Glomus mosseae* improves transplanting success.

Keywords: Inoculation, endomycorrhizae, coal mine spoils, *Atriplex canescens*, *Glomus mosseae*.

Recent work shows that growth of fourwing saltbush is enhanced under greenhouse conditions by the presence of vesicular-arbuscular (VA) endomycorrhizae (Williams et al. 1974). Endomycorrhizae are present on 13 other common shrubs found in the semiarid Southwest (Williams and Aldon 1975); identity of these mycorrhizae is under investigation. VA mycorrhizae on other plant species reduce internal plant resistance to water flow and water uptake (Safir et al. 1972), and assist in the uptake of phosphates (Daft and Nicolson 1969). The value of these attributes to plants growing in a semiarid environment is obvious, but heretofore untested. The purpose of this test, therefore, was to determine whether or not endomycorrhizae would improve survival and growth of fourwing saltbush, an important revegetation species in the Southwest, on coal mine spoils.

In this study, fourwing saltbush plants were grown from seed in small 4.75 x 6.35 cm asphalt plant bands by special techniques (Aldon 1970c). All bands were filled to 1.9 cm of the top with soil having a particle size less than 4.18 mm. The sandy loam soil was from an alluvial site, with a pH of 7.5 and a saturated conductivity of 0.67 mmho/cm. A 1.75 gram sample of soil infested with *Glomus mosseae* Nicol. and Gerd.,[3] a phycomycete reported to form endomycorrhizae on many species of plants, was added to one-half of the plant bands. The control soil was not treated.

Five dewinged fourwing saltbush seeds were planted in each band and covered with additional soil up to 0.5 cm from the top. They were grown outdoors and irrigated with municipal water. Plants were thinned to 1 plant per band, and overwintered in a lathhouse.

Twenty-one replications of each treatment (mycorrhizal and control) then were planted in the field by tested methods (Aldon 1970a) on coal mine spoils of the McKinley coal mine, 32 kilometers northwest of Gallup, New Mexico. The site is at an elevation of 2100 meters in the pinyon-juniper-sagebrush vegetation type. The spoils material resulted from mining completed in 1969.

---

[1] *The research reported here is a contribution to the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a USDA Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements. This work was conducted in cooperation with Pittsburg and Midway Coal Company. We appreciate the assistance we received.*

[2] *Principal Hydrologist, Rocky Mountain Forest and Range Experiment Station, located at the Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[3] *Inoculum furnished by D. H. Marx, Principal Plant Pathologist, Southeastern Forest Experiment Station, USDA Forest Service, Athens, Georgia.*

This site received 190 mm of precipitation during the study year, about half the normal amount. Some flooding occurred late in the second growing season, and the plants were under water for 30 hours. Inundation of this plant decreases survival markedly (Aldon 1970b). Sediment deposits covered many plants, leaving only half of the plants available for growth determinations. Survival was measured in July of the first growing season, and height and diameter of plants and root infection were measured after the second growing season. Root samples were taken at random from four treated plants and from three controls. Roots were cleared, stained, and examined for presence of endomycorrhizae (Williams et al. 1974). Controls were found to be nonmycorrhizal, but all treated samples had abundant intracellular and intercellular mycelia.

Average survival and growth were significantly better on plants grown in soil infested with *G. mosseae*:

	Mycorrhizal	**Control**
Height (cm)	41.7	27.4
Diameter (cm)	35.8	21.3
Size index (height times diameter)	1493	584
Survival (percent)	95	84

These results suggest that fourwing saltbush should be mycorrhizal prior to field planting. The findings are of special significance to those engaged in rehabilitation of mine spoils. Inoculation with *G. mosseae* could improve plant survival and growth on these sites.

Literature Cited

Aldon, Earl F.
1970a. Fourwing saltbush can be field planted successfully. USDA For. Serv. Res. Note RM-173, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Aldon, Earl F.
1970b. Fourwing saltbush survival after inundation. USDA For. Serv. Res. Note RM-165, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Aldon, Earl F.
1970c. Growing fourwing saltbush transplants for field planting. USDA For. Serv. Res. Note RM-166, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Daft, M. J., and T. H. Nicolson.
1969. Effect of *Endogone* mycorrhizae on plant growth. II. Influence of soluble phosphate on endophyte and host in maize. New Phytol. 68:945-952.

Safir, G. R., J. S. Boyer, and J. W. Gerdemann.
1972. Nutrient status and mycorrhizal enhancement of water transport in soybeans. Plant Physiol. 49:700-703.

Williams, Stephen E., and Earl F. Aldon.
1975. Endomycorrhizal (vesicular arbuscular) associations of some arid zone shrubs. (Southwest Natur., in press.)

Williams, S. E., A. G. Wollum II, and Earl F. Aldon.
1974. Growth of *Atriplex canescens* (Pursh) Nutt. improved by formation of vesicular-arbuscular mycorrhizae. Soil Sci. Soc. Am. Proc. 38:962-965.

Agriculture—CSU, Ft. Collins

ugst 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-295

OREST SERVICE
S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Predicting Frost Heaving Susceptibility of Arizona Soils

L. J. Heidmann[1]

In 1971 a study was initiated to determine the heaving susceptibility of six Arizona forest soils. A total of 15 variables were used in a stepwise regression analysis to develop an equation for predicting frost heaving susceptibility. By using the variables—bulk density, sand content, and calcium—an equation was constructed which accounted for 83 percent of the total variation (R^2) in heaving.

Keywords: Frost heaving, *Pinus ponderosa*.

INTRODUCTION

Frost heaving is a serious problem in the regeneration of many tree species. In northern Arizona it is a major cause of first-year mortality of ponderosa pine (*Pinus ponderosa* Laws.) seedlings (Larson 1961).

A review of the literature (Heidmann 1974b) revealed that frost heaving is due to a segregation of soil water, which freezes into layers of ice variously referred to as lenses, needle ice, stalactite ice, or comb ice (kameis) (Schramm 1958).

Soil water segregates primarily because water in the smaller soil pores and adsorbed on soil particles freezes at a lower temperature than pure water. The difference between the normal and depressed freezing points provides the free energy necessary to draw water to the freezing zone and to lift the soil (Martin 1958).

Water segregates in soils that are permeable to water flow and develop a negative pressure or tension. Both permeability and negative pressure are related to soil pore size, which is a function of soil particle size or texture. A silty soil is ideally suited to frost heaving because the pores are large enough for good permeability but small enough for a negative pressure to develop (Penner 1958).

In 1971, a comprehensive study of frost heaving in Arizona was begun to identify frost-susceptible soils, and to find possible methods of controlling heaving. This Note is limited to a discussion of the former subject.

EXPERIMENTAL APPROACH

Since pore size is a function of particle size or texture, it was decided that a study of frost heaving should include soils of differing textures.

Measurements of various soil characteristics were used in regression analysis in an attempt to find an equation for predicting heaving. Parameters studied were those that appeared to be related to water availability and flow: particle size, bulk density, type and amount of clay minerals, cation exchange capacity, total calcium and magnesium, and exchangeable amounts of sodium, calcium, and magnesium. Factors such as thermal conductivity that do not appear to be strongly correlated with frost heaving (Probst 1965) were not studied.

---

[1] *Silviculturist, located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Information contained in this paper is part of a Ph.D. Dissertation submitted to the University of Arizona.*

METHODS AND RESULTS

Collection of Soil Samples

Soils of varying texture from six locations within a 40-mile radius of Flagstaff, Arizona were selected for study (table 1). Selections were based on soil survey information (Williams and Anderson 1967). At each of the six locations, soil samples were collected from the 0 to 2.5, 2.5 to 7.6, and 7.6 to 15.2 cm depths.

Soil Tests

The bulk density of each soil was determined by the sand-cone method (Black 1965). The sand-cone method is especially useful when samples are collected from soils containing rocks and it is difficult to obtain undisturbed cores.

The bulk densities for the six soils and three depths ranged from less than 1 at S-3 West (S-3 W) to 1.79 at Beaverhead Flat (BF) (table 1). Soils with low bulk densities are usually characterized by higher percentages of the finer soil particles (clays and silts); soils with higher bulk densities are made up of coarser particles (sand and gravels).

Soil particle size was determined by the hydrometer method of Bouyoucos (Black 1965). Soil texture data are also given in table 1.

One of the soils studied, Tie Park (TP), had essentially no sand, while two, Kelly Tank and BF, were from one-half to two-thirds sand. All of the soils have a fairly high silt content.

Table 1.--Bulk density and textural classification[1] for six soils from northern Arizona at three depths

Location and soil depth *(cm)*	Elevation	Bulk density	Sand	Silt	Clay	Organic matter	Textural classification[1] (USDA system)	Heaving Characteristics
	Feet		- - - *Percent* - - -					
Tie Park (TP)	7,400							Unknown
0 - 2.5		1.21	0	66	34	4.33	Silty clay loam	
2.5 - 7.6		1.08	1	66	33	1.93	Silty clay loam	
7.6 - 15.2		1.27	0	62	38	1.90	Silty clay loam	
Beaverhead Flat (BF)	3,800							Unknown
0 - 2.5		1.56	60	30	10	.33	Sandy loam	
2.5 - 7.6		1.79	52	34	14	.20	Sandy loam	
7.6 - 15.2		1.75	51	32	17	.20	Loam	
Fort Valley Experimental Forest--								
S-3 West (S-3W)	7,300							Excessive
0 - 2.5		.93	15	68	17	2.27	Silt loam	
2.5 - 7.6		.97	13	66	21	3.43	Silt loam	
7.6 - 15.2		1.07	9	66	25	1.87	Silt loam	
S-3 East (S-3E)	7,300							Little heaving
0 - 2.5		1.14	16	64	20	2.47	Silt loam	
2.5 - 7.6		1.09	15	67	18	1.47	Silt loam	
7.6 - 15.2		1.20	10	66	24	.77	Silt loam	
Beaver Creek Watershed 14 (W-14)	7,400							Unknown
0 - 2.5		1.04	10	61	29	5.20	Silty clay loam	
2.5 - 7.6		1.24	3	66	31	6.83	Silty clay loam	
7.6 - 15.2		1.32	5	66	29	2.57	Silty clay loam	
Kelly Tank (Kelly)	7,200							Moderate
0 - 2.5		1.08	63	24	13	2.57	Sandy loam	
2.5 - 7.6		1.34	61	26	13	3.73	Sandy loam	
7.6 - 15.2		1.50	57	28	15	3.20	Sandy loam	

---

[1] As determined by the hydrometer method.

The amount of organic matter varied from less than 1 percent at BF to 7 percent at Watershed 14 (W-14) (table 1).

A sample from each soil depth was sent to the Department of Soils, Water, and Engineering, the University of Arizona, for analysis of clay minerals and soil nutrients. The clay mineral analysis, done by X-ray diffraction, was used to determine the relative amounts of montmorillonite (Mt.), mica (Mi.), vermiculite (Vm.), and Kaolinite (Ka.). Each soil was also analyzed for total calcium (Ca) and magnesium (Mg) content; cation exchange capacity (CEC); and exchangeable calcium, sodium, and magnesium (ExCa, ExNa, ExMg).

The clay mineral type and relative content varied considerably (table 2). Montmorillonite content was highest in samples from BF and TP, which exhibited the greatest total heaving in laboratory freezing tests. None of the samples contained chlorite.

Soil nutrients and CEC also varied considerably (table 2).

Freezing Tests

Soil frost-heaving experiments were conducted in the laboratory using a specially constructed chest

Table 2.--Results of mineral analysis for six soils in northern Arizona[1]

Location and soil depth *(cm)*	Clay mineral type Mt.	Ka	Vm	Mi	Ca	Mg	CEC	ExCa	ExNa	ExMg
					Meg		- - - - *Meg/100 g* - - - -			
Tie Park (TP)										
0 - 2.5	4	2	1	2	2.7	2.7	28.9	17.2	.18	11.5
2.5 - 7.6	4	2	2	2	1.4	1.1	32.4	21.0	.31	11.1
7.6 - 15.2	4	2	2	2	1.5	1.1	33.7	22.4	.33	11.0
Beaverhead Flat (BF)										
0 - 2.5	5	2	1	2	18.6	3.4	16.6	14.8	.02	1.8
2.5 - 7.6	5	1	1	2	7.6	1.9	23.5	20.1	.04	3.4
7.6 - 15.2	5	2	1	2	4.4	1.4	22.6	18.6	.06	4.0
Fort Valley Experimental Forest-- S-3 West (S-3W)										
0 - 2.5	1	3	1	3	4.3	2.8	33.8	23.5	.07	10.2
2.5 - 7.6	1	3	1	3	3.5	2.3	34.7	24.0	.07	10.6
7.6 - 15.2	1	3	1	3	3.5	2.2	35.9	25.2	.11	10.6
S-3 East (S-3E)										
0 - 2.5	1	2	1	3	4.9	3.1	36.6	22.9	.06	9.7
2.5 - 7.6	2	3	1	3	4.9	3.1	38.8	27.2	.07	11.5
7.6 - 15.2	2	2	1	3	4.2	3.7	32.5	20.4	.06	12.0
Beaver Creek Watershed 14 (W-14)										
0 - 2.5	4	2	1	2	5.8	5.2	45.4	28.3	.13	17.0
2.5 - 7.6	3	3	1	3	6.7	4.5	41.0	28.2	.14	12.7
7.6 - 15.2	3	3	1	3	6.8	5.2	43.3	28.5	.15	14.6
Kelly Tank (Kelly)										
0 - 2.5	1	3	1	3	2.7	2.3	19.0	12.1	.03	6.9
2.5 - 7.6	2	3	1	3	4.2	3.0	17.8	12.0	.05	5.7
7.6 - 15.2	2	3	1	2	4.5	3.5	17.8	11.7	.04	6.1

[1] Clay mineral type and amount determined by X-ray diffraction. A scale from 0 to 5 indicates relative amounts with 0 meaning none detected and 5 meaning that the type is dominant.

(fig. 1) (Heidmann 1974a). The chest was filled with small cylinders of soil and then placed in a chest-type freezer.

Numerous authors (Taber 1929, Haley 1953, Jumikis 1956, Higashi 1958, Kaplar 1971) described various types of freezing apparatus for conducting frost-heaving tests, most of which were elaborate and expensive. In addition, most of these experiments used cylinders of soil as large as 10 by 25 cm, which meant that not many samples could be studied at one time. The 3.3- by 7.6-cm cylinders used in this study are similar to the miniature cylinders described by Lambe (1956). The primary advantage of the smaller cylinders is that many more samples may be studied at one time.

A detailed description of the construction of the freezing chest and how the freezing tests were conducted is given by Heidmann (1974a). Only a brief description will be given here.

The freezing chest was designed to simulate an open system. Sifted oven-dried soil was placed in cylinders made of polyvinylchloride (PVC) plastic pipe covered on one end with cheesecloth. To simulate frost heaving as it occurs naturally, the soil samples should freeze from the surface downward. Therefore, the cylinders were insulated on the sides by imbedding them in a sheet of styrofoam. This sheet was then placed in a pan of water. The pan was set in a plywood box insulated on the sides and bottom with styrofoam insulation. The entire box was then placed in the freezer. Water in the pan was kept above the freezing point by means of a heating tape imbedded in the insulation underneath the pan.

Frost heaving at field bulk density.—Soil cylinders were filled with the weight of oven-dried soil (less than 2 mm) necessary to duplicate the field bulk density. It was necessary to wet the soil in order to pack all of the soil into the cylinders.

The cylinders with soil were placed in trays of tapwater and allowed to reach a constant weight, after which they were weighed to the nearest 0.1 g. The cylinders were then placed in the freezing chest. Each freezing experiment lasted for 10 days.

The surface of each sample was checked every 8 hours to determine onset of freezing. At the conclusion of the freezing period the amount of heaving (height of soil surface extending above) was recorded to the nearest millimeter. In addition, the total depth of freezing was measured for each cylinder.

The mean heave per day (table 3, Yobs.) for the various soil samples was analyzed by analysis of variance. Soil samples differed significantly ($P = 0.01$).

In general, the soil samples from BF, TP, and W-14 at the 2.5 to 7.6 and 7.6 to 15.2 cm depths heaved more than the other samples.

The soils at S-3 have been observed to heave spectacularly. Larson (1961) found that several hundred first-year ponderosa pine seedlings, over half of those in his study, heaved during one night in October 1957. Larson's study was located within the same enclosure from which the S-3 samples used in this study were collected. The heaving of these soil samples in the laboratory test was intermediate.

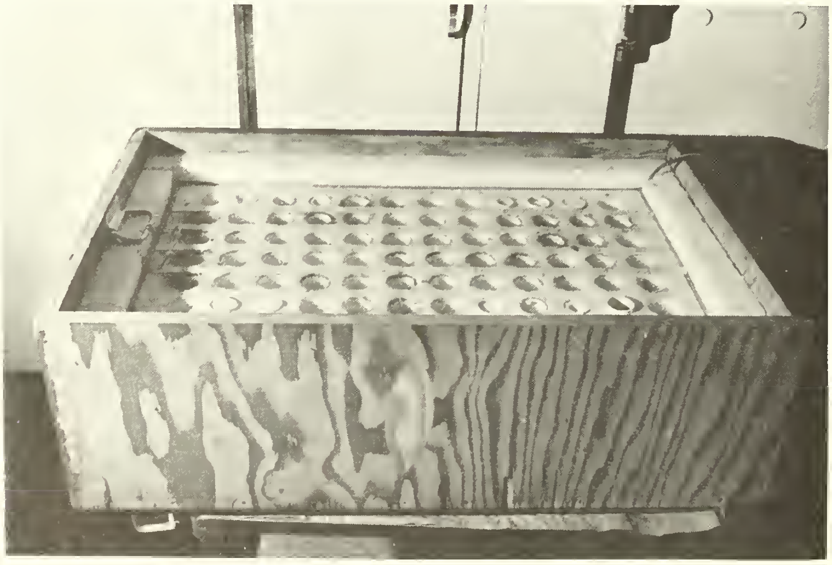


Figure 1.—Heaving characteristics of soils were studied in this plywood chest insulated with styrofoam.

Table 3.--Comparison of observed frost heaving and frost heaving as predicted by regression equation for six soils in Arizona

Location and soil depth *(cm)*	Yobs.	$\hat{Y}$	Yobs. - $\hat{Y}$
		mm/day	
Tie Park (TP)			
0 - 2.5	1.69	1.92	-.23
2.5 - 7.6	.86	1.42	-.56
7.6 - 15.2	3.04	2.14	+.90
Beaverhead Flat (BF)			
0 - 2.5	.48	1.64	-1.16
2.5 - 7.6	3.12	2.70	+.42
7.6 - 15.2	2.97	2.58	+.39
Fort Valley Experimental Forest--			
S-3 West (S-3W)			
0 - 2.5	0.77	0.50	+.27
2.5 - 7.6	.91	.75	+.16
7.6 - 15.2	1.16	1.17	-.01
S-3 East (S-3E)			
0 - 2.5	1.28	1.25	+.03
2.5 - 7.6	1.27	1.09	+.18
7.6 - 15.2	1.05	1.62	-.57
Beaver Creek Watershed 14 (W-14)			
0 - 2.5	.86	1.04	-.18
2.5 - 7.6	1.74	1.95	-.21
7.6 - 15.2	2.29	2.19	+.10
Kelly Tank (Kelly)			
0 - 2.5	.30	-.19	+.49
2.5 - 7.6	.77	.81	-.04
7.6 - 15.2	1.42	1.50	-.08

$Y = -2.52 + 3.67\ X_{BD} - .026\ X_{SAND}$

Regression Analysis

All of the data collected for the various soil parameters were used in a series of stepwise regressions to develop an equation for predicting susceptibility to frost heaving.

The regression included all of the variables for all of the soils and depths. The highest simple correlation (r) of frost heaving was with bulk density (0.61), followed by montmorillonite (0.53). None of the other variables had a strong positive correlation with frost heaving. Potassium had a negative correlation of 0.44. Montmorillonite and bulk density showed an r = 0.67.

Bulk density was the variable entered in the first step of the regression. This variable accounted for 37 percent of the variation (R^2). When sand content was added in step two, 71 percent of the variation was accounted for. These two variables gave a regression equation of:

$$\hat{Y} = -2.52 + 3.67\ X_{BD} - 0.026\ X_{SAND}$$

where $\hat{Y}$ is heaving in millimeters per day.

By adding calcium, the multiple R^2 was increased to 83 percent, and the equation became:

$$\hat{Y} = -2.67 + 4.10\ X_{BD} - .90\ X_{CA} - .02\ X_{SAND}$$

It is probably better to stop at step two, however, because it is easier to determine the bulk density and sand content for a particular soil than the calcium content.

The regression equation gives an index of frost heaving to be expected in laboratory tests. The $\hat{Y}$-variable is the expected heaving of a particular soil in millimeters per day when subjected to a constant ambient temperature of -3°C. A value less than 0.5 mm per day suggests heaving is not a problem. A value of 2 to 3 mm per day could indicate a serious heaving problem.

The regression performs reasonably well except for a negative value for Kelly at the 0 to 2.5 cm depth and an unusually large prediction for BF at the same depth (table 3).

DISCUSSION

The results of the various experiments in this study indicate that the susceptibility of forest soils to frost heaving may be predictable. The regression equation based on bulk density and sand variables requires further testing to determine its reliability. If the equation is reliable, then perhaps an index of heaving susceptibility can be derived similar to the one proposed by Haley (1953). In his system, a mean heaving of 0 to 0.5 mm per day is regarded as negligible, 2.0 to 4.0 mm is intermediate, and over 8 mm per day is high. None of the soils in the present study approached Haley's high rate, at least not in the laboratory. Soil at S-3 heaved almost 5 mm per night in December 1973, when the moisture content was approximately 50 percent. A laboratory heaving rate of 3 to 4 mm per day would seem to indicate a high susceptibility to frost heaving.

The two parameters used in the regression equation are bulk density and sand content. Reports indicate that a silty soil is most susceptible to frost heaving. Silt soils heave because the pores are small enough for a negative pressure to develop, but at the same time are large enough for water movement to occur (Penner 1958). Soils with high silt content thus tend to be ideally suited for segregation of soil water and formation of ice lenses. A heavy clay soil has limited permeability because of small pores, even though the water is under tension. A sandy soil is permeable, but water is under little tension because of the larger pores.

When the six soils were compacted in another study, heaving increased as bulk density increased (Heidmann and Thorud 1975). It seems logical to assume that compacting the soil should reduce the rate of water flow. When the soil samples were placed in pans of water, it was noted that the water reached the surface of samples packed at the minimum bulk density in a matter of minutes. It took several hours, in most instances, for water to reach the surface of the most dense samples. The total equilibrium amount of water absorbed was essentially the same, however, for the three density levels. Since the least dense samples contained the same amount of water as the most dense there must be more unsaturated pores at the lower density.

Compacting the soil decreases the pore size and probably increases capillary flow. The soils studied do not contain a large percentage of clay but do have high silt contents. Because of their relatively low clay content, they probably cannot be compacted enough to restrict water flow. However, the high silt content suggests that compaction could lead to higher rates of water movement.

The size of the clay particles alone does not limit frost heaving. The type of clay mineral is also important. Exploratory tests conducted with montmorillonite and kaolinite revealed that montmorillonite did not heave during a 7-day freezing period, while kaolinite heaved as much as 200 percent (Heidmann 1974b). According to Grim (1952) the type of adsorbed ion determines to a large extent the thickness of water layers absorbed on the clay particles. Montmorillonite with sodium as the adsorbed ion is capable of holding large amounts of water between the particles. This water does not segregate. Montmorillonite with calcium, magnesium, or hydrogen as the adsorbed ion holds little water between clay particles. Frost heaving in this study was positively correlated with montmorillonite content, although this variable does not appear in the regression equation. The six soils studied generally contained greater amounts of both exchangeable calcium and magnesium than exchangeable sodium (table 2). The reason that montmorillonite is correlated with heaving of these soils is possibly because of higher amounts of adsorbed calcium and magnesium, which results in more water being available for segregation.

The other variables studied do not appear to be strongly correlated with frost heaving. This finding tends to substantiate the theory that frost heaving is directly related to the flow of water to the freezing front, and that soil texture and permeability—which affect the rate of flow—are of primary importance.

LITERATURE CITED

Black, A. C.
1965. Methods of soil analysis, part 1, physical and mineralogical properties, including statistics of measurement and sampling. Am. Soc. Agron. No. 9, 770 p.

Grim, R. E.
1952. Relation of frost action to the clay-mineral composition of soil materials. Highw. Res. Board Spec. Rep. 2, p. 167-172.

Haley, James F.
1953. Cold room studies of frost action in soils, A progress report. Highw. Res. Board Natl. Res. Counc. Rep. 2:246-267.

Heidmann, L. J.
1974a. An inexpensive chest for conducting frost heaving experiments. U.S. Dep. Agric., For. Serv. Res. Note RM-269, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Heidmann, L. J.
1974b. An investigation into the causes and prevention of frost heaving of forest tree seedlings. Ph.D. Diss. Univ. of Ariz., Tucson. 183 p.

Heidmann, L. J., and David B. Thorud.
1975. The effect of bulk density on frost heaving of six soils in Arizona. USDA For. Serv. Res. Note RM-293, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Higashi, Akira.
1958. Experimental study of frost heaving. U.S. Army Corps of Eng., Snow, Ice, and Permafrost Res. Establ. Res. Rep. 45, Willmette, Ill., 20 p.

Jumikis, Alfreds R.
1956. The soil freezing experiment. Highw. Res. Board, B 135, p. 150-165.

Kaplar, Chester W.
1971. Experiments to simplify frost susceptibility testing of soil. U.S. Army Corps of Eng. Cold Reg. Res. and Eng. Lab., Hanover, N.H. 21 p.

Lambe, William.
1956. Modification of frost heaving of soils with additives. Highw. Res. Board Bull. 135:1-23.

Larson, M. M.
1961. Seed size, germination dates, and survival relationships of ponderosa pine in the Southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 66, 4 p. Fort Collins, Colo.

Martin, R. Torrence.
1958. Rhythmic ice banding in soil. Highw. Res. Board Bull. 218:11-23.

Penner, E.
1958. The nature of frost action. Proc. 38th Convention Canad. Good Roads Assoc. Tech. Pap. 53, p. 234-253.

Probst, John Norman.
1965. Frost heaving in relation to certain soil properties. M.S. Thesis. So. Ill. Univ., Carbondale, 50 p.

Schramm, J. R.
1958. The mechanism of frost heaving of tree seedlings. Am. Philos. Soc. Proc. 102(4): 333-350.

Taber, S.
1929. Frost heaving. J. Geol. 37:428-461.

Williams, John A., and Truman C. Anderson, Jr.
1967. Soil survey, Beaver Creek Area, Arizona. U.S. Dep. Agric. For. Serv. and Soil Conserv. Serv., and Ariz. Agric. Exp. Stn., 75 p.

Agriculture—CSU, Ft. Collins

ptember 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-296

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Carbon Black Increases Snowmelt and Forage Availability on Deer Winter Range in Colorado

Wayne L. Regelin and Olof C. Wallmo[1]

The use of carbon black offers a potential method of increasing the availability of deer forage on winter ranges in Colorado. On slopes with a southern exposure, over 40 cm of snow was melted to bare ground in February when air temperature averaged -8.8°C during daylight hours. Addition of the carbon black did not alter snow density.

Keywords: Forage availability, deer winter range, snowmelt, *Odocoileus hemionus*.

Availability of winter forage is an important factor limiting deer populations in much of North America. On many winter ranges, snow, more than any other factor, determines the availability of forage for deer (Gilbert and others 1970). The USDA Forest Service is therefore evaluating methods of manipulating snow cover to benefit deer.

Snowfences have effectively increased the availability of browse stands (Regelin 1974) by relocating snowdrifts, but often the snow falling directly upon the shrubs accumulates to depths that prohibit deer use. The possibility of reducing the depth of snow in such protected shrub stands by accelerating the snowmelt rate was examined in this study. Artificial darkening of the snow surface increases absorption of short-wave radiation, which increases the rate of snowmelt. Procedures based on this principle have been used for many years in Russia and Japan to accelerate spring snowmelt on airport landing strips and to increase summer runoff from glaciers. Slaughter (1966) cites numerous examples of such practices.

To date, most snowmelt experiments have been done in spring and early summer when temperatures are normally above freezing. Several papers report the influence of air temperature and new snowfall upon the melt rate of snow with an artificially darkened surface (Arnold 1960, Azuma 1956, Megahan 1968, Taketa and Murakami 1956). Many substances, including soil, coal dust, cinders, and carbon black, have been used. Megahan (1968) found carbon black much more effective in accelerating spring melt rate than other black materials. The purpose of this study was to determine the effectiveness of carbon black in causing midwinter snowmelt on deer winter ranges, and to determine whether such treatment changes snow density. The study was conducted under contract with the Colorado Division of Wildlife through Federal Aid in Wildlife Restoration Project W-38-R.

---

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

Study Area and Methods

Seven sites were selected on Junction Butte, Grand County, Colorado, latitude 40° N., longitude 106° W. at 2,310 to 2,350 m elevation. Effects of windblown snow were minimized on all sites by natural windbreaks provided by dense stands of serviceberry (*Amelanchier alnifolia*) and other shrubs. Each site consisted of a treatment plot, 10 m^2, and an adjacent control plot of equal size. Plots were paired on the basis of similar aspect, slope, and vegetative cover. Four sites were located on a generally northerly aspect and three on a southerly aspect:

Site	Aspect (*degrees*)	Slope (*percent*)
1	180	20
2	170	18
3	200	17
4	140	3
5	55	6
6	105	9
7	95	9

Carbon black (Philblack N 550)[2] was applied to each treatment plot with a "whirlybird" backpack fertilizer spreader at the rate of 336 kg/ha (34.4 g/m^2). The first application was made on January 30, 1974; two subsequent applications at the same rate were made on February 4 and 9, 1974. All applications were made during early morning hours with calm wind conditions, and resultant coverage was good. Treatments appeared as dark gray patches on the snow surface.

Snow depth in each treatment and control plot was measured daily at approximately 3:00 p.m. for 12 consecutive days after the first application of carbon black and on February 16, 16 days after the first application. Within each plot, 13 stakes marked in 10 cm increments were systematically located to facilitate snow-depth measurements. Snow density was measured at five locations within each plot using a Mount Rose snow sampler. Snow density was determined four times: before initial application of carbon black, before the two subsequent applications, and at the termination of the experiment. Hardness of the snow crust was recorded continuously near the plots.

Differences in snowmelt rate between treatment and control plots were so pronounced that statistical analysis was not considered necessary. Analysis of covariance was used to determine if snow density changed significantly.

Results and Discussion

Melting of snow was accelerated on all treated plots. The effect of the carbon black was more pronounced on the three sites with southerly aspect. Average snow depth was reduced by 91.8 percent, from 42.9 cm to 3.6 cm, compared to control plots where snow depth decreased naturally from 40.6 to 37.6 cm or 7.4 percent:

	Percent decrease in snow depth on:	
Date	Southerly aspects	Easterly aspects[3]
January		
31	17.7	5.3
February		
1	30.8	6.6
2	31.9	[3]2.8
3	32.4	[3]2.8
4	36.1	5.3
5	37.3	[3]0
6	38.9	[3]0.4
7	38.9	[3]0
8	38.9	[3]0
9	49.3	4.7
10	59.2	8.4
11	67.4	18.1
12	79.2	23.8
16	91.8	50.5

Average snow depth on the plots with an easterly aspect was reduced by 50.5 percent, from 53.3 to 27.4 cm, while depth did not decrease on the control plots.

A light snowfall, 2 days after the first application, covered the carbon black with 2 to 3 cm of snow. No melt occurred on the plots with an easterly aspect for the next 2 days. Carbon black was applied again on February 4, but 7 to 8 cm of snow fell that evening. The carbon black was not visible through this layer of new snow and no melt occurred for the next 4 days. Clear, cold weather prevailed for several days after the third application of carbon black, on February 9, and snow melted rapidly on all sites. The quantity of carbon black on the snow surface was increased threefold after approximately 10 cm of snow melted because the two prior applications of carbon black were again on the snow surface.

---

[2] *Trade and company names are used for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

[3] *Decreasing percentages indicate increases in snow depth due to new snowfall.*

At the termination of the study, 16 days after the first application and 7 days after the final application, all snow on the three treatment plots with southerly aspects had melted to bare ground except in small patches shaded by tall shrubs. The four treated plots with easterly aspects retained some snow, but small areas had melted to bare ground.

Maximum daily air temperature exceeded 0°C only twice during the study:

Date	**Mean**	**High**	**Low**
		- - (°C) - -	
January			
31	- 5.5	-0.6	-12.2
February			
1	- 5.2	-3.9	- 8.3
2	- 9.5	-5.6	-13.3
3	- 8.6	-1.7	-16.1
4	- 7.0	-1.1	-15.0
5	-10.6	-6.1	-12.2
6	- 9.9	-3.3	-17.8
7	-14.1	-8.9	-20.6
8	-15.2	-8.3	-25.0
9	-10.9	-3.3	-22.2
10	-10.4	-1.7	-19.4
11	- 8.6	-2.2	-19.4
12	- 4.6	-0.6	-11.6
13	- 5.4	+5.4	-15.6
14	- 7.1	+3.6	-19.4
15	- 8.1	0	-16.7

The average air temperature during daylight hours was -8.8° C. Water was observed near edges of the treatment plots when air temperature was -16° C. Temperature was not measured at the snow-atmosphere interface.

Analysis of covariance was used to test differences in snow density. Treated snow was slightly denser than on the control plots prior to both the second and third applications of carbon black, but the differences were not statistically significant (P<0.20). Snow-crust hardness values were too variable within both treatment and control plots to justify statistical analysis. General observations indicated that treatment with carbon black did not greatly alter the hardness of snow crust until snow depth was shallow, -8 cm. At this time, the rapidly melting snow was wet and slushy, and would form an ice crust at night.

Management Implications

After the treated plots had melted to bare ground, the control plots remained snow covered for 4 weeks to about March 15). Green vegetation was apparent early on the melted plots. Since deer are reaching their poorest physical condition in this period, the implications to management are obvious. Although new snowfall may negate or delay the melting effect, solar radiation is intensifying rapidly by late February, when forage needs are most critical, and the incidence of heavy snowstorms is decreasing on low-elevation winter ranges. Thus the probability of successful treatment is good.

Effects of the carbon black on vegetation were not investigated. While no influences were apparent from subjective examination the following summer, the long-term effects of residual carbon black on soil structure, soil moisture, plant phenology, growth rates, palatability, and so forth, should be studied.

Only in Finland (Rakkolainen 1971) has a blackening agent been applied extensively as a wildlife management tool. There, treatment of 180 ha with soot and "forest fertilizer" reportedly improved nesting conditions for black grouse (*Lyrurus tetrix*).

Currently, carbon black could be applied aerially at approximately $12 per ha. In the area where the present study was done (Middle Park, Colorado), approximately 10,000 mule deer (*Odocoileus hemionus*) spend the late winter on less than 2,600 ha of range. In some years thousands of deer die of starvation in February and March in this area (Wallmo and Gill 1971). Application of carbon black to selected, highly productive, snow-covered sites totaling no more than 100 ha could increase the availability of forage appreciably. If this practice were to prevent the death of several hundred deer and improve the condition of surviving does in late pregnancy, its effect on the population might be considerable.

Carpenter (1972) reported that nitrogen fertilizer increased herbage yields up to 87 percent and stimulated forage to initiate growth several weeks earlier on selected areas within this same winter range. Williams (1972) found that protein content of the net growth was appreciably increased. It is conceivable that a combination of carbon black and nitrogen fertilizer could compound these benefits at an application cost only slightly higher than for either applied separately.

Literature Cited

Arnold, K. C.
1960. An investigation into methods of accelerating the melting of ice and snow by artificial dusts. **In** Geology of the Arctic Proc., 1st Int. Symp. on Arctic Geol. 2:989-1013. [Toronto, Canada] Univ. Toronto Press.

Azuma, S.
1956. Micrometeorological observations on natural and artificially blackened snow surfaces. Sci. Rep. Saikyo Univ. (Japan). Nat. Sci. and Living Sci. Vol. 2 SIP 16051.

Carpenter, Len H.
1972. Middle Park deer study—range fertilization. p. 211-251. **In** Colo. Div. Wildl. Games Res. Rep., July, Part Two.

Gilbert, Paul F., Olof C. Wallmo, and R. Bruce Gill.
1970. Effect of snow depth on mule deer in Middle Park, Colorado. J. Wildl. Manage. 34:15-23.

Megahan, Walter F.
1968. Increasing snowmelt rate by surface additives. Ph.D. Diss. 175 p. Colo. State Univ., Fort Collins, Colo.

Rakkolainen, P.
1971. Snow melting in spring tends to assemble grouse. Suomen Rüsta 23:65-71.

Regelin, Wayne L.
1974. Middle Park deer study—Junction Butte wildlife habitat improvement project. p. 227-292. **In** Colo. Div. Wildl. Game Res. Rep. July, Part Two.

Slaughter, Charles W.
1966. Snow albedo modification, a review of literature. CRREL. TR 217, 25 p.

Taketa, M., and M. Murakami.
1956. Jinko uysetsu ni tsuite [On artificial snow melting]. Seppyo. 17(3):21-27. SIP 15660.

Wallmo, Olof C., and Bruce Gill.
1971. Snow, winter distribution, and population dynamics of mule deer in the central Rocky Mountains. Snow and Ice in Relation to Wildl and Recreation Symp. [Ames, Iowa, Feb. 1971] Proc. 1971:1-15.

Williams, Gary L.
1972. Effects of nitrogen fertilization on the nutritional quality of mule deer winter forages. M.S. Thesis. 85 p. Colo. State Univ., Fort Collins, Colo.

Agriculture—CSU, Ft. Collin

September 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-297

OREST SERVICE
.S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Early Survival and Growth of Ponderosa Pine Provenances in East-Central Kansas[1]

Frederick J. Deneke[2] and Ralph A. Read[3]

A provenance test of 78 sources of ponderosa pine (*Pinus ponderosa* Laws.) was established in 1968 near Junction City, Kansas. Initial adaptation and performance were evaluated from 6-year data on survival and growth. Progeny of sources in the Pacific Northwest and the southern Rocky Mountain regions performed poorly. Early growth appears to be clinally related to elevation of seed provenances. These preliminary results indicate that ponderosa pine planting stock for east-central Kansas should be grown from seed collected in the northeastern range of the species.

Keywords: *Pinus ponderosa*, provenance study, Great Plains.

Introduction

Ponderosa pine (*Pinus ponderosa* Laws.) is the most important pine species in western North America, and is commercially important in most States west of the Great Plains (Harlow and Harrar 1958). Its natural range (fig. 1) extends from British Columbia southward into northern Mexico, and from California eastward into the Great Plains, except Kansas (Critchfield and Little 1966).

Ponderosa pine has been planted extensively both in and outside its natural range. In the midwest it has been used in ornamental, windbreak, Christmas tree, and forest plantings. Unfortunately, few records of seed origin or performance have been maintained. Now, however, a 10-acre planting of more than 4,000 trees from 78 provenances (seed origins) grows near Junction City, Kansas (fig. 1). One of the long-range objectives of this study is to evaluate source performance, so that selection of seed for stock to be planted in central Kansas will be from best-adapted sources. Survival and height growth at age 6 have been used to evaluate early performance. The results presented here therefore should be regarded as preliminary, because early performance does not necessarily predict long-term results.

Methods and Materials

Seeds for this study were collected from at least 10 trees at each of 78 locations during 1962, 1963, and 1964. Trees were selected at random (not based on phenotype) to get good representation of germ plasm at each location. Seeds were sown in 1965 at the USDA Forest Service Bessey Nursery at Halsey, Nebraska. Seedlings were allowed to grow two seasons in seedbeds and one season in transplant beds. In 1968, 2 + 1 stock was planted below Milford Reservoir, near Junction City, Kansas, in loamy sand in the Republican River drainage area. The outplanting consists of a randomized complete block design, with individual four-tree linear plots for each of 78 sources, replicated in each of 15 blocks. This plantation is one of 13 established in the Great Plains States by the cooperative efforts of State Agricultural Experiment Stations and the Rocky Mountain Forest and Range Experiment Station Research Work Unit at Lincoln, Nebraska.

Survival percentages were recorded in 1968, 1969, and 1973. Heights to the nearest centimeter were recorded in 1968 and 1973, and the average of each four-tree plot was calculated.

Results and Discussion

Survival

Analyses of survival data for all years indicated significant differences among both provenances and blocks. Blocking effects are believed to have resulted from differences in time of spring planting. Planting required approximately 40 days, and survival declined directly with lateness of the date that blocks were established.

Average survival of all provenances has been quite high (table 1). Source 868 (California) failed

[1] *Contribution No. 556, Department of Horticulture and Forestry, Kansas Agricultural Experiment Station, Manhattan, Kansas 66506, in cooperation with the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, and funded through the North Central Tree Improvement Project NC-99 and McIntire Stennis project M.S. 771.*

[2] *Research Forester, Department of Horticulture and Forestry, Kansas State University, Manhattan.*

[3] *Principal Silviculturist, located at the Station's Research Work Unit at Lincoln, in cooperation with University of Nebraska; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

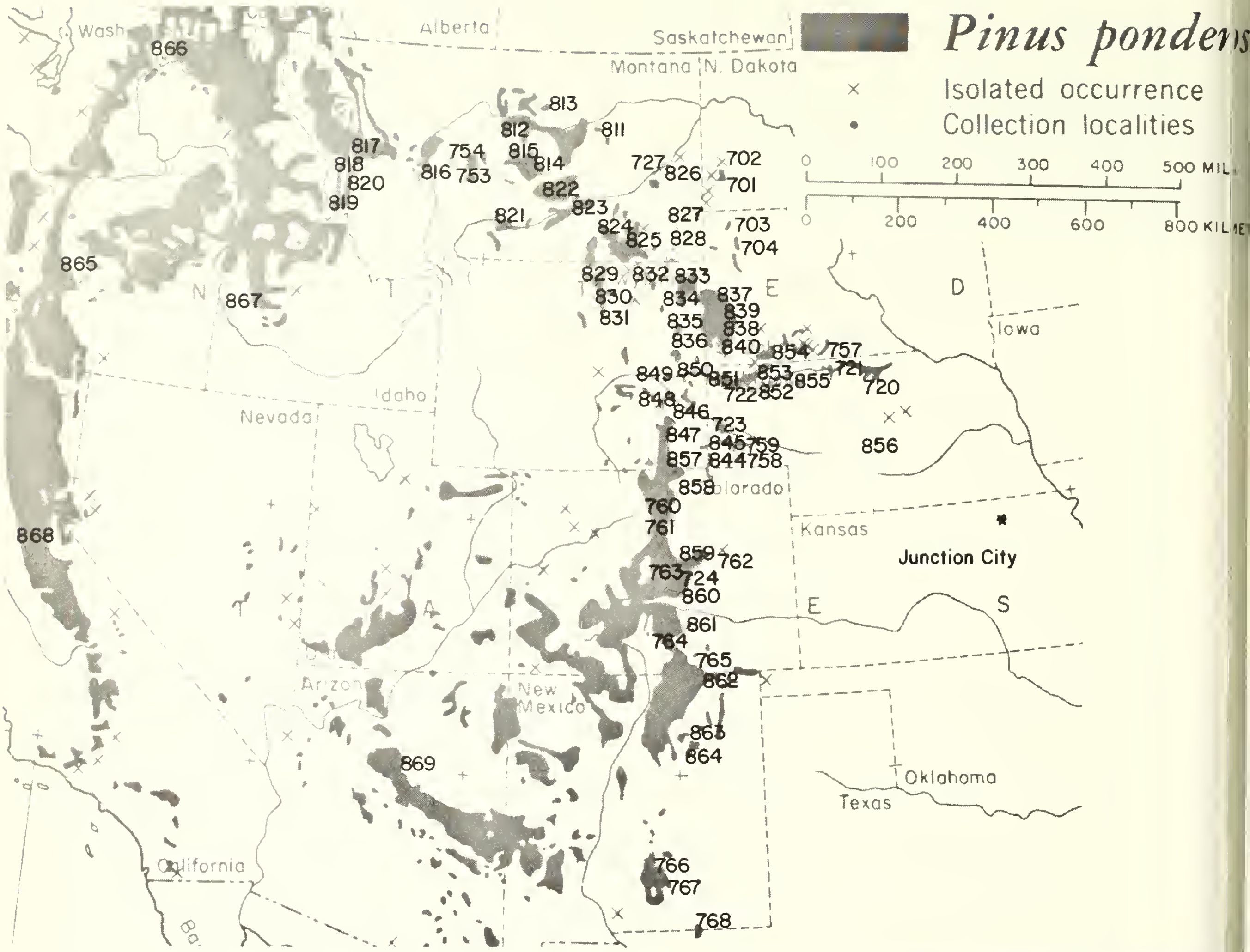


Figure 1.—Collection locations of ponderosa pi
Kansas provenance test initiated in 1968 n
tion City, Kansas. (Distribution map from C
and Little 1966.)

Table 1.--Kansas ponderosa pine provenance trial: provenance location data, and survival and height growth

Origin No.	Source data				Survival			Height growth	
	Location	Latitude	Longitude	Elevation	1968	1969	1973	1973 height	1968-73 growth
		°N	°W	*m*	- - - *percent* - - -			*cm*	*cm*
FAR WEST:									
866	WA	48.3	111.9	488	77	73	73	78.5	53.8
867	ID	44.0	116.0	1036	73	70	50	63.8	43.1
868	CA	38.6	120.7	762	0				
BITTERROOT VALLEY:									
817	MT	47.0	113.7	1036	65	60	48	70.2	55.8
818	MT	46.7	114.2	1433	65	53	40	62.5	47.9
819	MT	45.9	114.2	1250	63	58	58	62.6	44.6
820	MT	46.2	114.0	1372	85	83	75	67.3	49.5
NORTH CENTRAL MONTANA:									
816	MT	46.6	111.8	1372	100	98	95	97.6	77.8
754	MT	47.1	110.8	1372	97	93	93	96.8	78.3
815	MT	47.1	109.2	1463	88	87	87	75.0	59.2
814	MT	47.1	109.0	1128	75	75	75	82.9	66.4
812	MT	47.5	109.5	1036	88	88	88	99.9	78.9
813	MT	47.9	108.6	1433	97	95	93	92.9	75.0
811	MT	47.6	106.9	884	98	98	95	108.1	86.9

Table 1.--Kansas ponderosa pine provenance trial:
provenance location data, and survival and height growth (continued)

Origin	Source data				Survival			Height growth	
No.	Location	Latitude	Longitude	Elevation	1968	1969	1973	1973 height	1968-73 growth
		°N	°W	*m*	- - - *percent* - - -			*cm*	*cm*
SOUTHERN MONTANA:									
821	MT	45.8	109.0	1158	95	93	93	98.7	80.7
822	MT	46.2	108.4	1158	93	93	93	106.2	83.8
823	MT	46.1	107.4	884	95	93	88	109 3	87.9
824	MT	45.9	106.6	1036	93	93	88	96.3	79.5
825	MT	45.7	106.0	1097	97	95	95	112.9	91.7
MISSOURI PLATEAU:									
727	MT	46.9	105.2	808	77	75	75	76.7	57.9
826	MT	47.0	104.7	838	90	82	75	89.1	74.3
702	ND	46.9	103.5	762	90	90	90	87.9	69.5
701	NO	46.6	103.4	792	90	90	88	91.4	70.1
827	MT	45.8	104.5	1158	100	100	97	100.5	79.3
828	MT	45.6	104.1	1219	100	98	95	105.3	85.5
703	SD	45.8	103.5	975	93	90	90	89.9	70.7
704	SD	45.6	103.2	1052	97	97	97	97.6	77.8
BIGHORN MOUNTAINS:									
829	WY	44.8	107.3	1554	95	93	90	89.4	73.3
830	WY	44.6	107.1	2134	93	93	92	69.1	53.8
831	WY	44.2	106.8	1768	93	93	87	91.7	75.2
BLACK HILLS:									
832	WY	44.9	105.6	1189	95	95	95	97.1	79.6
833	WY	44.6	104.3	1219	95	95	95	89.9	69.7
834	WY	44.4	104.4	1676	92	90	90	91.6	72.1
835	WY	43.9	104.2	1548	98	97	92	90.3	71.7
836	WY	43.7	104.1	1244	93	92	85	84.1	67.5
837	SO	44.3	103.8	1920	97	97	90	97.9	77.9
838	SO	43.9	103.6	1731	82	82	82	92.4	74.3
839	SO	44.2	103.6	1646	62	62	62	84.4	65.6
840	SD	43.7	103.4	1280	85	85	83	87.1	66.7
PINE RIDGE AND NIOBRARA RIVER:									
849	WY	42.8	105.0	1584	95	92	88	87.3	70.4
850	WY	42.9	104.4	1524	95	95	90	97.3	77.6
851	NE	42.7	103.6	1280	92	92	92	92.1	70.9
722	NE	42.7	103.1	1311	90	90	90	92.7	70.5
852	NE	42.5	102.5	1158	97	95	93	99.8	78.8
853	NE	42.9	102.5	1097	95	95	95	108.6	86.3
854	SO	43.2	101.7	1006	87	87	78	93.3	73.8
855	NE	42.8	101.7	975	85	78	77	96.9	78.6
757	SO	43.2	101.0	792	92	88	88	111.5	91.7
721	NE	42.9	100.6	823	70	70	70	112.3	95.8
720	NE	42.7	99.8	701	90	90	90	123.7	103.6
NORTH PLATTE RIVER AND LODGEPOLE CREEK:									
848	WY	42.6	105.7	2103	92	90	90	70.9	54.4
847	WY	42.2	105.2	1676	93	90	75	72.7	56.2
846	WY	42.2	104.5	1280	98	98	90	102.7	82.4
723	NE	41.8	103.8	1402	97	93	93	98.9	78.5
845	NE	41.5	104.0	1554	82	82	82	76.9	61.0
844	NE	41.2	104.0	1585	88	88	82	68.6	53.2
758	NE	41.2	103.2	1372	87	83	83	84.5	68.0
759	NE	41.4	103.1	1311	87	87	87	90.9	70.1
856	NE	41.4	100.0	884	68	68	62	84.9	65.5
FRONT RANGE - NORTHERN COLORADO:									
857	WY	41.2	105.3	2347	100	100	95	79.9	63.9
858	CO	40.5	105.1	1615	90	90	88	91.3	71.8
760	CO	40.2	105.5	2560	95	95	95	77.0	62.8
761	CO	40.0	105.4	2438	90	88	88	77.1	60.1
859	CO	39.4	104.7	1981	82	80	68	70.8	54.7
762	CO	39.4	103.8	1798	78	75	75	74.7	60.1
724	CO	39.1	104.6	2256	88	87	83	84.5	66.8
763	CO	39.1	105.1	2377	78	78	78	79.6	63.7
860	CO	38.6	104.9	1981	77	75	72	87.4	69.3
FRONT RANGE - SOUTHERN COLORADO AND NORTHERN NEW MEXICO - ARIZONA									
861	CO	37.9	104.9	2012	98	98	92	90.0	71.9
764	CO	37.9	105.2	2682	95	92	92	98.6	83.0
765	CO	37.3	104.7	2134	93	93	93	107.6	84.5
862	NM	36.9	104.3	2240	95	93	88	90.8	70.0
863	NM	35.8	105.0	1951	73	73	73	81.0	62.0
864	NM	35.5	105.3	1951	60	53	53	87.4	67.7
869	AZ	35.2	111.8	2134	55	55	55	93.5	75.5
SOUTHERN NEW MEXICO:									
766	NM	33.3	105.6	2225	8	8	8	65.9	50.2
767	NM	33.0	105.4	1951	52	47	47	80.7	60.2
768	NM	32.2	104.8	1768	55	55	55	90.2	66.9
Mean					84.5	82.9	80.3	89.3	70.8
Standard deviation					17.8	18.1	18.4	21.4	19.9

completely the first growing season. Source 766 (New Mexico) also performed poorly. Generally speaking, survival was lowest in sources from west of the Continental Divide and from the southern Rocky Mountains. Survival problems in the southern sources may have resulted from unfavorable top/root ratios, since these sources were the tallest transplants, yet were dug at uniform depth.

Survival of progeny derived from natural stands in southeastern Montana, eastern Wyoming, North Dakota, South Dakota, eastern Colorado, and Nebraska was generally very good. The exception was source 856 in central Nebraska, the provenance nearest to the Kansas plantation site. Sources that survived best were from diverse locations throughout the northeastern part of the species range. Thus no well-established patterns were evident to relate survival to latitude or elevation of parent stands. Differences may become apparent in time.

Height Growth

Analyses of growth data showed significant source effects. Average growth of all sources at 6 years was 70.8 cm (table 1). As with survival, sources west of the Continental Divide and from the southern Rocky Mountains grew the least (table 1). Most growth was made by sources 720, 721 (Nebraska), 757 (South Dakota), and 811, 825 (Montana). Parent stands of sources 720 and 721 (Nebraska) and 757 (South Dakota) are at low elevations, and represent the easternmost extent of the species' natural range at mid-latitude of about 43° (fig. 1).

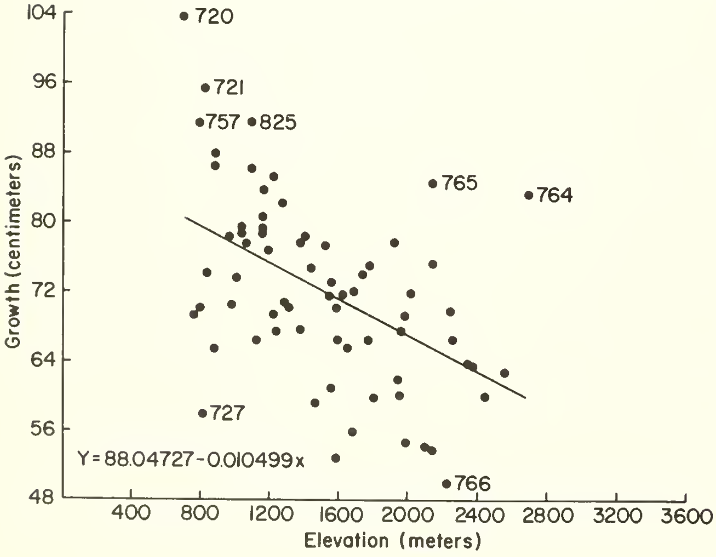


Figure 2.—Ponderosa pine in Kansas: 1968-73 growth related to elevation of seed source.

Growth data for sources east of the Continental Divide, which are known as the Interior variety (*Pinus ponderosa* var. *scopulorum*), were subjected to stepwise multiple regression analysis to determine if location and climatic variables could explain differences in growth. The variables were latitude, elevation, average annual precipitation, average annual temperature, and length of growing season. Sources 817, 818, 819, and 820 from western Montana, source 866 from Washington, and source 867 from Idaho were omitted from this analysis, because they belong to the distinct, well-recognized Pacific Coast variety (*Pinus ponderosa* var. *ponderosa*).

Results of the regression analysis indicated that only one variable, elevation, was significantly (inversely) associated with growth. It accounted for approximately 25 percent of the source growth variation (R = -0.50). In general, sources from lower elevations grew faster (fig. 2). Others have reported similar results with ponderosa pine (Mirov et al. 1952, Callaham and Hasel 1961, Squillace and Silen 1962, and Hanover 1963).

Summary

To assure good survival and growth of ponderosa pine in central Kansas, it appears that seed should be obtained from stands in the northeastern part of the species range east of the Continental Divide and from low elevations. A particularly promising location appears to be that of provenances 720, 721, and 757 in north-central Nebraska and adjoining South Dakota.

Literature Cited

Callaham, R. Z., and A. A. Hasel.
1961. *Pinus ponderosa* height growth of wind-pollinated progenies. Silvae Genet. 10(2):32-42.

Critchfield, W. B., and E. L. Little, Jr.
1966. Geographic distribution of the pines of the world. U.S. Dep. Agric., Misc. Publ. 991, 97 p.

Hanover, J. W.
1963. Geographic variation in ponderosa pine leader growth. For. Sci. 9(1):86-95.

Harlow, W. M., and E. S. Harrar.
1958. Textbook of dendrology. McGraw-Hill Book Co. Inc. 561 p.

Mirov, N. T., J. W. Duffield, and A. R. Liddicoet.
1952. Altitudinal races of *Pinus ponderosa*—a 12-year progress report. J. For. 50:825-831.

Squillace, A. E., and R. R. Silen.
1962. Racial variation in ponderosa pine. For. Sci. Monogr. 2, 27 p.

Agriculture—CSU, Ft. Collins

September 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM 298

OREST SERVICE
J S DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Sexing Large Aspen Tortrix Pupae

Daniel T. Jennings [1] and Robert E. Acciavatti [2]

Large aspen tortrix pupae can be sexed by the position and configuration of the genital pore.

Keywords: Pupal sexing methods, Lepidoptera: Tortricidae, *Choristoneura conflictana*.

The large aspen tortrix, *Choristoneura conflictana* (Walker), ranges from the northern regions of North America into the Southwestern United States (Beckwith 1973). It is considered a serious pest because periodically the larvae severely defoliate quaking aspen, *Populus tremuloides* Michx., its principal host. Life history and ecological information have been obtained for *C. conflictana* in Manitoba and Saskatchewan by Prentice (1955), in California by Wickman (1963), and in Alaska by Beckwith (1968, 1973). However, only limited information is available on the habits of this insect in Arizona and New Mexico.

For biological studies, we need to know how to differentiate the pupal sexes. A method for distinguishing pupal sex is required for determining pupal sex ratios, for rearing virgin female moths to be used in sex-attractant studies, and for determining sex of parasitized pupae. This Note describes an easy, reliable method for sexing pupae of *C. conflictana*.

Prentice (1955) determined pupal sex of the large aspen tortrix by counting the number of abdominal segments visible ventrally and posterior to the wing pads. He described the male pupa as having five abdominal segments while the female pupa has only four. Beckwith (1970) used the same method for determining pupal sex in Alaska. Because pupae often "curl" and "telescope," we have found that counting visible segments is sometimes difficult, confusing, and even nondiagnostic for sex differentiation. The position and shape of the genital opening offers a more reliable, stable, and diagnostic character.

In the female pupa, the genital pore or opening is found ventrally on the 8th abdominal segment (fig. 1A). The opening spans the 8th segment and bisects its caudal margin. The opening extends posteriorly into the cephalic region of the 9th segment. Mesially, the caudal margin of the 8th and the cephalic margin of the 9th segment project cephalad in female pupae.

The shorter genital opening of the male pupa is found ventrally on the 9th abdominal segment (fig. 1B). The opening has distinctly elevated tubercles on each side.

In both sexes of the large aspen tortrix, the anal opening is found on the 10th abdominal segment. The cremaster, a prolongation of the 10th segment, bears eight strongly hooked setae. Setae are absent on the anal rise.

Dorsally, the 1st and 10th abdominal segments are devoid of spines. Two rows of spines, a cephalic row and a caudal row, are found on each of segments 2 through 7. These are sometimes reduced to a single row on segment 8 and completely absent on segment 9. The thoracic region appears to be considerably enlarged while the abdomen is tapering.

Criteria other than the genital opening are less reliable for distinguishing pupal sex. Pupal coloration changes with age and is not a good diagnostic character. Both Prentice (1955) and Beckwith (1973) described pupae of the large aspen tortrix as being light green when first formed, later changing to reddish brown or black. We have observed that both

---

[1] *Research Entomologist, located at the Station's Research Work Unit at Albuquerque, in cooperation with the University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Entomologist, Forest Insect and Disease Management, State and Private Forestry, Southwestern Region, USDA Forest Service, Albuquerque, New Mexico.*

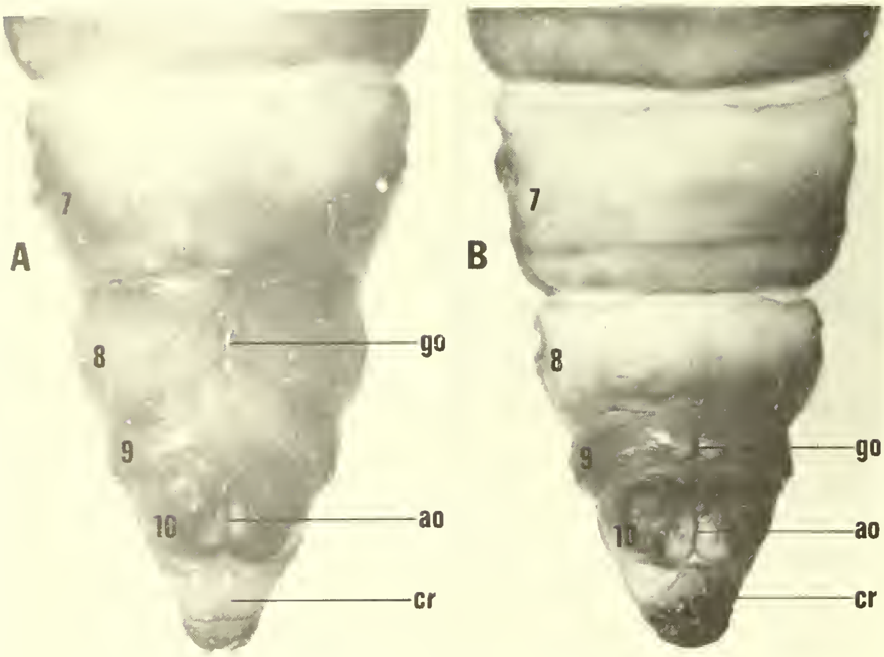


Figure 1.—

Ventral view of female (**A**) and male (**B**) pupae of *Choristoneura conflictana,* showing genital (**go**) and anal (**ao**) openings, cremaster (**cr**), and abdominal segments 7-10.

male and female pupae may be reddish brown or black.

Harvey and Stehr (1967) discussed differences in hemolymph pigmentation for several spruce- and pine-feeding *Choristoneura.* Only *C. pinus pinus* Freeman was sexually dimorphic in color, with 100 percent of the males yellow and 100 percent of the females green. For most species of *Choristoneura,* they reported that pupae become progressively darker with age. Although *C. conflictana* males are generally darker than females, coloration by itself is not a good sexing character.

Beckwith (1970) found that large aspen tortrix females were heavier than males when they were reared on the same kind of foliage. He also noted a gradual loss in daily pupal weight until emergence, and that weight varied with humidity. Thus pupal weight also is not a good sexing criterion.

The best criteria for separating pupal sexes of *C. conflictana* are the relative position and shape of the genital opening. Intact pupae can be quickly and accurately sexed. Pupal fragments can also be sexed if the last three abdominal segments are present. Actually, only the 8th or 9th segment need be present if they can be recognized. As often happens with parasitized pupae, the host pupa is broken into fragments when the parasitoid emerges. Dipterous parasitoids characteristically break pupae into about equal halves, leaving the posterior portion of the host pupa intact. These can easily be sexed by the method described here.

Pupae of this large tortricid can be sexed in the field with a 10X hand lens. Confirmation of sex depends on the position of the genital opening. Relying on coloration or counting number of segments posterior to the wing pads may lead to errors.

Literature Cited

Beckwith, Roy C.
1968. The large aspen tortrix, *Choristoneura conflictana* (Wlkr.), in interior Alaska. USDA For. Serv. Res. Note PNW-81, 10 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Beckwith, Roy C.
1970. Influence of host on larval survival and adult fecundity of *Choristoneura conflictana* (Lepidoptera: Tortricidae). Can. Entomol. 102:1474-1480.

Beckwith, Roy C.
1973. The large aspen tortrix. U.S. Dep. Agric., For. Pest Leafl. 139, 5 p.

Harvey, G. T., and G. Stehr.
1967. On coniferophagous species of *Choristoneura* (Lepidoptera: Tortricidae) in North America. III. Some characters of immature forms helpful in the identification of species. Can. Entomol. 99:464-481.

Prentice, R. M.
1955. The life history and some aspects of the ecology of the large aspen tortrix, *Choristoneura conflictana* (Wlkr.) (N. Comb.) (Lepidoptera: Tortricidae). Can. Entomol. 87: 461-473.

Wickman, Boyd E.
1963. The large aspen tortrix, *Choristoneura conflictana,* in California (Lepidoptera: Tortricidae). J. Econ. Entomol. 56:593-596.

Agriculture—CSU, Ft. Collins

September 1975

USDA FOREST SERVICE
RESEARCH NOTE RM-299

FOREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Modifications in the Malaise Insect Trap

Max H. Schroeder,[1] James C. Mitchell,[2] and J. M. Schmid [2]

Bronze screen funnel replaces plastic, and a metal frame replaces wood to make the Malaise insect trap more durable and rigid on windswept rangelands.

Keywords: Malaise insect trap, insect traps.

Dr. Henry Townes[3] provided plans for the construction of an insect-collecting trap named after Dr. Rene Malaise, and suggested that this trap can be modified and adapted to various habitat types. Reported here are some modifications in the Malaise trap for its use on the windswept sagebrush rangelands of south-central Wyoming.

In Townes' design, the Malaise trap was constructed with a wood frame holding the net and clear plastic for the insect-collecting funnel. During the 1972 summer field season, traps of this design were erected in a sagebrush community at 7,500 feet elevation 15 miles west of Saratoga, Wyoming. During this and subsequent field seasons, strong westerly winds often exceeded 30 miles per hour with occasional gusts to 50 m.p.h. These winds overturned the standard Malaise trap, damaging both nets and frames. Lesser winds also disrupted collecting by jostling the trap which splashed the alcohol from the insect-collecting jars, and by bending and cracking the framework and the clear plastic funnels.

To correct these problems, Townes' original design was modified in two ways. The first modification was to strengthen the funnel section by replacing the clear plastic with a bronze screen funnel topped with a piece of galvanized metal (fig. 1). While this created a somewhat darker funnel area toward which the insects must move to be caught, it is more rigid and durable than plastic and does not seem to have adversely affected the catch.

Figure 1.—Side view of bronze screen funnel.

---

[1] *Research Biologist, Denver Wildlife Research Center, Fish and Wildlife Service, U.S. Department of the Interior, Denver, Colorado.*

[2] *Forestry Research Technician and Entomologist, respectively, Rocky Mountain Forest and Range Experiment Station. Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[3] *Townes, Henry. 1962. Design for a Malaise trap. Proc. Entomol. Soc., Wash. 64(4):253-262.*

In the second modification, the wood framework of the trap was abandoned in favor of a more sturdy one of angle iron and aluminum tubing (conduit). To form the corner posts, 5½-foot lengths of 3/16- by 1- by 1-inch angle iron were driven into the ground at about 75-inch intervals to form a square. To these posts, 80-inch lengths of ½-inch thin-walled conduit were attached with ¾-inch U-bolts through pre-drilled holes to form the horizontal cross members of the frame (fig. 2). This framework is slightly heavier than the wood frame, but fewer pieces are required for assembly and this frame is much more durable. Assembly time for wood and metal frames is about the same the first year. In subsequent years, however, the metal framework can be assembled more quickly because wood frames tend to weather and warp during field exposure. When the wooden pieces are reassembled, it is often difficult to get them together properly unless they are distinctly marked while being disassembled. If subsequent years of trapping are anticipated in the area, the metal frames have the added advantage of being able to stand in place through the winter months thus eliminating the need for reassembly each year.

Comparative costs for the wooden and metal frames at time of construction were $13.49 and $15.92, respectively:

	Cost	
	Per unit	Per frame
Metal		
Vertical posts (angle iron)	$0.38/ft	$ 8.36
Horizontal braces (conduit)	.185/ft	4.92
U-bolts with nuts and washers	.32 each	2.56
Dowel rod, ½ inch (conduit pin)	.08/ft	.08
Total		$15.92
Wood		
Vertical posts	.14/ft	4.67
Horizontal braces (upper)	.14/ft	3.57
Horizontal braces (lower)	.14/ft	3.57
Stove bolts, nuts, washers	.07 each	1.68
Total		$13.49

Conduit is purchased in standard 120-inch lengths. After cutting the 80-inch horizontal bars, the remaining 40-inch pieces can be joined at the center by fitting them over a section of ½-inch dowel rod.

Although the original cost of the metal framework is slightly higher, we believe that the relative ease of reassembly and its durability make it the more economical choice, especially in long-term studies where the frames are left in place overwinter.

Figure 2.—
Metal framework assembly. Insert shows method of fastening conduit to angle iron posts.

nber 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-300

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Avalanche Fatalities in the United States, 1950-75

Knox Williams[1]

Snow avalanches in the United States have caused 147 deaths over the last 25 years—an average of 6 deaths per year. In the last 5 years, however, the death rate has doubled to about 12 per year. Nearly three-fourths of all avalanche victims are recreationists.

Keywords: Avalanche, avalanche accidents.

In this Note we will look at snow avalanche fatalities in the United States for the last 25 years; that is, the winters of 1950-51 through 1974-75. Reasonably accurate records exist for this period so that the statistics can be presented with confidence. Only those fatalities that could be properly verified, as with formal accident reports, newspaper articles, and similar documentation are included in this summary. No doubt there are accidents that eluded the author's search and are not included; nonetheless, the statistics presented should put into perspective the scope and magnitude of the avalanche problem in the United States.

In the last 25 years there have been 147 avalanche fatalities in the United States—an average of 6 deaths per year. No winters have been without a fatality, although only one death occurred in each of 3 winters (1952-53, 1954-55, and 1960-61). The greatest number of deaths was 22 in 1974-75 (table 1).

The United States has not had, in the last 25 years, any catastrophic avalanches claiming scores of lives, as have occurred in other countries of the world. Loss of life in any single accident has been relatively small: The most serious accident claimed seven lives; two more accidents took five lives each; and three more, four lives each.

In its history, however, the United States has not been free of major avalanche catastrophies. The worst avalanche accident in United States history happened in the State of Washington in 1910, when two snowbound railroad trains were swept off the tracks by a large avalanche; 96 men, women, and children lost their lives. In 1926, 40 lives were lost when an avalanche buried the mining community of Bingham Canyon, Utah.

An Upward Trend

In only 4 winters have avalanches claimed more than 10 victims, and 3 of these 4 winters have been in the last 5 years (fig. 1). The 5-year moving average in figure 1 smooths the data considerably. The

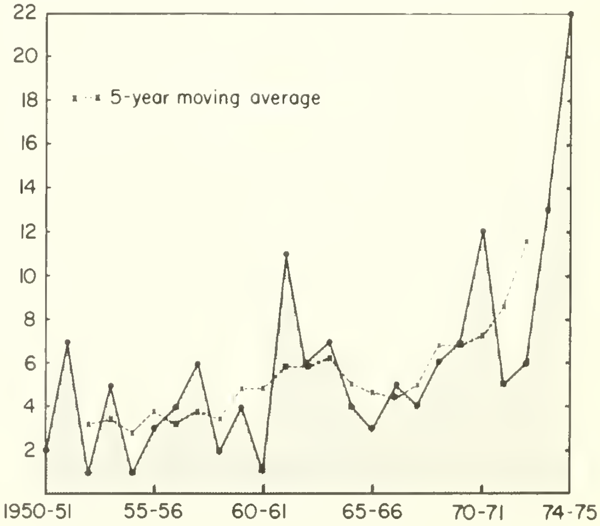


Figure 1.—The number of avalanche fatalities in the United States per winter (1950-51 to 1974-75) and 5-year moving average (dashed line).

---

[1] *Meteorologist at the Station's Research Work Unit at Fort Collins; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Table 1.—Fatal avalanche accidents in the United States, 1950-51 through 1974-75

Season and Date	Location	Fatalities
1950-51		
Apr. 23	Monarch Pass, Colo.	2 motorists
1951-52		
Dec. 30	Wolf Creek Pass, Colo.	2 truckers
Jan. 19	Sun Valley, Idaho	4 lift skiers
Feb. 29	Cobalt, Idaho	1 snowplow driver
1952-53		
Feb. 7	Source Lake, Wash.	1 ski tourer
1953-54		
Feb. 12	Mt. Washington, N.H.	2 climbers
Feb. 27	Harbor Mt., Sitka, Alaska	2 lift skiers
Apr. 2	Moon Pass, Wallace, Idaho	1 snowplow driver
1954-55		
Jan. 15	Squaw Valley, Calif.	1 lift skier
1955-56		
Feb. 19	Mt. Washington, N.H.	1 climber
Mar. 2	Mace, Idaho	1 resident
Mar. 5	Leeks Canyon, Wyo.	1 ski tourer
1956-57		
Feb. 5	Wardner, Idaho	1 resident
Feb. 24	St. Mary's Lake, Colo.	1 climber
Apr. 8	Berthoud Pass, Colo.	1 photographer, 1 hwy. employee
1957-58		
Feb. 14	Camp Bird Mine, Colo.	3 miners, 1 hwy. employee
Mar. 9	Snow Basin, Utah	2 ski tourers
1958-59		
Feb. 3	Aspen, Colo.	1 lift skier
June 20	Mt. Hood, Oregon	1 climber
1959-60		
Feb. 13	Berthoud Pass, Colo.	1 ski tourer
Mar. 9	Superior Creek, Idaho	2 workers
Mar. 19	La Plata Peak, Colo.	1 climber
1960-61		
Feb. 23	Aspen, Colo.	1 lift skier
1961-62		
Nov. 24	Arapahoe Basin, Colo.	1 lift skier
Jan. 21	Twin Lakes, Colo.	7 residents
Feb. 10	Swift Creek, Wyo.	1 snowshoer
Mar. 25	Granite Mt., Wash.	2 climbers
1962-63		
Dec. 31	Taberg, N.Y.	2 misc. recreationists
Mar. 3	Red Mt. Pass, Colo.	3 motorists
May 18	Lundin Peak, Wash.	1 climber
1963-64		
Mar. 7	Pocatello, Idaho	2 misc. recreationists
Mar. 12	Snow King, Jackson, Wyo.	1 lift skier
Mar. 14	Squaw Valley, Calif.	1 lift skier
Mar. 29	Snow Basin, Utah	1 ski tourer
Apr. 4	Mt. Washington, N.H.	2 climbers
1964-65		
Jan. 2	Sugar Bowl, Calif.	1 ski tourer
Jan. 29	Snowbank Mt., Idaho	1 snowplow driver
Jan. 31	Homestake Lake, Colo.	1 construction worker
Apr. 1	Gunnison, Colo.	1 construction worker
1965-66		
Dec. 20	Geneva Basin, Colo.	1 lift skier
Dec. 31	Park City, Utah	1 lift skier
Feb. 5	Mt. Baker, Wash.	1 ski tourer
1966-67		
Jan. 7	Loveland Pass, Colo.	2 climbers
Feb. 12	Pharaohs Glen, Utah	1 climber
Feb. 18	Skyline, Idaho	2 lift skiers
1967-68		
Nov. 26	Arapahoe Basin, Colo	1 lift skier
Feb. 19	Rock Canyon, Utah	1 hiker
Feb. 24	Leadville, Colo.	1 snowmobiler
Mar. 17	Mammoth Mt., Calif.	1 lift skier
1968-69		
Dec. 27	Slide Mt., Nevada	1 ski tourer
Feb. 24	Mineral King, Calif.	1 resident
Feb. 25	Kyle Canyon, Nevada	2 residents
Mar. 9	Mt. Rainier, Wash.	1 ski tourer
Mar. 16	Blackfoot River, Mont.	1 motorist
1969-70		
Dec. 29	Glacier N.P., Mont.	5 climbers
Jan. 29	Alta, Utah	1 lift skier
Mar. 2	Red Mt. Pass, Colo.	1 snowplow driver
1970-71		
Dec. 28	Mt. Baker, Wash.	1 lift skier
Dec. 28	Alum Creek, Reno, Nev.	1 snowmobiler
Jan. 10	Juneau, Alaska	1 climber
Jan. 15	Snoqualmie Pass, Wash.	1 motorist
Jan. 20	Willow Creek, Idaho	1 snowmobiler
Jan. 24	Yodelin, Wash.	4 residents
Mar. 16	Aspen, Colo.	1 ski tourer
Apr. 12	Eklutna Glacier, Alaska	2 climbers
1971-72		
Oct. 17	Pole Creek Mt., Colo.	1 hunter
Jan. 29	Slide Mt., Nevada	2 lift skiers
May 10	Garfield Peak, Wash.	2 climbers
1972-73		
Aug. 20	Mitchell Lake Glacier, Colo.	1 climber
Sept. 26	Yosemite N.P., Calif.	1 climber
Dec. 8	Aspen, Colo.	1 lift skier
Dec. 13	Steamboat Springs, Colo.	1 lift skier
Jan. 22	Sun Valley, Idaho	1 ski tourer
Mar. 24	Taos, N.M.	1 lift skier
1973-74		
Oct. 13	Rocky Mt. N.P., Colo.	2 climbers
Nov. 19	Mt. Shasta, Calif.	1 climber
Dec. 29	Park City West, Utah	1 lift skier
Dec. 30	Flattop Mt., Alaska	1 climber
Jan. 1	Kotoya Peak, Alaska	1 climber
Jan. 16	Grand Teton N.P., Wyo.	3 ski tourers
Jan. 27	Source Lake, Wash.	2 snowshoers
Feb. 7	Juneau, Alaska	1 snowplow driver
Mar. 2	Heavenly Valley, Calif.	1 lift skier
1974-75		
Nov. 18	Mt. Rainier, Wash.	1 climber
Nov. 23	Arapahoe Basin, Colo.	1 lift skier
Dec. 15	Monarch Pass, Colo.	1 ski tourer
Dec. 21	Guanella Pass, Colo.	1 ski tourer
Dec. 28	Aspen, Colo.	1 lift skier
Jan. 9	Crested Butte, Colo.	1 lift skier
Jan. 14	Monarch Pass, Colo.	2 ski tourers
Jan. 15	Ashcroft, Colo.	1 ski tourer
Jan. 16	Chugach St. Park, Alaska	1 climber
Jan. 19	Owen Creek, Wyo.	1 ski tourer
Feb. 5	Sun Valley, Idaho	1 lift skier
Feb. 8	Centennial, Wyo.	1 innertuber
Mar. 21	McGinnis Glacier, Alaska	1 climber
Mar. 23	Lion Mt., Mont.	1 snowmobiler
Apr. 26	Mt. St. Helens, Wash.	5 climbers
Apr. 26	Mt. Hood, Oregon	1 climber
May 10	Portage, Alaska	1 hunter

resulting trend is apparent: **Avalanche fatalities in the United States are increasing.** In the last 5 years, the average number of deaths has soared to 12 per winter, twice the 25-year average.

What are the causes of this trend, especially the jump in fatalities in the last 5 years? We will explore this question after first looking at some other data presentations.

Distribution by Month and by States

Figure 2 shows the monthly distribution of fatal avalanche accidents and number of fatalities. In all, 100 accidents have resulted in 147 victims, with January proving to be the most lethal month. This figure shows also that avalanches are not exclusively a winter phenomenon, but can and have occurred during the summer months. Only July has had no fatal accidents.

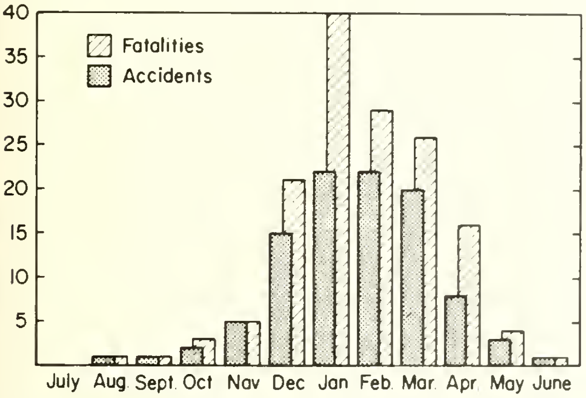


Figure 2.—Fatal avalanche accidents and fatalities by month (1950-51 to 1974-75).

In figure 3 we see the distribution of avalanche deaths by States. Colorado leads the list by far.

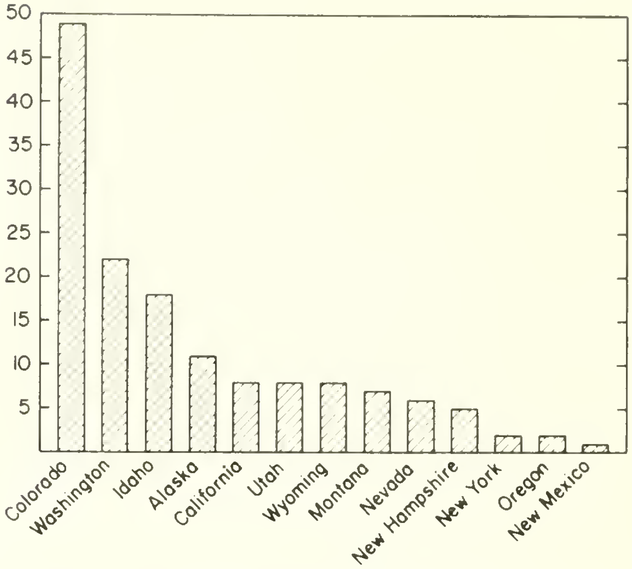


Figure 3.—Avalanche fatalities by States (1950-51 to 1974-75).

Distribution by Activity Groups

Figure 4 shows the distribution of avalanche fatalities by recreation and nonrecreation activity groups. The recreation groups include climbers, lift skiers, ski tourers, snowmobilers, and miscellaneous recreationists. Lift skiers and ski tourers are listed separately because **lift skiers** pursue their sport in and around developed ski areas and rely on ski lifts

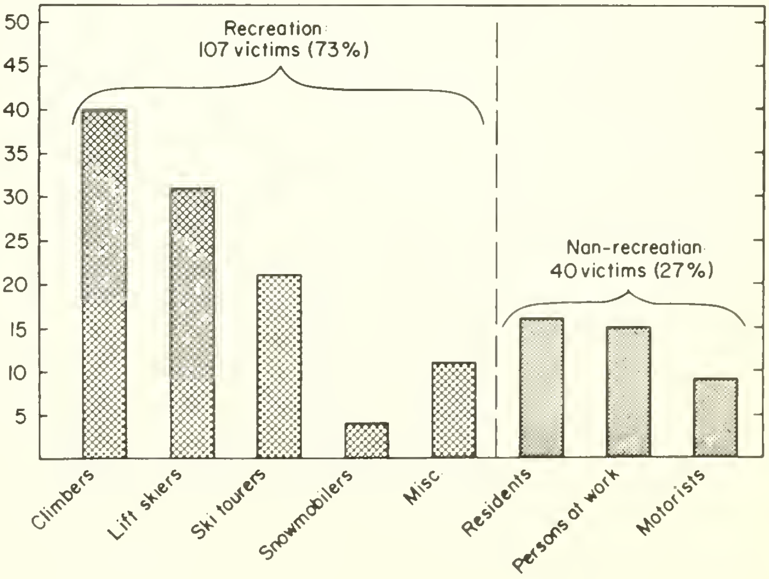


Figure 4.—Avalanche victims by activity categories (1950-51 to 1974-75).

to carry them uphill, whereas **ski tourers** take their pleasure in the backcountry, often far from any developed area. (Ski mountaineers are included as ski tourers.)

Snowmobilers have only recently fallen victims to avalanches; the first fatality of this sort occurred in 1968.

Miscellaneous recreationists include four persons playing in the snow, three snowshoers, two hunters, a hiker, and an innertuber.

The nonrecreation victims are made up of residents (persons in their homes or vacation homes), persons at work (miners, construction workers, power company workers, highway department workers—especially snowplow drivers—, and a photographer), and motorists (automobile drivers and passengers, and truck drivers).

Collectively, recreationists account for nearly three-fourths of all the fatalities.

Interpreting Recent Trends

We can now combine the facts shown in figures 1 and 4 to interpret trends in avalanche accidents. The recent jump in the number of avalanche deaths coincides with the phenomenal growth in winter sports. And, as figure 4 shows, winter recreationists have borne the brunt of avalanche fatalities. We can attribute the increase in deaths to one major cause: **More and more people—many with little or no avalanche-awareness training—are venturing into steep mountain terrain.** With the desire to get away from the crowd (and the rising expenses of lift skiing), many winter sports enthusiasts are now crossing steep slopes that had not before seen a climber, skier, or snowmobiler. With more people taking risks, the number of avalanche victims can only increase.

Comparison with Other Countries

Let us now compare the statistics for the United States with those of some other countries of the world. Austria appears to have the highest average yearly death toll—36 (table 2). Commenting on avalanche trends in Switzerland, Karl Breu (USDA-FS 1975) says:

> In recent years, there has been a clear increase in avalanche accidents affecting skiers. As a result of increased opening up of the Alps and of the lower Alps, ever greater numbers of people are entering the mountains.

In Japan, Akitaya (1974) states that "recently there is a general tendency that avalanche accidents are decreasing in industrial and residential areas, and increasing in mountains and skiing areas."

These trends echo precisely the current trends in the United States. Our zeal for winter recreation and our willingness to take risks in pursuit of pleasure often are not balanced by proper thought and preparation. Such attitudes will insure a generous number of avalanche victims every winter.

Table 2.—Avalanche statistics from selected countries

Country and authority	Fatalities		Period of record
	Annual average	Total	
Austria (Aulitzky 1974)	36	751	1949-50 to 1969-70
Japan (Akitaya 1974)	27	1,555	1918-74
Switzerland (USDA-FS 1975)	25	743	1940-41 to 1969-70
Norway (Ramsli 1975)	12	1,600- 1,700	1836-1975
France (Aulitzky 1974)	10	207	1949-50 to 1969-70
Italy (Aulitzky 1974)	10	206	1949-50 to 1969-70
Canada (Perla[1])	6	30	1970-75
Yugoslavia (Aulitzky 1974)	5	96	1949-50 to 1969-70
Iceland (Jonsson 1957)	4	602	1800-1957
Germany (Aulitzky 1974)	3	55	1949-50 to 1969-70

---

[1] Personal communication with R. I. Perla, Research Scientist, Glaciology Division, Environment Canada, Calgary, Alberta, 1975.

Literature Cited

Akitaya, E.
1974. Statistics of avalanche accidents in Japan (1918-1974) by the use of hand-sorting edge-punched cards. J. Jap. Soc. Snow and Ice 36(3):12-13.

Aulitzky, H.
1974. Endangered alpine regions and disaster prevention measures. Counc. of Europe, Strasbourg, France. 103 p.

Jonsson, O.
1957. Skriduföll og Snjoflod [Avalanches and snowfields] Akureyri, Iceland. [In Icelandic].

Ramsli, G.
1975. Report on avalanche zoning in Norway with reference to other Scandinavian countries. Paper presented at UNESCO meeting on the delimitation of zones subject to avalanches [Davos, Switzerland, July 29-31, 1975].

U.S. Department of Agriculture. Forest Service.
1975. Avalanche protection in Switzerland [Lawinenschutz in der Schweiz, translated by U.S. Army, CRREL]. USDA For. Serv. Gen. Tech. Rep. RM-9, 168 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Agriculture—CSU, Ft. Collins

ember 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-301

OREST SERVICE
S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Sturdy Probe for Measuring Deep Snowdrifts[1]

Robert L. Jairell[2]

Sections of hexagonal aluminum rod joined with pump couplings form a rigid probe that does not bend while penetrating ice layers. Bit design is important.

Keywords: Snow management, snowpack, snow measurement, snow-depth data.

Large snowdrifts in windswept terrain often are too dense, icy, or deep to measure with conventional coring equipment. When only snow-depth data are needed, the most convenient and fastest method of measuring snow is to probe the snowpack. A probing rod is commonly used to measure depths of deep snowdrifts. Our experience has shown, however, that probe design is a critical factor for accurate results. This Note describes a snow probe we have developed over a 10-year period to sample drifts as deep as 40 feet.

Description

The probe consists of sections of 9/16-inch hexagonal aluminum rod (alloy 2011-T3) coupled together with threaded steel stock and "pump-rod" couplings (fig. 1).

Hexagonal aluminum rod is superior to other materials because it is rigid, light weight (4.25 pounds for a 12-foot section), and rust resistant, and the flat surfaces are ideal for marking scales. We found ½-inch rod to be too flexible for sampling deep, dense snowdrifts because of the tendency for the probe to bend on ice layers (fig. 2). A probe made of 5/8-inch rod works well on dense snowdrifts, but requires two men to push the probe down.

Proper design of the point (or "bit") is important (fig. 3). Bit diameter must be larger than the probe rod to reduce friction and to prevent the rod from freezing in the snowpack. The point, however, must not be so large as to resist penetration excessively. The bit must be sharp enough to penetrate dense snow or ice layers, but not so sharp as to make it difficult to detect contact with the ground.

Construction

Where portability is needed, the hexagonal bar can be cut into 6-foot sections (or shorter if necessary); but for hard, deep drifts it is best to maintain the bottom section as a one-piece 12-foot section. All upper sections should be in 6-foot lengths. The cut rod should be polished on a wire wheel to remove the

---

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

[2] *Forestry Research Technician, located at the Station's Research Work Unit at Laramie, in cooperation with University of Wyoming. Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

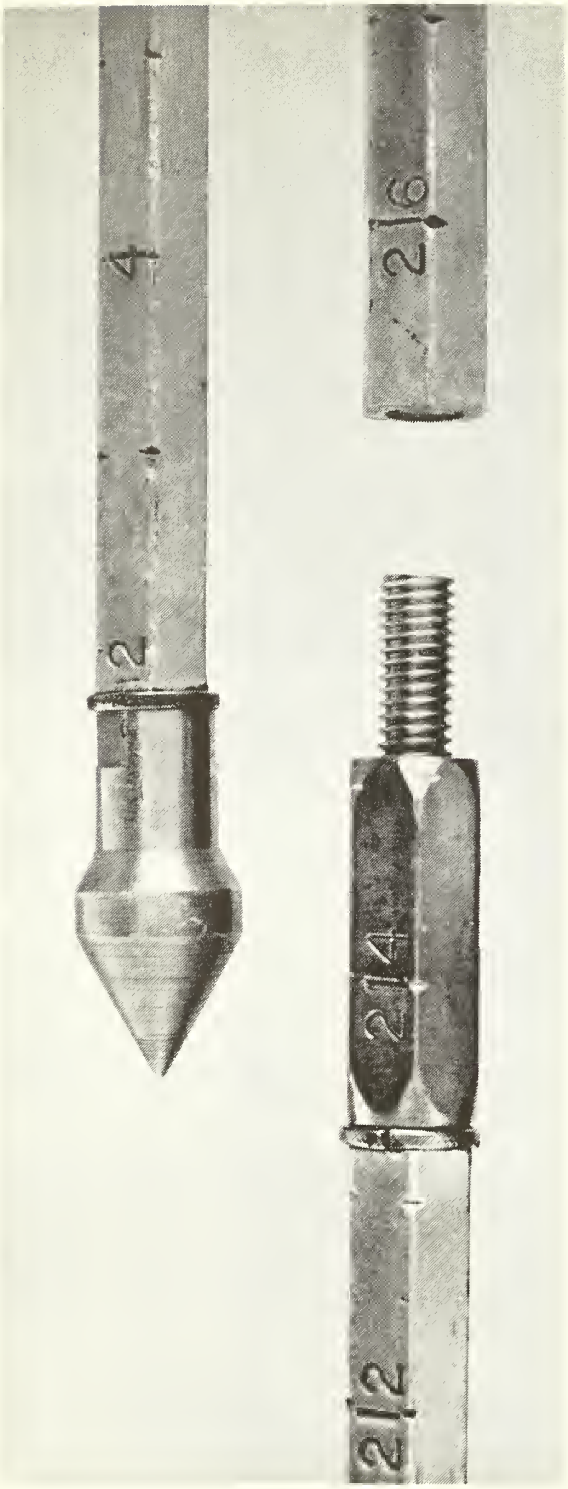


Figure 1.—Sections of a snow probe are connected with threaded steel stock and a pump rod connector.

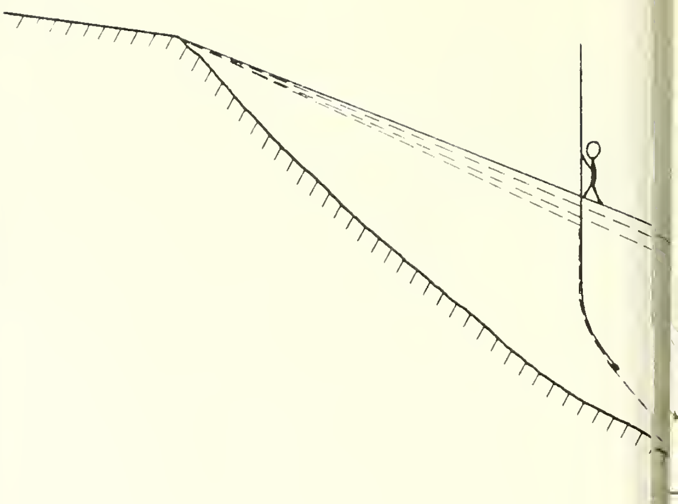


Figure 2.—A

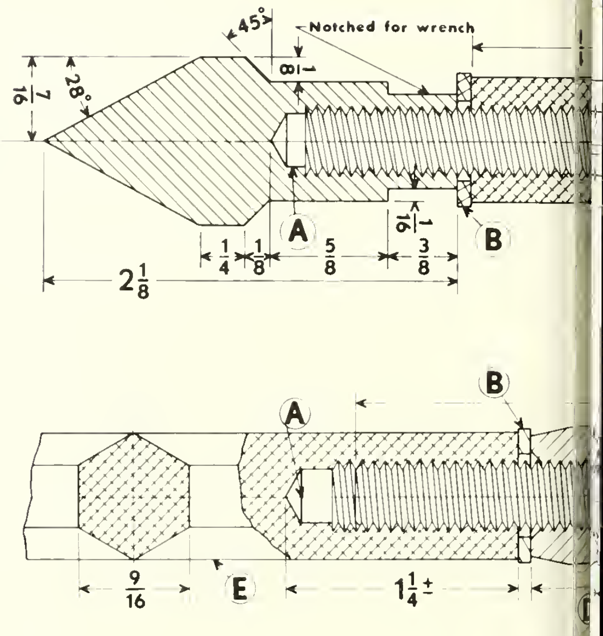


Figure 3.—De

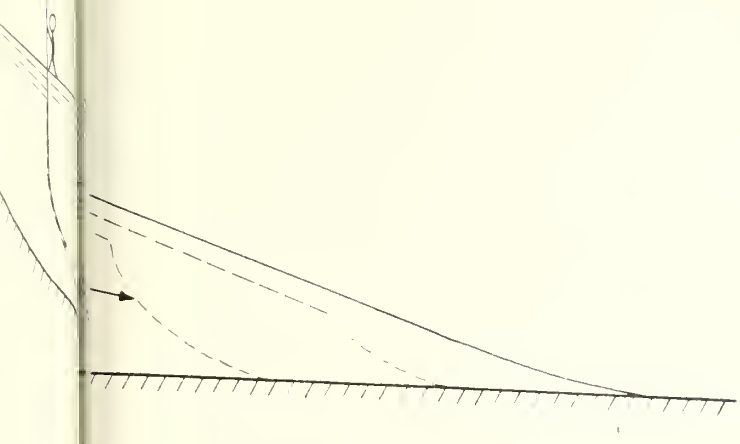


Figure 2.—A can be turned

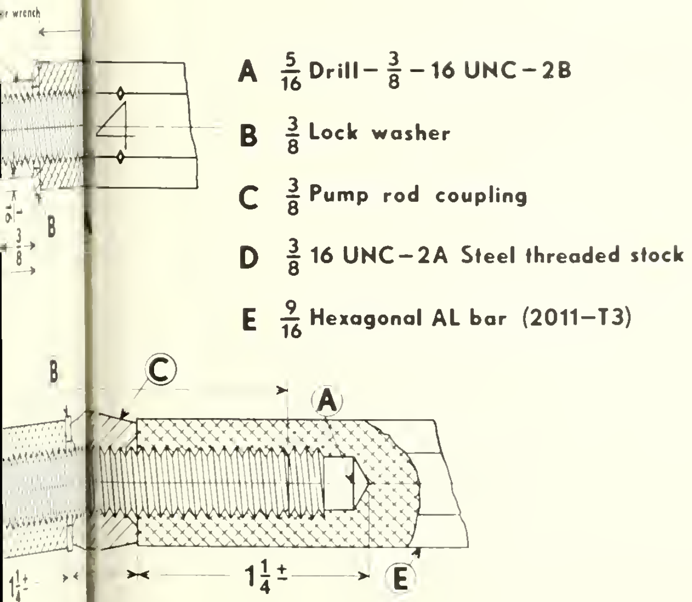


Figure 3.—D /16-inch snow

factory coating, which otherwise causes snow to stick to the probe. Holes 5/16 inch in diameter and 1¼ inch deep are drilled in both ends of each section, using a lathe to insure proper alinement. The holes then are tapped (threaded) with a 3/8-inch bottoming tap.

A 3½-inch length of threaded steel stock is then screwed into one end of each section. Next, a 3/8-inch pump-rod coupling (with a 3/8-inch lock washer) is screwed onto the steel stock and tightened in place with a wrench.

The bit (fig. 3) is machined on a metal lathe. It is made from 7/8-inch cold-rolled steel rod. The probe end of the bit has the same diameter as the probe (5/8 inch) and is 1 inch long. A 5/16-inch diameter, 1-inch deep hole is drilled into the probe end and tapped (threaded) with a 3/8-inch bottoming tap to attach the bit to the probe rod. An expanded diameter collar (7/8 inch in diameter and ¼ inch long) is machined on the pointed end of the bit. The angle from the collar to the tip is 28 degrees.

After the probe is assembled, depth scale divisions are measured off, scribed with a file, and stamped with numbers. Artists' oil-base paint rubbed into the numbers makes them more visible.

Materials for a 9/16-inch snow probe 24 feet long and their approximate 1974 purchase cost are listed below:

Part	Quantity	Amount
9/16-inch hexagonal aluminum bar (Alloy 2011-T3)	24 feet	$15.76
3/8-inch threaded stock	10½ inches	.69
3/8-inch pump rod coupling	2 each	1.14
3/8-inch lock washer	3 each	.09
7/8-inch cold-rolled steel rod	4 inches	.20
Total		$17.88

Field Techniques

With two men pushing the probe down in strong thrusts, we have measured depths up to 40 feet in snow with a 50 percent water equivalent. When probing drifts deeper than 12 feet, single 6-foot sections are added successively as the probe is pushed into the pack. These sections of rod should be removed as they are pulled from the pack to prevent bending the rod.

The design of this probe minimizes rod freezing, but occasionally snowpack conditions and air temperatures combine to make this situation unavoidable. In this event, the probe can be freed by either twisting the rod (clockwise) with a wrench, or by tapping the top of the probe with a wooden mallet, quickly followed by an upward pull on the probe.

Agriculture—CSU, Ft. Collins

ember 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-302

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Submerged Burlap Strips Aided Rehabilitation of Disturbed Semiarid Sites in Colorado and New Mexico[1]

Burchard H. Heede[2]

Two planting sites with narrow submerged burlap strips showed 14 times less soil loss than control sites without burlap. Gullies and deep rills need to be reshaped to gentle swales before burlap is installed. Plant cover should become established before burlap disintegrates—about 5 years.

Keywords: Erosion control, bank stabilization, grassed waterways, flow control, mountain slopes.

The main objective in rehabilitating disturbed or deteriorated sites is to establish a vegetation cover that will not only alleviate erosion, but, by perpetuating itself, will also eliminate further maintenance costs.

Often, however, a plant cover cannot be achieved directly, and supplemental measures are needed. Some steps may be performed before planting or seeding, such as reshaping the topography; others may be applied simultaneously, such as fascine works, nylon netting, and brush and stone sills on hillslopes or road cuts. The submerged burlap strip, placed vertically into the soil and protruding somewhat above the ground surface, is a relatively new type of supplemental measure that has been effective in certain situations. This aid, closely followed by planting was used in two semiarid sites: one, on four manmade waterways in the Colorado Rocky Mountains; the other, on a road-cut slope in the Gila Mountains of New Mexico. The methods and results from these two tests are described in this Note.

Design Criteria

The basic concept of burlap strip application for site stabilization is twofold:

1. A strip set vertically into the ground, acts as a mechanical reinforcement of the upper soil mantle. This strip cannot prevent soil creep or slides along its full length; however, it can prevent or reduce soil movement when only part of the strip length is endangered. Also, this method cannot stabilize slides that are seated deeper than strip depth.
2. The protruding portion of the burlap strip acts as a barrier to surface soil movement, thus increas-

---

[1] *Paper presented at the winter meeting of American Society of Agricultural Engineers, Chicago, Ill., Dec., 1975.*

[2] *Principal Hydraulic Engineer, located at the Station's Research Work Unit at Tempe, in cooperation with Arizona State University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

ing surface stability. Because surface soil movement can hinder the establishment of plants with undeveloped root systems, surface stability is especially important where seeds or young plants are to be planted. Also, the several layers of burlap create a certain stiffness that prevents the surface-protruding portion of the strip from flattening. The protrusion retains its stiffness for about 2 years, and maintains a convex cross section that acts as a water spreader and miniature check dam for the surface flows (fig. 1). Flow concentrations and flow velocities are thus reduced. This change of flow regimen is especially important immediately following treatment when erosion hazards are greatest.

An additional consideration is how deep to insert the burlap strip. For soil mantle stabilization, the strip should be installed as deep as practical, time- and costwise. When slope angle, geologic structure, degree of solifluction, and other factors are compatible, a well-established grass cover effectively stabilizes the soil. Also, the main root system of most grasses and other herbaceous vegetation is located from a few inches to a foot below the ground surface (Berndt and Gibbons 1958). For our tests, the strips were inserted 10 inches deep, with a 1- to 3-inch protrusion. The rill depth on the test areas averaged less than 5 inches. Burlap strips would not be effective if the erosion channels exceeded 10 inches.

Study Sites

Alkali Creek Watershed

The first test area was on the Alkali Creek watershed in western Colorado, where four waterways were installed in 1963 to replace gullies. Altitude is approximately 8,000 feet, and annual precipitation averages 19.2 inches, 60 percent of which is snow.

The soils are derived from the Wasatch formation, of fluvial sedimentary origin, and consist of alternating layers of shale and sandstone. The alluvial soils where the waterways were imbedded have a clay content that approximates 60 percent; the remainder is primarily silt with a small percentage of sand. The montmorillonite clays give rise to high rates of expansion and contraction with soil-moisture changes that lead to excessive soil cracking.

The natural vegetation on the site of the waterways was oak brush and bunchgrass, with sagebrush on the bottomlands and depressions. Immediately following waterway construction, annual grasses and yellow sweetclover were planted to form a quick cover. The plan was to plant perennial grasses—smooth brome, intermediate wheatgrass, Kentucky bluegrass, and orchardgrass—the year after construction. The annual grasses, however, did not prevent rilling, and submerged burlap strips were installed in 1964 as additional surface protective measures.

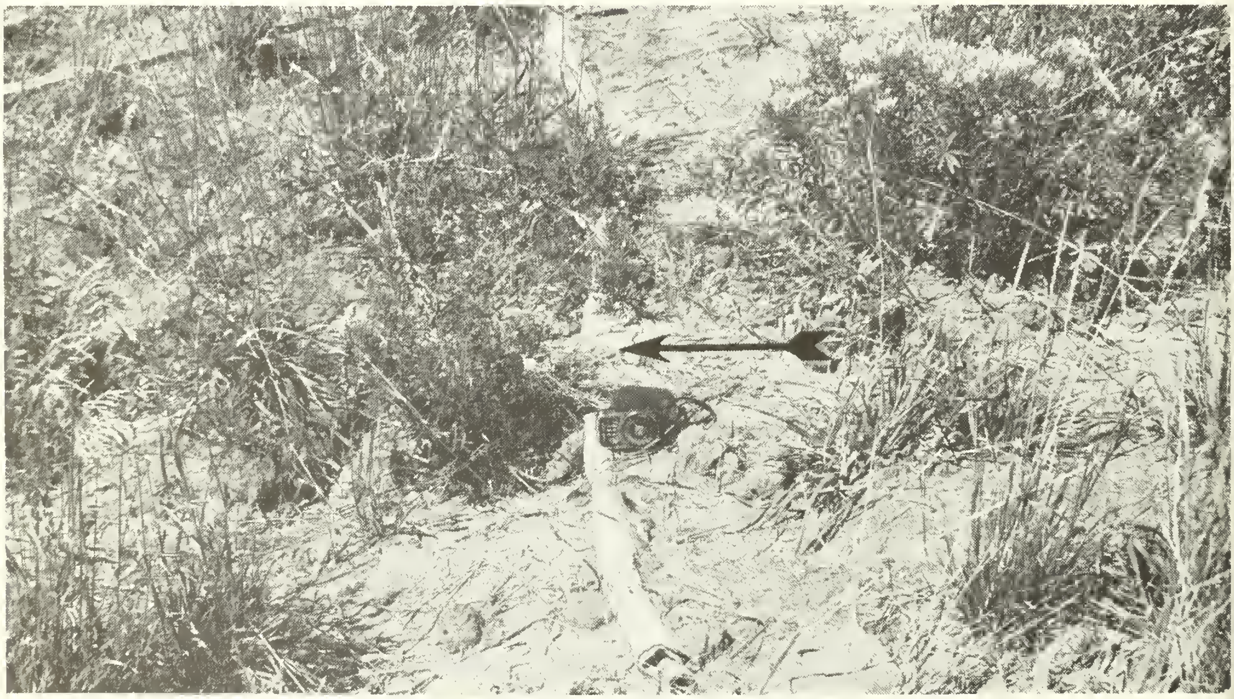


Figure 1.—Looking at a submerged burlap strip installed on waterway No. 6 on Alkali Creek watershed. Arrow indicates the direction of flow.

The cross sections of the newly installed waterways resemble topographic swales with gentle side slopes (1:8 to 1:12); flow depth is shallow and flow velocities much reduced. The average gradient of the longitudinal profile now ranges from 9 to 17 percent, and the average width of the waterway bottoms is 10 feet.

To install the burlap strips, we made 10-inch-deep furrows on the contour, with a moldboard plow. Burlap sheets, 10 feet by 10 feet, were folded into strips 12 inches wide and 10 layers thick. The strips were placed on the downhill side of the furrows, leaving 2 to 3 inches of burlap protruding above the ground surface. The furrows were then filled with the excavated soil, and the disturbed areas seeded to perennial grasses. Installation of 316 feet of burlap strips along with broadcast seeding took 8 hours for one man and a team of horses.

For the first 4 posttreatment years (1964-68), cattle were excluded from the watershed; then controlled grazing was reintroduced. Elk also used the watershed, especially in winter. Two herds of 26 animals each were counted repeatedly. Thus, from the beginning of the project, animal use was an integral part of the test.

From 1964 through 1969, the effectiveness of the submerged burlap strips was observed three times annually, which included snowmelt and runoff seasons, and the end of the summer. From 1969 through 1975, when the test ended, plots were observed sporadically.

Although high-intensity summer thunderstorms are common, the snowmelt runoffs that deliver concentrated flows for 4 to 6 weeks are a more severe test of our treatments. During snowmelt, saturation of the surface soil layer takes place, and the fine soils are erosion prone. While saturated, the soils disperse easily, and erosion hazard is especially pronounced on the slope gradients as high as 17 percent.

Gila Road Cut

Our second test with burlap strips began in July 1971 on a new road cut on the Gila National Forest in New Mexico, at about 8,500 feet elevation. The vegetation type is open ponderosa pine with some grass and brush understory. Nearby weather stations average 19.4 inches of annual precipitation; however, the fall seasons of 1971 and 1972 were unusually wet with high-intensity storms, and our erosion-control treatments were severely tested.

Soils on the cut slope were mainly reworked volcanic rock, tuff, and basalt. Like the Wasatch in Colorado, this formation had been fluvially deposited. The formation of duripan horizons indicates prolonged intervals of standstill, but the intervals were not long enough for more advanced soil development. On the cut slope, six horizons of duripan exist, separated by 3- to 6-foot layers of loose, sandy textured parent material that contains some gravel and cobbles of tuff and basalt. The platy duripans, ranging from a few to 9 inches thick, are relatively hard when newly exposed, but weather rapidly under the influence of precipitation and the atmosphere. Slope length on the area is about 50 feet, with average slope gradient of 50 percent.

Three plots, each 20 feet wide, were selected; a buffer zone separated the individual plots to avoid edge effects. The first plot was treated with burlap strips and western wheatgrass transplants. The second was planted to western wheatgrass without burlap strips, and the third remained untreated to serve as a control.

The burlap strips on the first plot were installed in hand-dug trenches 10 inches deep and as narrow as the tools permitted. Work started at the top of the bank and proceeded downslope. Excavated material was thrown above the trench. Burlap obtained in 4-foot wide rolls, was cut into sheets 20 feet long and folded into four-layer strips 1 foot wide. A burlap strip was placed against the vertical downhill wall of the trench so that about 2 inches of burlap protruded above the original slope surface (fig. 2). Then the excavation was filled and compacted by foot and hand tools. Western wheatgrass transplants were then planted above and adjacent to the strips (fig. 3).

Spacing between strips varied from 1.5 to 4 feet, and averaged 2 feet, to avoid duripans. The burlap installation obliterated rills. Not counting travel time, about 4 man-days were required to install 440 feet of burlap strip.

Sixteen transects, located on the slope gradient, were permanently marked by angle irons. The transects were established inside the plots, leaving buffer strips 3 to 5 feet wide. At each transect, a steel measuring tape was strung under tension between the angle irons. To obtain the same tension for later surveys, the distance between the iron supports was recorded with an accuracy of 0.01 foot. Elevations were measured by survey rod and engineer's level at points spaced 2 feet along the transects, for a total of 431 points. This survey was made immediately after treatment (July 1971), and repeated in October 1973.

When the new elevations were plotted on the original slope profiles, cross-sectional areas of erosion and deposition could be computed. The application of end area procedures yielded volumes, and subtracting deposition from erosion produced net erosion volumes.

The plots were revisited in November 1975; photographs taken in 1971 were compared with those of 1975 to aid in field evaluation.

Figure 2.—Placement of burlap strip into trench of road-cut slope on the Gila National Forest.

Figure 3.—The Gila burlap plot after planting. Straw mulch covers the transplants for protection against intense heating and excessive soil moisture depletion.

Results

Alkali Creek Watershed

On the Alkali Creek watershed, the submerged strips lasted and functioned for 5 to 6 years before they disintegrated and became ineffective. Remnants of the strips remain, however, 12 years after installation (fig. 4). It took 2 to 3 years for an effective perennial plant cover to become established. During the vulnerable time, the strips provided much needed stability to the waterways (fig. 5). Yet, on one reach of waterway 18, plants and burlap strips together did not stop the development of a major rill. The V-type cross section of the waterway in this reach, forced on the construction by a constriction of the valley bottom, did not allow adequate water spreading and flow concentrations took place. After 3 years, the burlap strips formed small check dams, which caused the flows to drop on unprotected ground surface below, where scour holes developed (fig. 6). Now a continuous channel up to 8 inches deep exists in this reach, and control by loose rock is planned.

Since time of installation, no maintenance on the strips was done, but the vegetation cover was enhanced by fertilization during the first 2 project years.

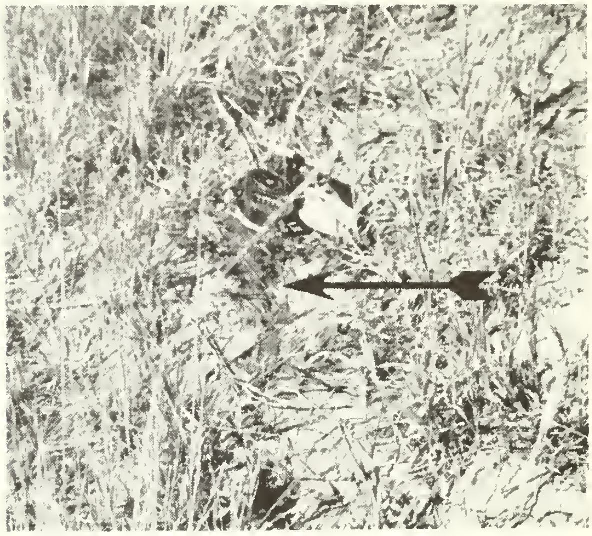


Figure 4.—Remnant of a burlap strip (arrow), 12 years after installation in Alkali Creek waterway No. 9.

Figure 5.—Upstream view of Alkali Creek waterway No. 6, 2 years after treatment.

Figure 6.—Looking upstream on middle reach of Alkali Creek waterway No. 18, where V-shaped waterway cross sections caused concentrations of flow.

Gila Road Cut

The October 1973 resurvey of the road-cut slope showed that, in spite of heavy soil disturbances on the plot with transplants and burlap, the differences in net erosion between it and the undisturbed control plot were nil for practical purposes (table 1). This result became obvious within a year after treatment (figs. 7, 8).

Although the gross erosion volume was somewhat larger on the burlap plot, it was offset by a larger volume of deposition (table 1). This finding must be evaluated in light of the fact that during treatment, the soil was disturbed more on the burlap than on the control plot where there was practically no disturbance.

In fall 1975, 2 years after the resurvey, the rills on the control plot had increased somewhat in depth and width, but were absent on the burlap plot. The strips toward the bottom of the slope could hardly be detected by eye, and toward the top they had flattened and formed one surface with the ground. The burlap was still fully intact in all strips. Our fear that water overfall at the strips on a 50-percent slope gradient might lead to undercutting and erosion had not materialized.

Also, although strip installation and planting had disturbed the soil surface much more than planting alone, the plants-only plot had 14 times more net erosion than the planted plot with burlap (table 1). The gully of the plants-only plot was still present 4 years after the survey and had increased.

Table 1.--Road-cut slope (treated July 1971), and influence of treatments on erosion and deposition as measured in October 1973

Treatment	Gross erosion	Deposition	Net-erosion	
			Volume	Depth
	Ft³	*Ft³*	*Ft³*	*Ft*
No treatment (control)	23.82	18.90	4.92	0.0082
Transplants:				
With burlap	26.46	21.84	4.62	.0077
Without burlap	71.57	6.17	65.40	.1090

Figure 7.—The Gila control plot (no treatment) 1 year after study began. Note that continuous rills and gullies dissect the slope. The horizontal striations are duripan horizons.

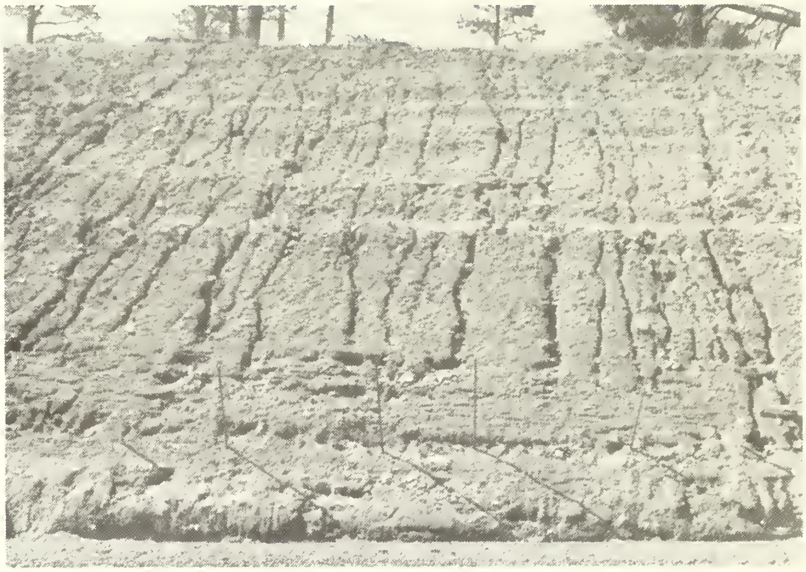


Figure 8.—The road-cut burlap plot 1 year after treatment. Continuous rills and gullies did not develop. Stakes in foreground and on crest of slope are transect markers.

Discussion and Conclusions

Alkali Creek Watershed

From the waterway study in the Colorado Rocky Mountains we learned that submerged burlap strips can effectively stabilize surface soil if two specific requirements are met. First, an effective vegetation cover must become established within the limited life (5-6 years) of the strips. When the mechanical control no longer exists, rill or gully erosion may develop. Once continuous erosion channels are formed, erosion rates will increase manyfold and control requires a major effort. All this means that for successful application, the potential for vital plant growth must be high—naturally or fortified by man with fertilizer or other means.

Second, the morphology of the ground surface plays a major role for success or failure. Narrow depressions such as gullies or rills, should be reshaped to gentle swales before burlap strips can be used successfully. Otherwise, flow concentrations in depressions lead to larger depths of flow and render the submerged structures ineffective.

That one reach of our waterway failed cannot be attributed to the strips, since the morphology of this reach had an overriding influence. Where flow concentrations did not occur, that is, on the other three waterways, submerged burlap strips combined with an effective vegetation cover were successful.

Gila Road Cut

The road-cut slope study in the Gila Mountains indicated processes basic to a successful strip application. It demonstrated that the burlap strips can control surface disturbance caused during installation, that is, increased local surface soil movements are checked by the protruding part of the strips. Furthermore, the study showed that under the severe conditions of fresh road cut, strips were a beneficial addition to planting. After 2¼ years of treatment the burlap decreased net erosion from the slope by a factor of 14. One reason for this difference is that existing rills were obliterated (fig. 3) when the burlap strips were installed. This is not the case during planting alone, and the small grass seedlings are not effective in preventing additional rilling.

All strips were still intact 4¼ years after treatment, and in spite of a 50-percent slope gradient, undermining of the burlap by water overfalls did not take place. The flexibility of the burlap allowed the strips to conform with the ground surface.

Literature Cited

Berndt, H. W., and R. D. Gibbons.
1958. Root distribution of some native trees and understory plants growing on three sites within ponderosa pine watersheds in Colorado. Rocky Mt. For. and Range Exp. Stn., U.S. For. Serv., Stn. Pap. 37, 14 p. Fort Collins, Colo.

Heede, Burchard H.
1968. Conversion of gullies to vegetation-lined waterways on mountain slopes. USDA For. Serv., Res. Pap. RM-40, 11 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Agriculture—CSU, Ft. Collins

mber 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM 303

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Service Life of Treated and Untreated Black Hills Ponderosa Pine Fenceposts: A Progress Report

Donald C. Markstrom and David H. Clark[1]

Preliminary service-life tests indicate that ponderosa pine fenceposts treated with preservatives are performing favorably after field exposures of 13 to 14 years. Test sites are in the Northern Great Plains—one in the semiarid western portion near Scenic, South Dakota; the other in the more humid eastern portion near Brookings.

Keywords: Fenceposts, preservatives, service life, *Pinus ponderosa*.

The market for wood fenceposts in the Black Hills area possibly can be expanded by demonstrating that the service life of posts can be extended with preservative treatments. Expanded post markets, in turn, could provide more outlets for roundwood that should be harvested to improve growing conditions in the Black Hills forests, and could enhance local economies through sales of unutilized tree resources.

Service tests for evaluating wood preservatives and treatment methods have been used successfully elsewhere (Blew 1955, Blew and Kulp 1964).

During 1960 and 1961, ponderosa pine (*Pinus ponderosa*) fenceposts were installed on two test sites in the Northern Great Plains—one in the semiarid western portion near Scenic, South Dakota, and the other in the more humid eastern portion near Brookings. The tests are being used to determine the service life of the posts, to evaluate the effectiveness of various preservatives and retention levels, and to demonstrate the commercially treated posts. Both pressure- and nonpressure-treated posts are being compared with untreated (control) posts.

This Note reports the progress to 1974; within 10 years, or at the conclusion of this study, complete details on the treating procedures and the chemical composition of each preservative will be published.

Methods

The semiarid test site near Scenic, on the Wall Ranger District of the Nebraska National Forest, has two plots; one is well drained, the other poorly drained (figs. 1-3). The humid site, near Brookings, located on South Dakota State University land, has one plot (fig. 4).

A total of 975 ponderosa pine fenceposts were set 2.5 feet deep on three rectangular plots. Each plot contains 325 posts, with 13 posts in each of 25 rows. One post from each treatment and retention level and one untreated post were randomly located within each row. Posts were spaced 3 feet apart in each direction. This rectangular arrangement is more advantageous than a line fence for comparing preservative treatments, because the plots are exposed to more uniform soil and drainage conditions. Drifting snow, however, tends to accumulate within the rectangular plots, and trapped snow may increase soil water content and possibly may increase decay in the posts.

---

[1] *Wood Technologist and Forestry Technician, respectively, located at the Station's Research Work Unit at Fort Collins, Colorado; Station's central headquarters is also maintained at Fort Collins, in cooperation with Colorado State University.*

Figure 1.—The poorly drained plot in the semiarid area near Scenic, South Dakota, is in the foreground; the well-drained plot is in the background (arrow). Note elevation and drainage differences. Annual rainfall averaged about 15 inches during 1960-64.

Figure 2.—The poorly drained plot near Scenic has a clay soil with a pH of 8.2. Note that soil has washed into the plot from the surrounding area.

Figure 3.—The well-drained plot near Scenic has a clay soil with a pH of 7.4. This plot has no washed-in soil. Posts are being tested with the 50-lb lateral pull.

Figure 4.—The plot in the more humid area near Brookings, South Dakota, has a silt loam soil with a pH of 6.3. Annual rainfall averaged about 25 inches during 1960-64.

All test posts were 6.5 feet long and machine peeled, with the following characteristics:

	Mean	**Range**
Diameter, small end (inches)	3.6	3.0-4.4
Sapwood thickness (inches)	1.5	0.2-2.1
Growth rate (rings/inch)	18	7-45

Local treating plants used commercial methods to treat the posts (table 1), and usually placed them in the same charge with other products. In some charges, the volume of test posts amounted to only 3 percent of the total volume being treated. Average calculated retention for most treatments differed substantially from the target retentions, possibly because other posts or products in the same charge may not have uniformly absorbed the target amounts of preservative.

The retention level of each test post treated with oilborne preservatives (PP, H&CC, CSP, VP) was calculated as follows:

$$Y = \frac{W(100 + M_1) - X(100 + M_2)}{Z(100 + M_1)}$$

where

Y = retention of preservative (lb/ft^3)

W = weight of treated post (lb)

X = weight of untreated posts at time of moisture-content determinations on sample post (lb)

Z = volume of post (ft^3)

M_1= Average moisture content, ovendry weight, of five sample posts before treatment (%)

M_2= Average moisture content, ovendry weight, of five sample posts after treatment (%)

Table 1.--Service record of 975 Black Hills ponderosa pine posts, untreated and treated with preservatives, installed on two test sites (three plots) in the Northern Great Plains of South Dakota in 1960 and 1961, with failures recorded by 1974

Treatments[1]	Retention		Penetration	Failures recorded by 1974			
				Semiarid, western (Scenic)		Humid, eastern (Brookings)	All sites
	Target	Average		Well drained	Poorly drained		
	Lb/ft^3		%	%	%	%	%
PRESSURE TREATMENTS:							
PC---50% petroleum distillate and 50% coal tar creosote	3	8.10	82.0	0	0	0	0
	6	8.60	100.0	8	0	0	3
PP---5% pentachlorophenol in petroleum oil[2]	6	7.10	100.0	0	0	0	0
PO---Osmosalts[3]	0.35	0.41	62.0	0	0	4	1
	.55	.63	64.0	0	0	8	3
NONPRESSURE TREATMENTS:							
H&CC-Hot and cold bath in 100% coal tar creosote	3	7.10	51.0	8	4	4	5
	6	9.60	81.0	0	0	0	0
CSP--Cold soak, 5% pentachlorophenol in petroleum oil[2]	3	3.90	80.0	0	0	8	3
	6	5.60	93.0	0	0	0	0
OMS--Osmoplastic,[3] butt dip only	--	--	18.7	0	16	48	21
VP---Vacuum, 5% pentachlorophenol in petroleum oil[2]	3	3.00	72.0	0	0	4	1
	6	4.70	89.0	0	0	0	0
UNTREATED (CONTROL)	--	--	--	52	68	96	72

[1] The term pressure indicates that pressure beyond that of the atmosphere was applied to the preservative during treatment; vacuum indicates that a partial vacuum was drawn and held on the posts before the preservative was applied at atmospheric pressure.

[2] Retention values include the weight of the solvent.

[3] Osmosalts, as described by the manufacturer, contains: sodium fluoride, 33.0%; disodium arsenate, 25.0%; sodium bichromate, 32.3%; dinitrophenol, 6.3%. Osmoplastic compound contains: sodium fluoride, 43.7%; dinitrophenol, 3.1%; potassium bichromate, 2.0%. Solvent in Osmoplastic compound was Avenarius Carbolineum supplied by the Carbolineum Wood Preserving Company.

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

Retention of the posts treated with the waterborne Osmosalts (PO) was calculated as follows:

$$Y = \left(\frac{W - X}{Z}\right) C$$

where

Y, W, X, and Z = same as above, and

C = concentration of solution (lbs of Osmosalts/lb of solution)

In this study, retention of Osmosalts is based on the total solid preservative absorbed by the post, and not on oxide retentions, which is the common commercial basis.

Penetration of each preservative into the post was measured on end-grain sections 15 inches from the top and the bottom, and at groundline, 30 inches from the butt. Measurements of both penetration and sapwood thickness were taken to the nearest 0.1 inch along two perpendicular lines that divided the section into four approximately equal areas. The sample consisted of five posts from each treatment group.

All test posts were air seasoned prior to treatment except those pressure treated with 5% pentachlorophenol (PP), and those that were butt dipped with Osmoplastic compound (OMS). The PP posts were steam seasoned in a pressure cylinder prior to treatment, whereas the OMS posts were treated while green.

An annual inspection to test service life consisted of applying a 50-lb lateral load to each post. Any post that broke off when pulled or had deteriorated in the top and no longer could hold a stapled wire fence was recorded as a failure.

Results to 1974

Test results (see table 1) show that, after 13 to 14 years of service at both test sites, no posts failed under the following treatments and retention levels: PC-8.1, PP-7.1, H&CC-9.6, CSP-5.6, and VP-4.7. Only one or two failures were noted from PC-8.6, PO-0.41, PO-0.63, CSP-3.9, and VP-3.0.

The H&CC-7.1 treatment had four failures (5%); OMS had 16 failures (21%), 12 of which were at Brookings and 4 were on the poorly drained plot at Scenic. The untreated posts totaled 54 failures (72%), with 24 (96%) at the Brookings plot, 17 (68%) at the poorly drained plot, and 13 (52%) at the well drained plot near Scenic.

All of the failures were butt decay at or near groundline. No posts have checked or deteriorated to the extent that fence staples would not have held.

Conclusions

Treated ponderosa pine fenceposts have a longer service life than untreated posts, especially where humid climate promotes decay. Performance of Osmoplastic butt-dip treatment is below that of other treatments, perhaps because of limited preservative penetration (about 19%) of the sapwood thickness (see table 1).

The probable life of a post is an estimate of the average life through the use of mortality curves; the estimate can be made after 10% or more of the posts have failed (MacLean 1951, Blew and Kulp 1964).

For untreated posts, the probable life at the Brookings plot is estimated at 11 years; at the poorly drained plot near Scenic, 14 years; and at the well drained plot, 16 years. The probable life of the OMS posts is estimated at 15 years at the Brookings plot and 20 years at the poorly drained plot near Scenic.

For the remaining treatments, estimating and comparing probable service life would be premature because of the low percentage of failures. Posts that have been in service for 15 years or longer with few or no failures indicate good performance (Blew and Kulp 1954). From this criterion, all except the OMS-treated and the untreated posts are performing favorably.

Literature Cited

Blew, J. Oscar, Jr.
1955. Service test on posts as a means of evaluating wood preservatives and methods. U.S. Dep. Agric., For. Prod. Lab. Rep. 1726, 12 p. Madison, Wis.

Blew, J. Oscar, Jr., and John W. Kulp.
1964. Service records on treated and untreated fence posts. USDA For. Serv. Res. Note FPL-068, 52 p. U.S. For. Prod. Lab., Madison, Wis.

MacLean, J. D.
1951. Percentage renewals and average life of railway ties. U.S. Dep. Agric., For. Prod. Lab. Rep. R886, 7 p. Madison, Wis.

Agriculture—CSU, Ft. Collins

nber 1975

U S D A FOREST SERVICE
RESEARCH NOTE RM-304

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Nutritive Value of Mule Deer Forages On Ponderosa Pine Summer Range in Arizona

P. J. Urness,[1] D. J. Neff,[2] and R. K. Watkins[3]

Chemical analyses and apparent in vitro dry matter digestibilities were obtained for mule deer (*Odocoileus hemionus*) forages appearing in monthly diets. Relative values among individual forage species were calculated based upon nutrient contents and percentage composition in the diet. These data provide land managers with the means to more precisely assess some impacts of vegetation management practices upon mule deer habitat, and to aid in designing habitat improvements.

Keywords: Mule deer, nutritive values, forages, summer range, *Odocoileus hemionus*.

Forage quality on western deer summer ranges has seldom been accorded much concern because of the prevailing view that extent and quality of winter range limits herd size. However, recent studies have underscored the importance of high-quality summer range to assure good body condition and better winter survival (Nordan et al. 1968, Trout and Thiessen 1973, Snider and Asplund 1974). Nutritional levels in summer diets also appear to influence reproductive success (Swank 1958, Julander et al. 1961, Hungerford 1965).

This study related values of individual forage species to dietary nutrients through diet composition data obtained by Neff (1974). An earlier report (Urness et al. 1975) summarized mean nutrient levels in monthly diets; this Note emphasizes the relative values among forages (table 1).

Ponderosa pine is an extensive forest type in Arizona; it occupies about 7 percent of the land area in a belt between 1,600 and 2,500 m (Nichol 1937). The ponderosa pine forest serves as spring-through-fall range for mule deer and elk (*Cervus canadensis*) and summer range for livestock (Reynolds 1972).

Precipitation ranges from 500 to 600 mm annually in a two-season pattern about equally divided between July-August monsoons and December-March snowstorms (Jameson 1969). Temperature extremes lie between -34°C and 38°C, with mean growing season temperatures ranging from 10°C and 16°C.

Understory vegetation is somewhat variable, depending upon tree density and site. Arizona fescue (*Festuca arizonica*) and mountain muhly (*Muhlenbergia montana*) are the usual dominants, but blue grama (*Bouteloua gracilis*), bottlebrush squirreltail

---

[1] *Wildlife Biologist at the Station's Forest Hydrology Laboratory, at Tempe, in cooperation with Arizona State University, when research was conducted; now with Range Science Department, Utah State University, Logan. Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Research Biologist, Arizona Game and Fish Department, Flagstaff.*

[3] *Wildlife Technician, at the Station's Forest Hydrology Laboratory, at Tempe.*

(*Sitanion hystrix*), and dropseed (*Sporobolus* spp.) are also common. Exotic grasses, frequently seeded along roadsides and on logged areas, include orchardgrass (*Dactylis glomerata*) and several wheatgrasses (*Agropyron* spp.). Native forbs are abundant; important genera include *Aster, Astragalus, Eriogonum, Geranium, Lotus, Lupinus, Senecio,* and many others. Common adventives include *Melilotus, Taraxacum, Tragopogon,* and *Trifolium.*

Common shrubs are Fendler ceanothus (*Ceanothus fendleri*), New Mexico locust (*Robinia neomexicana*), serviceberry (*Amelanchier utahensis*), and mountainmahogany (*Cercocarpus breviflorus*). Besides pine, Gambel oak (*Quercus gambelii*) is abundant in the overstory, and quaking aspen (*Populus tremuloides*) occurs as scattered patches on the more mesic sites at higher elevations.

Study Area and Methods

This study was conducted on the Beaver Creek watersheds near Stoneman Lake, 50 km south of Flagstaff on the southwestern slope of the Mogollon

Table 1.--Chemical analysis, in vitro dry matter digestibility, and relative importance (weighted value, proportional contribution to diet) of mule deer forages, Beaver Creek watershed, Arizona, May through September 1972-73

Month and plant species	Plant part	Diet composition	Protein		Acid-detergent fiber		Calcium		Phosphorus		Digestible dry matter	
			Nutrient content	Relative importance	Nutrient content	Relative importance	Nutrient content	Relative importance	Nutrient content	Relative importance	Nutrient content	Relative importance
		Pct	*Pct*		*Pct*		*Pct*		*Pct*		*Pct*	
MAY--												
Browse:												
Quercus gambelii	Leaves	11.8	24	11.6	22	10.2	0.25	6.5	0.57	14.5	58	10.4
Pinus ponderosa	Leaves;buds	6.4	7	1.8	36	9.1	.19	2.7	.13	1.7	39	3.8
Ceanothus fendleri	Leaves	2.8	22	2.6	25	2.8	.75	4.7	.44	2.6	59	2.5
Salix sp.	Leaves	.4	29	.5	28	.4	.63	.7	.83	.6	55	.3
Forbs:												
Trifolium sp.	Whole plant	15.4	33	21.0	25	15.1	.63	21.8	.57	19.2	76	18.0
Astragalus recurvus	Whole plant	13.1	23	12.8	27	13.9	.50	14.9	.37	10.6	72	14.3
Geranium sp.	Whole plant	7.0	14	4.0	27	7.4	1.00	15.8	.42	6.3	67	7.2
Lathyrus sp.	Whole plant	4.1	25	4.3	28	4.6	.88	8.1	.37	3.2	67	4.2
Vicia pulchella	Whole plant	2.2	28	2.6	28	2.5	.69	3.4	.60	2.8	70	2.4
Taraxacum officinale	Whole plant	.9	17	.6	30	1.1	.86	1.8	.50	1.1	59	.8
Geum sp.	Whole plant	.9	22	.8	14	.5	.50	1.1	.64	1.3	74	1.0
Aster commutatus	Whole plant	.2	18	.1	25	.2	1.00	.5	.57	.2	74	.2
Grasses:												
Dactylis glomerata	Leaves	26.7	31	34.9	23	24.8	.25	15.1	.57	32.8	76	31.1
Poa sp.	Leaves;flowers	3.8	12	1.9	40	6.1	.25	2.3	.30	2.4	52	3.0
Sitanion hystrix	Leaves;flowers	.9	12	.5	38	1.4	.31	.7	.32	.6	49	.7
TOTAL		96.6		100.0		100.0		100.0		100.0		100.0
JUNE--												
Browse:												
Quercus gambelii	Leaves	43.3	16	43.7	29	45.4	.44	28.9	.24	46.4	51	43.7
Cercocarpus breviflorus	Leaves	3.3	11	2.4	38	4.6	.94	4.7	.11	1.8	40	2.6
Ceanothus fendleri	Leaves	1.4	14	1.3	37	1.9	.78	1.7	.17	.9	46	1.3
Robinia neomexicana	Leaves	.8	25	1.3	25	.7	.63	.8	.32	1.3	39	.6
Pinus ponderosa	Leaves;buds	.6	8	.3	41	.9	.13	.2	.15	.4	41	.5
Amelanchier utahensis	Leaves	.5	13	.5	20	.4	1.44	1.1	.25	.4	54	.5
Forbs:												
Astragalus recurvus	Whole plant	13.2	17	14.9	30	14.4	.75	15.0	.19	11.2	67	17.7
Trifolium sp.	Whole plant	8.5	22	11.9	31	9.6	1.25	16.1	.28	10.7	63	10.7
Eriogonum racemosum	Whole plant	3.6	16	3.7	26	3.5	.63	3.5	.25	4.0	44	3.2
Lathyens sp.	Whole plant	3.6	24	5.6	28	3.7	1.44	7.9	.27	4.5	60	4.3
Taraxacum officinale	Whole plant	3.3	13	2.7	31	3.7	1.19	5.9	.36	5.4	60	3.9
Lotus wrightii	Whole plant	3.3	19	4.0	31	3.8	1.13	5.6	.21	3.1	39	2.6
Lactuca sp.	Whole plant	1.7	20	2.2	23	1.4	1.13	2.9	.37	2.7	70	2.4
Geranium sp.	Whole plant	.8	12	.6	30	.9	1.44	1.8	.37	1.3	58	.9
Melilotus officinalis	Whole plant	.6	22	.8	31	.7	1.13	1.1	.19	.5	65	.8
Tragopogon sp.	Whole plant	.6	15	.6	28	.6	.88	.8	.28	.9	67	.8
Vicia pulchella	Whole plant	.3	23	.5	37	.4	1.06	.5	.25	.5	62	.4
Oenothera sp.	Whole plant	.3	21	.4	17	.2	1.31	.6	.29	.5	72	.4
Grass:												
Dactylis glomerata	Leaves;flowers	2.6	15	2.5	34	3.2	.29	1.2	.31	3.6	54	2.8
TOTAL		92.3		100.0		100.0		100.0		100.0		100.0

Table 1.--Chemical analysis, in vitro dry matter digestibility, and relative importance (weighted value, porportional contribution to diet) of mule deer forages, Beaver Creek watershed, Arizona, May through September 1972-73--Continued

Month and plant species	Plant part	Diet composition	Protein		Acid-detergent fiber		Calcium		Phosphorus		Digestible dry matter	
			Nutrient content	Relative importance	Nutrient content	Relative importance	Nutrient content	Relative importance	Nutrient content	Relative importance	Nutrient content	Relative importance
		Pct	*Pct*		*Pct*		*Pct*		*Pct*		*Pct*	
JULY--												
Browse:												
Quercus gambelii	Leaves	40.3	12	32.0	31	42.1	.56	22.8	.14	31.1	46	34.3
Forbs:												
Melilotus officinalis	Whole plant	41.3	20	55.1	28	38.8	1.44	60.0	.22	50.6	66	50.8
Polygonum aviculare	Whole plant	4.5	11	3.3	42	6.4	1.00	4.5	.20	5.0	44	3.6
Dalea albiflora	Whole plant	3.1	19	3.8	31	3.2	1.06	3.5	.15	2.8	54	3.1
Geranium sp.	Whole plant	2.9	11	2.0	32	3.1	1.38	4.0	.29	4.4	55	3.0
Monardella odoratissima	Whole plant	1.6	7	.7	45	2.4	1.38	2.2	.20	1.7	51	1.5
Lactuca sp.	Whole plant	1.4	13	1.2	29	1.4	1.19	1.7	.25	2.2	69	1.8
Erigeron sp.	Whole plant	.3	12	.3	35	.4	1.06	.3	.21	.6	59	.3
Lotus wrightii	Whole plant	.2	16	.2	40	.3	1.44	.3	.16	Trace	38	.1
Desmanthus cooleyi	Whole plant	.2	15	.2	30	.2	1.13	.2	.14	Trace	38	.1
Grass:												
Sitanion hystrix	Whole plant	1.2	15	1.2	41	1.7	.50	.6	.24	1.7	59	1.3
TOTAL		97.0		100.0		100.0		100.0		100.0		100.0
AUGUST--												
Browse:												
Quercus gambelii	Leaves	50.5	12	50.2	31	52.3	0.75	49.7	0.18	50.6	41	49.5
Ceanothus fendleri	Leaves	6.9	19	10.3	27	6.3	.88	8.0	.18	6.0	51	8.4
Amelanchier utahensis	Leaves	1.4	11	1.2	26	1.2	1.75	3.3	.35	2.8	50	1.7
Cercocarpus breviflorus	Leaves	1.2	12	1.1	41	1.7	.75	1.2	.12	.6	46	1.3
Pinus ponderosa	Leaves	.2	6	.1	39	.3	.25	.1	.13	Trace	43	.2
Forbs:												
Lotus wrightii	Whole plant	9.4	14	10.8	34	10.7	1.13	13.9	.14	7.2	43	9.7
Eriogonum racemosum	Whole plant	5.7	13	5.7	35	6.8	.56	4.2	.22	7.2	34	4.7
Astragalus recurvus	Whole plant	3.1	20	5.0	29	3.1	.81	3.3	.19	3.3	72	5.3
Geranium sp.	Whole plant	2.0	9	1.3	31	2.1	.94	2.5	.29	3.3	55	2.6
Taraxacum officinale	Whole plant	1.8	11	1.6	40	2.4	1.13	2.6	.36	3.9	42	1.8
Lathyrus sp.	Whole plant	1.4	23	2.5	31	1.5	1.19	2.2	.22	1.7	65	2.2
Erigeron sp.	Whole plant	1.0	10	.8	30	1.0	.88	1.2	.26	1.7	64	1.5
Senecio neomexicanus	Whole plant	.8	11	.7	30	.8	.94	1.0	.25	1.1	57	1.1
Polygonum aviculare	Whole plant	.8	9	.6	34	.9	.63	.7	.18	.6	54	1.0
Lupinus sp.	Whole plant	.8	23	1.5	32	.9	.75	.8	.18	.6	66	1.2
Vicia pulchella	Whole plant	.8	20	1.3	43	1.1	.75	.8	.22	1.1	56	1.0
Desmanthus cooleyi	Whole plant	.7	17	1.0	34	.8	1.38	1.3	.14	.6	46	.8
Dalea albiflora	Whole plant	.5	15	.6	38	.6	.94	.7	.18	.6	53	.6
Gilia multiflora	Whole plant	.5	10	.4	33	.5	.69	.5	.24	.6	58	.7
Euphorbia fendleri	Whole plant	.2	12	.2	29	.2	1.06	.3	.43	.6	59	.3
Grass:												
Dactylis glomerata	Leaves	3.5	11	3.0	40	4.7	.38	1.7	.27	5.6	51	4.3
TOTAL		93.2		100.0		100.0		100.0		100.0		100.0
SEPTEMBER--												
Browse:												
Quercus gambelii	Leaves	48.6	12	58.8	31	50.0	.88	43.9	.20	43.5	46	49.0
Forbs:												
Eriogonum racemosum	Whole plant	12.8	10	13.6	33	14.1	1.13	14.9	.39	22.4	40	11.1
Gilia multiflora	Whole plant	9.6	8	7.4	33	10.4	1.44	14.1	.22	9.4	55	11.5
Erigeron sp.	Whole plant	8.5	7	6.5	33	9.4	1.19	10.3	.22	8.5	58	10.6
Taraxacum officinale	Whole plant	4.0	12	4.7	32	4.2	1.38	5.6	.42	7.6	54	4.7
Aster commutatus	Whole plant	3.0	9	2.7	33	3.2	1.75	5.4	.13	1.8	68	4.4
Senecio neomexicanus	Whole plant	2.1	8	1.7	35	2.5	.81	1.7	.20	1.8	57	2.6
Euphorbia fendleri	Whole plant	2.0	8	1.7	33	2.2	.50	1.0	.16	1.3	56	2.4
Geranium sp.	Whole plant	.8	6	.5	38	1.0	.63	.5	.20	.9	56	1.0
Potentilla sp.	Whole plant	.6	7	.4	35	.7	.88	.5	.20	.4	57	.7
Lotus wrightii	Whole plant	.5	11	.5	39	.6	1.56	.8	.44	.9	42	.5
Desmanthus cooleyi	Whole plant	.4	14	.6	28	.4	.69	.3	.28	.4	50	.4
Amaranthus sp.	Whole plant	.4	9	.3	51	.7	1.00	.4	.28	.4	44	.4
Aster sp.	Whole plant	.4	8	.3	36	.5	.69	.3	.25	.4	60	.5
Grass:												
Bouteloua gracilis	Leaves	.2	9	.2	41	.3	.38	.1	.18	Trace	49	.2
TOTAL		93.9		100.0		100.0		100.0		100.0		100.0

Plateau. Dietary composition was determined on ponderosa pine summer range during numerous trials using tame deer (Neff 1974). Data were taken on species consumed, number of bites per species, and average weight per bite estimated from weighed simulated bites. Monthly dietary composition (May-September) was estimated from percentages of total consumption contributed by individual forage species from all trials during the month. The estimate for the July diet, based on only 650 total bites, was weakest; the other months ranged from about 3,000 to 12,000 bites.

Plant parts eaten by trained deer were hand clipped at Beaver Creek in 1972 and 1973. The objective was to sample all forages appearing in monthly diets, but actual percentages tested ranged from 92 to 97. Composited samples of individual forages from 25 or more plants were ovendried at 65°C (Schmid et al. 1970) to constant weight, ground in a Wiley mill[4] through a 16-mesh per cm screen, and stored in sealed jars. Standard chemical analyses for crude protein, acid-detergent fiber, calcium, and phosphorus were completed by a commercial laboratory (table 1).

In vitro digestibility percentages (Tilley and Terry 1963) were obtained by using rumen inocula from deer killed on pine watersheds at Beaver Creek within a week of plant collection. Rumen contents were placed in insulated bottles and taken to the Forest Hydrology Laboratory at Tempe within a maximum lapsed time of 3 hours. Fluids were separated from rumen solids by straining through four layers of cheesecloth into preheated (39°C) buffer solution at the ratio of one part fluid to four parts buffer solution.

Half-gram forage samples and 50 ml of buffered inocula were placed in 100-ml digestion tubes fitted with gas valves. Fermentations proceeded in a constant-temperature water bath (39°C) for 48 hours, followed by an acid:pepsin phase for a like period. The tubes were swirled every 4 hours for the first 12 hours, then on a 12-hour schedule until the end of the trial. Filtration and drying of insoluble residues on tared filter paper completed the process. Digestion percentages were calculated by subtracting residual dry weight from original sample dry weight, corrected for inocula dry weight.

Relative values of individual forages were estimated by multiplying their monthly nutrient content percentages by monthly dietary composition percentage. The weighted values were totaled and a percentage value for each forage calculated as its proportional contribution to the total.

Results

Since deer characteristically feed on a wide array of forage species, analyses of nutritional value are complex. Specific relationships established at one location cannot be assumed to offer precise estimates elsewhere. The ponderosa pine type in Arizona, however, is relatively homogeneous in vegetational composition and other habitat factors, and, the data presented here have considerable application across the type.

While mean percentages of dietary nutrients provide a useful measure of potential range deficiencies or adequacy of habitat to produce deer, the relative values of individual forage species are also important. More precise assessments of impacts on deer from resource management activities can be made from an understanding of (1) plant composition changes wrought by these activities, and (2) the contribution of affected plants to the deer forage resource. Alterations in cover values are also significant (Reynolds 1966). Table 1 presents chemical analyses and in vitro dry-matter digestibilities for May-through-September diets of mule deer.

May.—The species listed in table 1 comprised almost 97 percent of the May diet. Only a few species contributed the bulk of dietary nutrients, but overall quality was excellent with few exceptions. Most species were high in protein, phosphorus, and digestibility; moderate in calcium; and low in acid-detergent fiber.

The most important species was a seeded exotic, orchardgrass (*Dactylis glomerata*), which was of considerable value and attractiveness to deer in early spring (Hungerford 1965). Clover (*Trifolium* sp.) and locoweed (*Astragalus recurvus*) were the primary forbs, but neither was highly available. Gambel oak (*Quercus gambelii*) was the major browse, taken at this period as immature leaves.

June.—Nutrient content changed abruptly from May levels with advancing maturity of many forages, and species shifts to browse from grass (table 1). Although protein remained generally high, there was a sharp decline in browse species and orchardgrass. Fiber content increased with corresponding decreases in digestibility, but the latter remained high for most forbs and some browse species. Calcium content increased markedly in most forages, and phosphorus declined, resulting in wider P:Ca ratios.

[4] *The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

Gambel oak leaves were important in June diets (92 percent was analyzed) despite the abundance of forbs during this period. For this reason Gambel oak, particularly in a form available as browse to deer, should be prominent in any habitat development plan. Mast crops from this tree are also important (Reynolds et al. 1970).

The same two forbs, clover and locoweed, remained prominent in June. Several new species were added, but overall forb percentages changed little.

July.—A strong shift to forbs appeared in July, mostly to new species that develop following midsummer rains. Foremost among them was sweetclover (*Melilotus officinalis*), a seeded adventive.

Gambel oak was the only important browse, and although it had declined greatly in protein content, its moderate calcium level tended to offset the high levels in forbs to keep overall P:Ca levels within acceptable limits.

August.—Again Gambel oak predominated, but maturity had reduced its quality to average levels. Less abundant browse such as Fendler ceanothus and serviceberry were superior to Gambel oak in most respects.

Use of forbs declined in August and their quality was inconsistent. That is, species with good protein levels may have been low in digestibility and phosphorus or the reverse. Overall quality was still quite satisfactory.

September.—The value of Gambel oak in terms of quantity consumed and quality was accentuated during late summer. It retained a good protein level while that of most other species had declined abruptly. Gambel oak also contained less calcium, which balanced the much higher levels in forbs to maintain an acceptable overall P:Ca ratio. Conversely, most forbs were more digestible than oak leaves, and contained more phosphorus.

Summary.—Although forage quality generally declines from early summer to fall, dietary nutrient levels for mule deer on ponderosa pine summer ranges are adequate or better for deer growth and reasonable production (table 2). The lower values occur toward the end of summer when physiological demands for high-quality diets are much reduced for adult deer and to some extent for fawns.

Complete diets were not analyzed. Omissions tend to include species of restricted availability but frequently of high nutritive value. Consequently, dietary nutrient estimates are somewhat conservative. Other factors associated with laboratory analyses likewise can contribute to results that underestimate actual values for some nutrient factors.

Table 2.--Estimated nutrient levels in summer diets of mule deer derived by weighting values of individual forages

Month	Digestible dry matter	Protein	Acid-detergent fiber	Calcium	Phosphorus	P:Ca ratio	Proportion of diet analyzed
	- - - -	Percent	- - - - -				Percent
May	68	25	26	0.46	0.48	1:1.0	97
June	54	17	29	.72	.24	1:3.0	92
July	56	16	31	1.02	.19	1:5.4	97
Aug.	46	14	32	.82	.19	1:4.3	93
Sept.	49	10	32	1.04	.24	1:4.3	94
Mean	55	16	30	.81	.27	1:3.0	--

Forages contribute nutrients to deer diets roughly in proportion to their percentage composition, especially those making up sizable percentages in the diet. Since only a few species usually dominate monthly diets, opportunities abound to positively affect deer habitat through alterations in the food supply. For example, some pine stands have but small amounts of oak browse within reach of deer. Management practices are available to stimulate oak sprouts and to periodically reduce their height. Seeding disturbed sites such as logged areas and wildfire burns to orchardgrass, sweetclover, and other nutritious and palatable species is also recommended.

Finally, maintenance of maximum diversity is desirable. Few forage species alone supply a good balance of nutrients, and phenological changes often mean that a particular species is a high-value forage for a relatively short time.

Literature Cited

Hungerford, C. R.
1965. Response of Kaibab mule deer to reseeded forest and meadow. Trans. N. Am. Wildl. Conf. 30:310-321.

Jameson, D. A.
1969. Rainfall patterns on vegetation zones in northern Arizona. Plateau 41(3):105-111.

Julander, O., W. L. Robinette, and D. A. Jones.
1961. Relation of summer range condition to mule deer herd productivity. J. Wildl. Manage. 25(1):54-60.

Neff, D. J.
1974. Forage preferences of tame trained mule deer on the Beaver Creek watersheds. Ariz. Game and Fish Dep. Spec. Rep. 4, 61 p. Phoenix, Ariz.

Nichol, A. A.
1937. The natural vegetation of Arizona. Ariz. Agr. Exp. Stn., Tech. Bull. 68, p. 181-222.

Nordan, H. C., I. McT. Cowan, and A. J. Wood.
1968. Nutritional requirements and growth of black-tailed deer, *Odocoileus hemionus columbianus,* in captivity. p. 89-96. **In** Comparative nutrition of wild animals, M. A. Crawford, ed. Symp. Zool. Soc. London. Academic Press, N.Y.

Reynolds, H. G.
1966. Use of a ponderosa pine forest in Arizona by deer, elk, and cattle. U.S. For. Serv. Res. Note RM-63, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Reynolds, H. G.
1972. Wildlife habitat improvement in relation to watershed management in the southwest. Ariz. Watershed Symp. Proc. 16:10-16.

Reynolds, H. G., W. P. Clary, and P. F. Ffolliott.
1970. Gambel oak for southwestern wildlife. J. For. 68(9):545-547.

Schmid, A. R., G. C. Marten, and R. D. Goodrich.
1970. Influence of drying methods and temperatures on in vitro dry matter digestibility of corn and sorghum fodder and silage. Agron. J. 62(4):543-546.

Snider, C. C., and J. M. Asplund.
1974. In vitro digestibility of deer foods from the Missouri Ozarks. J. Wildl. Manage. 38(1):20-31.

Swank, W. G.
1958. The mule deer in Arizona chaparral and an analysis of other important deer herds. Ariz. Game and Fish Dep. Wildl. Bull. 3, 109 p.

Tilley, J. M. A., and R. A. Terry.
1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassland Soc. 18(2):104-111.

Trout, L. E., and J. L. Thiessen.
1973. Physical condition and range relationships of the Owyhee deer herd. Idaho Fish and Game Dep. Wildl. Bull. 5, 37 p.

Urness, P. J., D. J. Neff, and J. R. Vahle.
1975. Nutrient content of mule deer diets from ponderosa pine range. J. Wildl. Manage. 39(4):670-673.

Agriculture—CSU, Ft. Collins

tri
im
ne
tri
us
in
to

we
ni
sa
Or
sp
se
pi

Ex
Co

ruary 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-305

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A Tripod Mount to Aid in Lifting Heavy Objects

Howard L. Gary[1]

Describes an easily constructed tripod that can be mounted on legs of varying length. When equipped with a sheave or block and tackle, the mount can accommodate a wide variety of hoisting needs.

Keywords: Hoisting, tube pulling, construction aid.

Many types of derricks or towers—ranging from a tripod formed by chaining three poles together to an imaginary "sky hook"—have long been used or needed for hoisting or lowering heavy objects. The tripod mount described here, which has proved useful for such jobs, is easily constructed in a welding shop, durable, inexpensive, readily portable, easy to store, and can be used on legs of varying lengths.

Materials and Construction

Three legs of the tripod mount, about 2 feet long, were cut from 1-inch inside diameter (i.d.) galvanized steel pipe. An 8-inch-long spacer cut from the same sized steel pipe was used to join two of the legs. One end on two of the legs and both ends of the spacer were cut on a 25° diagonal. A 5-inch-long section of 1½-inch (i.d.) steel pipe was used as a pivotal sleeve. An 8-inch-long piece of 5/8-inch iron bar was heated and shaped to form a half hoop for a bail. Materials used in constructing the tripod mount are readily available. Depending on expected use, various sizes of steel pipe and iron bar stock may be substituted for the bail, pivotal sleeve, and legs. The basic tripod mount without legs weighs about 13 pounds, and is easily transported to any work site.

Assembly instructions were as follows:

1. Weld the half hoop to the pivotal sleeve to form a bail for attaching a sheave or block and tackle (fig. 1-A).
2. Notch the end of one leg to straddle the pivotal sleeve. This leg is centered and positioned on the pivotal sleeve to form a 40°-45° angle between it and the bail and then welded to the sleeve (fig. 1-B).
3. Weld one of the diagonally cut legs to the spacer to form a 110° angle (fig. 1-C).
4. The pivotal sleeve with attached bail and leg is then slipped over the free end of the spacer. The third leg is positioned and welded to the free end of the spacer to form another 110° angle to complete construction of the tripod mount.

---

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

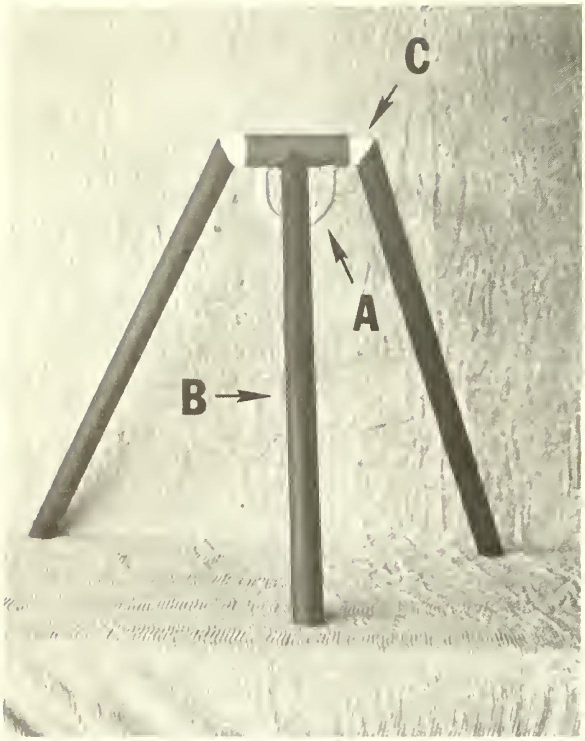


Figure 1.—Component parts of the tripod mount: **A**, bail; **B**, leg welded to pivotal sleeve, and **C**, spacer welded between two legs.

Figure 2.—Tripod mount equipped with 21-foot-long, 1½-inch pipe legs and block and tackle.

Setup and Use

For use, the tripod is spread full length with the bail against the ground. Sections of 1½-inch (i.d.) steel pipe are then inserted over each leg of the tripod mount. Length of the supporting pipe legs will depend on requirements of the individual lifting operation. Pipe sections up to 21 feet long have been satisfactorily used as legs for the tripod mount (fig. 2).

For overhead use, a sheave or block and tackle should be attached to the bail before the tripod is raised. To raise the tripod mount and attached legs, the pivotal leg is pushed upward and toward the two rigidly spaced legs. When the tripod is raised to about maximum obtainable height and/or when it is steady, it can be lifted or skidded one leg at a time to center it over the point of operation. The tower can be raised and positioned by one or two persons in a few minutes. If the pipe legs do not penetrate the ground to provide stability, they should be roped or chained together at ground level and/or midheight for safety.

The tripod mount and pipe legs have accommodated a wide variety of hoisting needs. During several years of testing, the mount has proved valuable for soil sampling, soil penetration tests, pulling well tubing, lifting motors and other bulky equipment, and for lifting and holding trees weighing up to 1,000 pounds without any evidence of failure.

F ruary 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-306

OREST SERVICE
.S DEPARTMENT OF AGRICULTURE

KY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Fertilizer Response of Alkali Sacaton and Fourwing Saltbush Grown on Coal Mine Spoil[1]

Earl F. Aldon, H. W. Springfield, and David G. Scholl[2]

The response of two native species to nitrogen and phosphorus fertilizer was tested on New Mexico mine spoil.

Three levels and three times of application of N and P were tested in the greenhouse. Spoils were a composite sample from strip mining done in the Fruitland Formation. Results showed that adding N or P alone at any level had little effect on yield. Combined application of N and P, however, increased yield two to three times in both species. Yield responses differed between species depending on both relative amount of N or P in the mix and the time of application.

Keywords: *Atriplex canescens, Sporobolus airoides*, fertilizer response, coal mine spoil.

The need for reclamation on mined areas of the West has become acute with the recent acceleration in surface mining of coal. State and Federal laws demand mined areas be returned to a stable condition through topographic shaping and vegetation establishment. Hopefully, these lands can also be returned to productivity. Establishment of adapted plant species can enhance productivity by providing forage for domestic livestock, shelter and food for wildlife, and protection from wind and water erosion.

Alkali sacaton (*Sporobolus airoides*) and fourwing saltbush (*Atriplex canescens*), the two species tested here, are valuable forage plants in semiarid plant communities. They provide palatable forage for domestic livestock and retard erosion on alluvial flood plains. Methods of establishing these plants have been worked out for wildland conditions (Springfield 1970, Aldon 1974). In laboratory studies, soil amendments showed some promise in improving growth of these species on mine spoil materials (Aldon and Springfield 1973). The objective of this study was to determine the optimum time and rate of fertilizer application for the two species on New Mexico coal mine spoil.

Methods

Spoil materials were composite samples from two selected areas on the Navajo Mine, 20 miles southwest of Farmington, New Mexico. The spoils from the Fruitland Formation were less than 2 years old. Physical and chemical characteristics of the material are as follows:

Sand (percent)	22.7
Silt (percent)	24.4
Clay (percent)	52.9
Texture class	Clay
Sodium absorption ratio	40.1
Electrical conductivity of saturation extract (m mhos/cm)	8.0
Determined from saturation extract:	
pH	8.0
Na (ppm in soil)	1850
Ca (ppm in soil)	141
Mg (ppm in soil)	45
NO_3(ppm in soil)	68
P (ppm in soil)	8.5

---

[1] *The research reported here is a contribution of the SEAM program. SEAM, an acronym for Surface Environment and Mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping meet the Nation's mineral requirements. This work was conducted in cooperation with Utah International, Inc. who furnished study areas and materials.*

[2] *Principal Hydrologist, Range Scientist, and Soil Scientist, Rocky Mountain Forest and Range Experiment Station, located at Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

The spoil material was put in 1-liter plasticized round pots (10 cm in diameter by 12 cm tall). Each pot was filled with 1,200 g of the spoil material, which had been screened through a 1.3 cm mesh.

Fertilizer treatments included three levels of nitrogen (N_0, N_1, N_2) and phosphorus (P_0, P_1, P_2) in all combinations. Nitrogen was applied as ammonium sulfate (21-0-0) and phosphorus as treble superphosphate (0-45-0). Levels of application were as follows:

N_0 or P_0 = no fertilizer.
N_1 or P_1 (lower level) = 89.7 kg/ha (80 lbs/acre).
N_2 or P_2 (higher level) = 179.4 kg/ha (160 lbs/acre).

Fertilizers were applied at one of the following times:

T_1 = time of seeding (May 31).
T_2 = 1 month after seeding (July 1).
T_3 = 2 months after seeding (August 1).

Procedures for adding the fertilizer at the time of seeding were (1) 4 cm of spoil were removed from the pot; (2) the proper amount of fertilizer was mixed thoroughly with this 4 cm; then (3) the mixture was returned to the pot. For the other two times of application, the fertilizer was spread uniformly over the surface of the spoil.

Thirty seeds of one species were planted in each pot at the start of the experiment. Alkali sacaton seeds were harvested in 1969 at the Los Lunas Plant Materials Center (NM-184). Fourwing saltbush seeds were harvested in 1968 at the Los Lunas Plant Materials Center (NM-155).

Procedures for seeding varied slightly by species. For alkali sacaton, about 0.5 cm of spoil was removed from the pot, the surface was smoothed, seeds were uniformly distributed, and the spoil was returned as a covering. For fourwing saltbush, about 1.0 cm of spoil was removed to provide a deeper covering for the seeds.

For germination comparisons, seeds of both species were placed on moist blotters in petri dishes, which were put adjacent to the pots on benches in the greenhouse.

Moisture content of the pots was held approximately at field capacity for the duration of the experiment. Field capacity was arrived at by saturating 840 ml of spoil, allowing excess water to drain out for 24 hours, then determining the water still present by ovendrying. Three samples were used for these determinations. The average weight of water determined in this way was added to the pots at the start of the experiment. Gross weight of pots was checked periodically to maintain moisture near the desired level.

Temperatures recorded in the greenhouse during the 90 days ranged from 56° to 100°F (mean maximum 89.4°F: mean minimum 63.8°). Pots were completely randomized on the greenhouse benches. There were two replications of each fertilizer treatment.

Data were obtained on seedling emergence, seedling height at 15-day intervals, and ovendry weight of shoots at the end of 90 days. Data were analyzed by analysis of variance and multiple range tests at the $P = 0.05$ level.

Results

Seedling Emergence

Emergence of fourwing saltbush and alkali sacaton seedlings were not affected by fertilizer treatment. Average emergence of saltbush was 25.6 percent compared to 76.2 percent for sacaton. These percentages may be compared to 37.7 percent for saltbush and 76.5 percent for sacaton in petri dishes.

Plant Height

Seedling heights were influenced by fertilizers to varying degrees. Date of application of fertilizer did not influence height of sacaton. Delaying application until 2 months after seeding resulted in shorter plants of saltbush. The highest level of P in combination with either level of N tended to produce the tallest plants of fourwing saltbush, whereas the highest level of N in combination with either level of P produced the tallest plants of alkali sacaton.

Yield

Plant yields were significantly affected by time of fertilizer application as well as by levels of N and P.

Time of fertilizer application was probably significant because the experiment was terminated before there was opportunity for the plants to fully respond to the fertilizer applied 2 months after seeding. Alkali sacaton apparently was able to utilize the N and P applied 30 days after seeding, whereas the fourwing saltbush appeared to respond more slowly to fertilizer.

Neither species yielded more when N or P was applied singly, regardless of level. There was a tendency, however, for saltbush yields to increase when more N was added in the absence of P. In general, adding N or P alone at either level had very little effect on yield (fig. 1).

Combining N and P significantly increased yield of both species. Alkali sacaton plants fertilized with N and P, for example, yielded 2½ to 4 times more than the unfertilized controls. Similarly, fourwing saltbush plants fertilized with N and P generally yielded 2 to 3 times more than unfertilized plants. The best response of alkali sacaton was obtained when N and P were applied at the high level 1 month after seeding. With saltbush, however, the higher levels of fertilizer did not result in much additional yield.

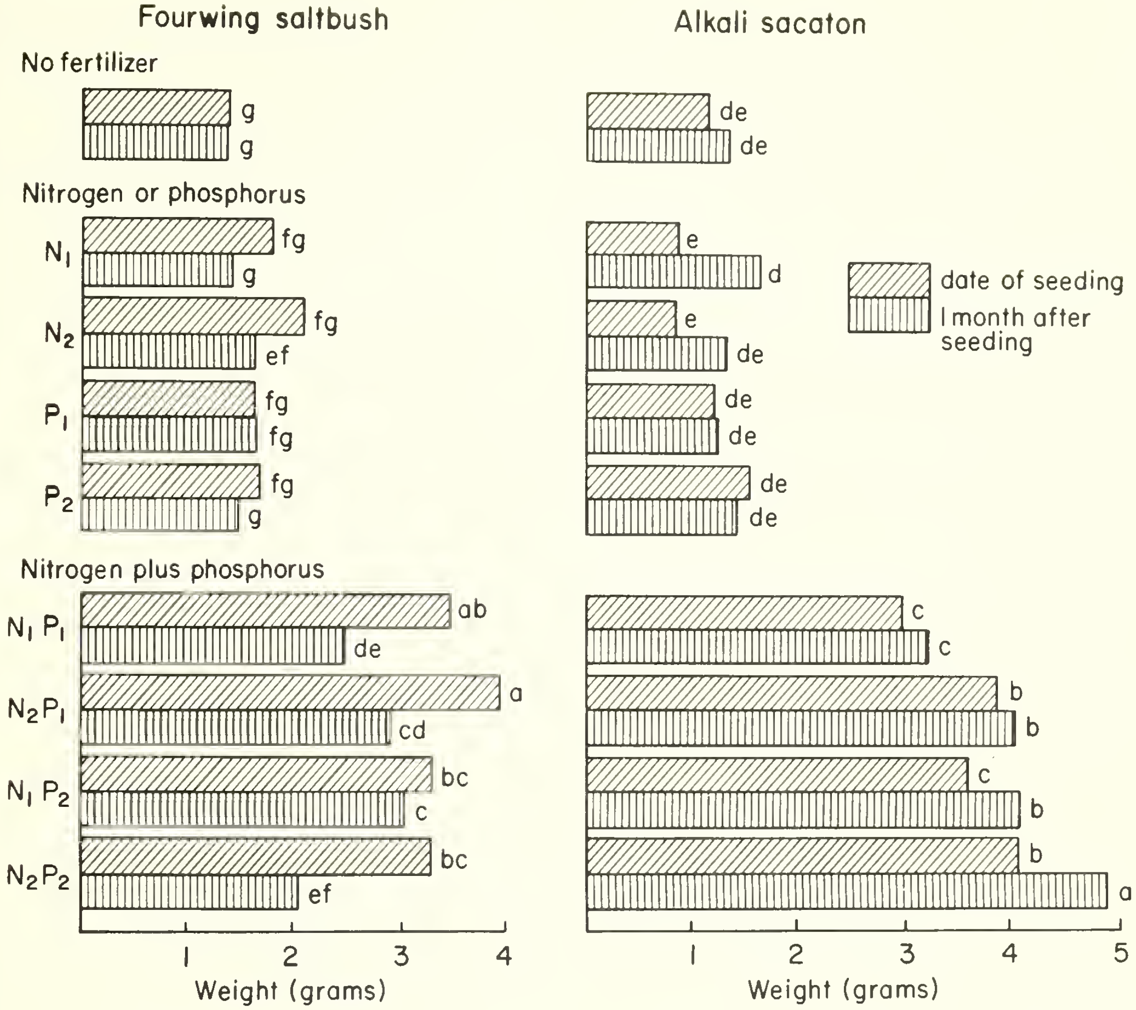


Figure 1.—Response of fourwing saltbush and alkali sacaton to N and P fertilization at two different times. Bars labeled with the same letter are not significantly different at the 0.05 level.

Saltbush seemed to be slower than sacaton in responding to fertilizer. Consequently, the highest yields of saltbush generally came from applying fertilizer at the time of seeding. Statistical comparisons indicate that when fertilizer was applied at the time of seeding, the N_1P_1 treatment was an effective as the N_2P_2 treatment for saltbush plants. Even when fertilizer was applied 30 days after seeding, the yield from N_1P_1 was as high as the yield from N_2P_2. These comparisons suggest the lower level of N and P is satisfactory for saltbush.

Conclusions

1. Seedling emergence was not affected by fertilizer treatment.

2. Effects of fertilizer on plant height generally was reflected in plant yield.

3. Neither species yielded more if either N or P was applied alone.

4. Combinations of N and P increased yields of both species two to three times.

5. Alkali sacaton yielded the most when N and P were applied 1 month after seeding at the higher level. Doubling the fertilizer level to obtain this additional yield, however, would probably be uneconomical.

6. The higher levels of fertilizer did not increase the yield of fourwing saltbush over what was obtained from the lower level.

7. Applying fertilizer at the time of seeding appeared best for saltbush, whereas delaying fertilizer application (especially P_2) until a month after seeding showed some advantages for sacaton.

Literature Cited

Aldon, Earl F.
1974. Establishing alkali sacaton on harsh sites in the Southwest. J. Range Manage. 28(2):129-132.

Springfield, H. W.
1970. Germination and establishment of fourwing saltbush in the Southwest. USDA For. Serv. Res. Pap. RM-55, 48 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Aldon, Earl F., and H. W. Springfield.
1973. Revegetating coal mine spoils in New Mexico: A lab study. USDA For. Serv. Res. Note RM-245, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

SURFACE ENVIRONMENT & MINING

SEAM

PROGRAM

Agriculture—CSU, Fort Collins

February 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-307

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Trapping, Anesthetizing, and Marking the Abert Squirrel

David R. Patton,[1] Howard G. Hudak,[2] and Thomas D. Ratcliff[3]

Folding live traps placed at 250-foot intervals on a 1,000-foot grid provide a density of approximately two traps per acre for capturing the Abert squirrel. Procedures are described for anesthetizing squirrels for physical examination. Squirrels are marked with ear tags and colored collars for visual identification.

Keywords: Marking and trapping, *Sciurus aberti aberti*.

In several research studies on the Apache, Coconino, and Kaibab National Forests in Arizona we have tried different techniques of trapping, anesthetizing, and marking the Abert squirrel (*Sciurus aberti aberti*). Because we have been successful in our efforts, others may want to use the same methods or modify them for their own particular use. We make no claim of originality for marking devices and traps, but the scheme of operations and trapping grid are our own design.

Field Methods

We used a folding live trap (6 by 6 by 19 inches) manufactured by Tomahawk.[4] The Number 202 has a single door operated by a trip plate. This trap weighs 2½ pounds, and folds into a convenient 13- by 22- by 1-inch size for carrying or storage.

Forty-one traps were placed at 250-foot intervals in a grid, 1,000 feet on a side (22.95 acres). They were located so alternate rows had five and four traps, respectively (fig. 1). This design provides a distance of 177 feet between any two traps, and a density of approximately two traps per acre. We have found from experience that this trap density insures that a squirrel will have a good chance to come in contact with a trap.

When locating traps on the grid, the amount of sun hitting the trap must be considered. The Abert squirrel tends to become excited while he is enclosed and will move constantly. Traps should be placed in a shady location to reduce the chances of the squirrel dying from shock. We lost several squirrels in this manner.

Choice of bait is always an important consideration in capturing wild animals. We went through the usual process of bait trials, using everything from walnuts to apples. Raw, unshelled peanuts were by far the most successful bait.

After a site was selected and the traps were in place, we walked through the area spreading peanuts. We followed this procedure for about a week before the traps were opened. During the trapping period each trap was baited behind the trip plate and in front of the entrance as traps were checked.

---

[1] *Principal Wildlife Biologist, located at the Station's Forest Hydrology Laboratory at Tempe, in cooperation with Arizona State University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Wildlife Biologist, North Kaibab Ranger District, Kaibab National Forest, USDA Forest Service, Fredonia, Arizona 86022.*

[3] *Instructor, Department of Natural Science, College of Siskiyous, Weed, California 96094.*

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

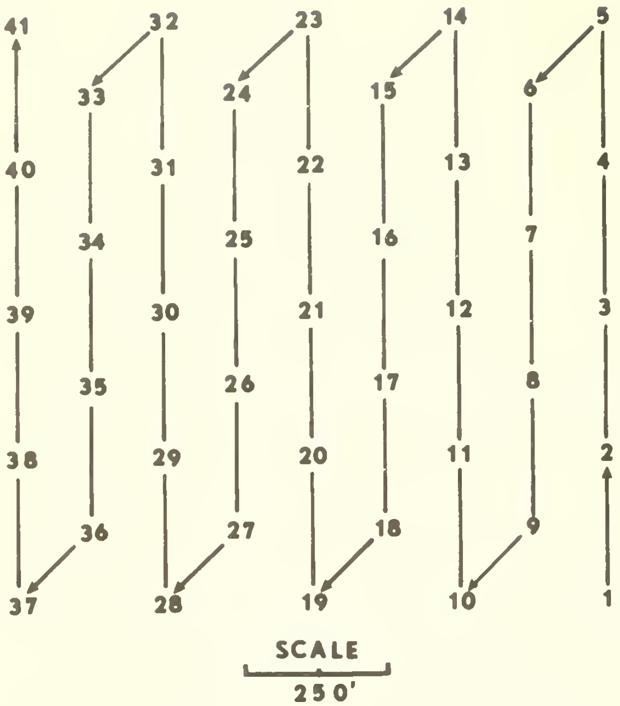


Figure 1.—Grid and traverse lines for checking traps.

Traps were checked twice a day—around noon and again just before dusk. These two times insure that a squirrel will not remain in a trap more than 7 or 8 hours and none will remain overnight. Our observations indicate squirrel activity peaks early in the morning and again in the late afternoon. Squirrels also tend to be more active on rainy days. In our studies two people checked traps. For a two-man operation, three sites (69 acres) with a total of 123 traps is the maximum number of traps that can be checked twice a day.

The question always arises on length of trap period. Initially we used a 20-day period, but analysis of our data from approximately 16,000 trap days showed a 15-day period would have accounted for 98 percent or our marked squirrels. Although we recommend a 15-day trapping period, it is wise to be a little conservative at first. Start with a 20-day period and later change to 15 if no unmarked squirrels are captured in the last 5 days.

Once a squirrel was caught, we removed it from the trap in a cone constructed from hardware cloth and lightweight canvas. The squirrel was marked with a numbered aluminum tag and a colored plastic washer. This tag and washer combination allowed recognition of an individual when it subsequently was recaptured or sighted. The ear tag we used was manufactured by National Band and Tag Company. In addition to ear tags, collars made from self-locking, nylon cable ties are excellent for visual identification. Cable ties are available in many sizes and colors from electronic equipment suppliers.

The Abert squirrel is easily anesthetized with Metofane (methoxyflurane). With the squirrel in the handling cone, the cone is inserted into the mouth of a plastic half-gallon, wide-mouth jar containing a cotton ball soaked with the anesthetic. Immobilization generally takes from 15 to 45 seconds. In several instances we had to expose the squirrel to the anesthetic for just over a minute before it could be handled safely.

A squirrel in a holding cone generally will snug his nose against the wire end. It is a good idea to stuff a cotton cloth into the end of the cone to prevent injury. A squirrel occasionally will cut itself on the trip plate or wire. In these cases we applied a topical antiseptic to reduce infection and to speed healing.

Over a period of 3 years we have successfully immobilized 60 squirrels without any losses. Each squirrel was allowed to recover from the anesthetic in a trap for 15 to 20 minutes before it was released. The trap was covered with a canvas cloth to exclude light. This tends to keep the squirrel calm and reduces injury.

Cost of trapping equipment is approximately $836. This includes 20 extra traps to replace losses. An outline of the items needed is as follows:

Item	Amount	Cost
Traps	143	$822.25
Ear tags	100	3.50
Ear tag gage	1	.60
Ear tag punch	1	1.00
Colored washers	100	1.25
Metofane	4 oz.	21.60
Handling cone construction	—	5.00
Lightweight canvas	3 by 4 in.	3.00
Antiseptic	—	5.00
	Total	$863.20

Summary

The procedures and equipment described have been successful for us in trapping, anesthetizing, and marking the Abert squirrel. The size and number of trapsites, number of traps per trapsite, and length of trap period we used provide researchers and managers with an efficient trapping design.

Agriculture—CSU, Ft. Collins

ruary 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-308

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Characteristics of the Forest Floor on Sandstone and Alluvial Soils in Arizona's Ponderosa Pine Type

Peter F. Ffolliott, Warren P. Clary, and Malchus B. Baker, Jr.[1]

The forest floor affects the hydrologic cycle, herbage production, tree regeneration, and fire behavior. Forest floor depths and weights under ponderosa pine stands on soils developed from sedimentary parent materials were similar to those previously found on soils developed from volcanic parent materials.

Keywords: Alluvial soils, sandstone, forest litter, *Pinus ponderosa* type.

The forest floor, defined as the accumulation of dead organic matter above mineral soil, affects hydrologic characteristics of a site (Johnson 1940, Rowe 1955), herbage production (Wahlenberg et al. 1939, Pase and Hurd 1958, Clary et al. 1968), and tree regeneration (Pearson 1950, Davis et al. 1968). It is also an important forest fuel component. Generally, three layers are distinguished: the **L** layer, unaltered organic matter; the **F** layer, partly decomposed matter, and the **H** layer, well decomposed matter.

In a previous study, the characteristics of ponderosa pine (*Pinus ponderosa* Laws.) forest floor on basalt and volcanic cinders were described (Ffolliott et al. 1968). The objectives of this current study were to characterize ponderosa pine forest floor on sandstone and alluvial soils, and compare these characteristics to those on soils developed from volcanic parent materials.

Study Area

Forest floor was studied on four experimental watersheds, two with soil formed from parent material derived from sandstone (60 acres each), and two with soil formed from parent material derived from tertiary alluvium (20 and 30 acres), located near Heber in central Arizona. Uneven-aged stands of cutover ponderosa pine characterized the overstory, with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gord. and Glend.) Lindl.), Gambel oak (*Quercus gambelii* Nutt.), and alligator juniper (*Juniperus deppeana* Steud.) as minor species.

Timber volume averaged 1,650 cubic feet and 6,450 board feet per acre. Site index ranged from 60 to 80 feet at 100 years (Minor 1964).

Annual precipitation averages 25 inches on the study areas. The sandstone-derived soils were of the McVickers series, with fine sandy loam surface textures. Soil developed on tertiary alluvium were of the Overgaard series, with gravelly fine, sandy loam surface textures.

---

[1] *Ffolliott is Associate Professor, School of Renewable Natural Resources, University of Arizona, Tucson. Clary is Principal Plant Ecologist and Baker is Associate Hydrologist, Rocky Mountain Forest and Range Experiment Station, located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Methods

Depth of individual forest floor layers was measured at 90 sample plots systematically located on each watershed. Depth was measured to the nearest 0.1 inch without compressing the layers.

The weight of individual forest floor layers was obtained from 1-square-foot samples taken at approximately every third sample plot. Thirty samples were obtained on each watershed. This resulted in a total sample size similar to that reported in Ffolliott et al. (1968). These samples were brought into the laboratory to determine ovendry weights. Corresponding depth measurements were taken at four sides of the 1-square-foot samples.

The previous study indicated timber basal area was the only stand or site variable tested that was significantly related to amounts of individual layers or total forest floor (Ffolliott et al. 1968). Therefore, basal area was estimated at each sample plot by point sampling with an angle gage corresponding to a basal area factor of 25.

Results

No consistent differences were found in the forest floor characteristics between sandstone and alluvium soils. Therefore, the data were grouped for further analysis.

The means (with 0.95 confidence limits) for depth and weight of individual forest floor layers (as follows) are comparable with those for forest floors developed on volcanic soils (Ffolliott et al. 1968).

Forest floor layer	**Depth** (*Inches*)	**Weight** (*Tons per acre*)
L	0.3 ± 0.08	0.6 ± 0.2
F	0.3 ± 0.10	1.8 ± 0.8
H	0.4 ± 0.20	4.6 ± 2.8
Entire forest floor	1.0 ± 0.34	7.0 ± 3.6

The variance of the means is significantly larger, however, indicating greater variability on the current study area. The apparent reason is a significantly greater variability in the basal area of the tree stands on sedimentary soils as compared to those on volcanic soils.

Frequency distributions of forest floor depths by individual layer are plotted in figure 1. Plots with little or no forest floor occur more frequently on sedimentary soils than on soils developed from volcanic parent materials (fig. 2).

The relationships between weights of forest floor layers and corresponding depths (fig. 3) were determined from the average of the ratios of weight and depth (Natrella 1965). The relationships (expressions of bulk density) are similar to those developed on volcanic soils for the **L** and **H** layers (Ffolliott et al. 1968), while the **F** layer and total forest floor relationships differ. Logging within the past 10 years may have contributed to this difference by changing the distribution of the ages of ponderosa pine needles within the **F** layer.

Equations for predicting forest floor depth and weight from timber basal area were similar to those reported by Ffolliott et al. (1968).

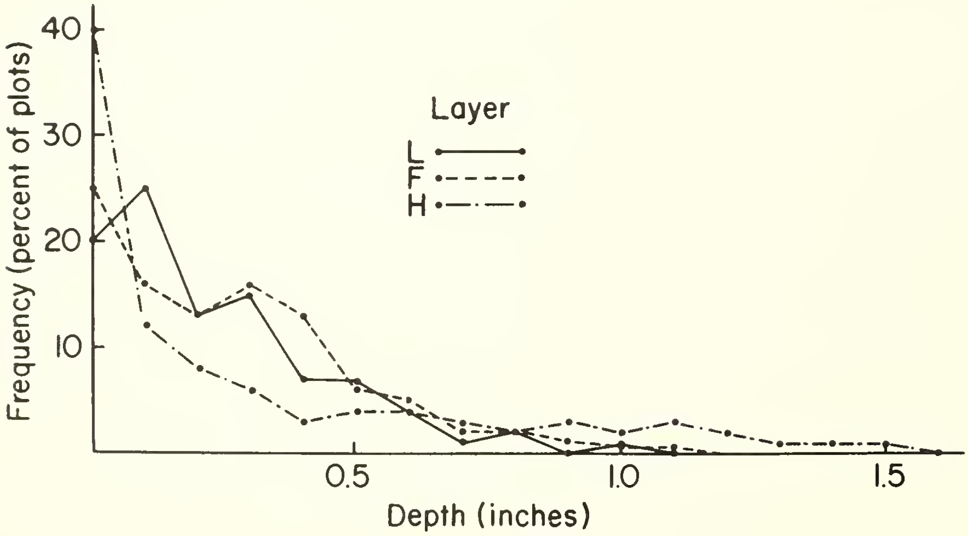


Figure 1.—Frequency distribution of individual forest floor depths.

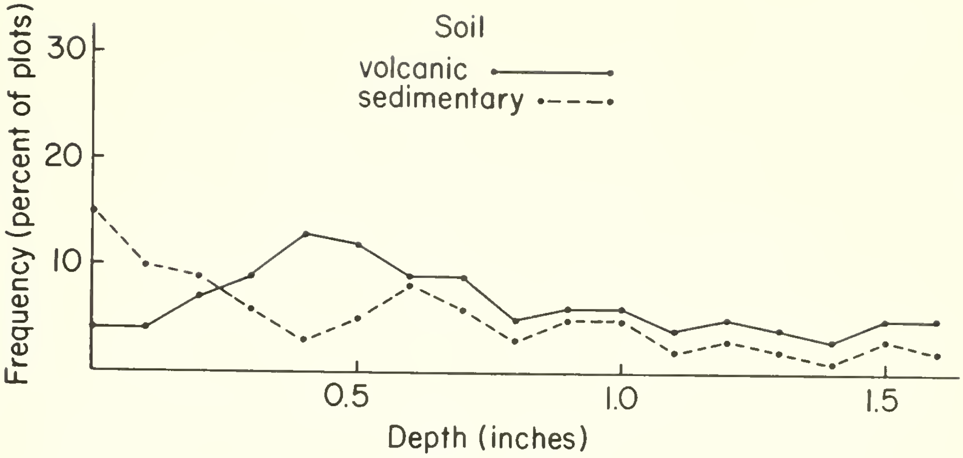


Figure 2.—Frequency distribution of total forest floor depths.

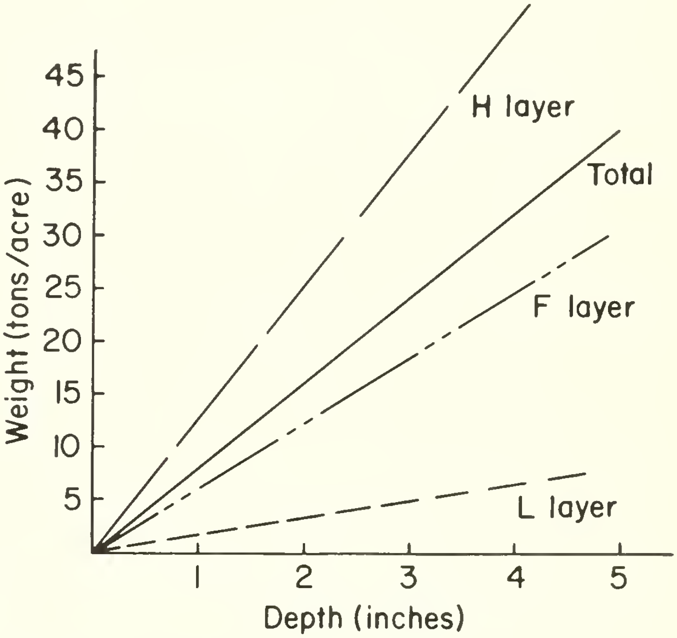


Figure 3.—Relationships between forest floor depth and weight.

Summary

1. The mean weight and depth of the forest floor in Arizona ponderosa pine on sedimentary soils averaged 7.0 tons per acre and 1.0 inch in depth, with the greatest accumulation in the **H** layer.

2. Forest floor varied more on sedimentary soils, including greater frequency of plots with little or no forest floor, than on soils developed from volcanic parent materials. This variability, however, was probably due more to logging history of the timber stand than to the effect of soils.

3. The bulk density of the **F** layer on sedimentary soils was greater than that previously recorded on volcanic soils. This difference may also be related to logging history.

4. Equations for predicting forest floor depth and weight from timber basal area are not significantly different between sedimentary soils and the previously studied volcanic soils.

Literature Cited

Clary, Warren P., Peter F. Ffolliott, and Donald A. Jameson.
1968. Relationship of different forest floor layers to herbage production. USDA For. Serv. Res. Note RM-123, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Davis, James R., Peter F. Ffolliott, and Warren P. Clary.
1968. A fire prescription for consuming ponderosa pine duff. USDA For. Serv. Res. Note RM-115, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ffolliott, Peter F., Warren P. Clary, and James R. Davis.
1968. Some characteristics of the forest floor under ponderosa pine in Arizona. USDA For. Serv. Res. Note RM-127, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Johnson, W. M.
1940. Infiltration capacity of forest soil as influenced by litter. J. For. 38:520.

Minor, Charles O.
1964. Site-index curves for young-growth ponderosa pine in northern Arizona. USDA For. Serv. Res. Note RM-37, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Natrella, Mary Gibbons.
1965. Experimental statistics. Nat. Bur. Stand. Handb. 91, 360 p.

Pase, Charles P., and Richard M. Hurd.
1958. Understory vegetation as related to basal area, crown cover and litter produced by immature ponderosa pine stands in the Black Hills. Soc. Am. For. [Syracuse, N.Y., Nov. 1957] Proc. 1957:156-158.

Pearson, G. A.
1950. Management of ponderosa pine in the Southwest. U.S. Dep. Agric., Agric. Monogr. 6, 218 p.

Rowe, P. B.
1955. Effects of the forest floor and disposition of rainfall in pine stands. J. For. 53:342-348.

Wahlenberg, W. G., S. W. Greene, and H. R. Reed.
1939. Effects of fire and cattle on longleaf stands as studied at McNeill, Mississippi. U.S. Dep. Agric. Tech. Bull. 683, 52 p.

Agriculture—CSU, Ft. Collins

ary 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-309

OREST SERVICE
.S. DEPARTMENT OF AGRICULTURE

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Stand Ratings for Spruce Beetles

J. M. Schmid[1] and R. H. Frye[2]

Engelmann spruce-subalpine fir (*Picea engelmannii* Parry and *Abies lasiocarpa* (Hooker) Nuttall, respectively) stands can be rated for potential spruce beetle (*Dendroctonus rufipennis* (Kirby)) outbreaks on the basis of physiographic location, tree diameter, basal area, and percentage of spruce in the canopy.

Keywords: *Dendroctonus rufipennis, Picea engelmannii.*

Background

Spruce beetles are a major mortality factor in unmanaged mature stands of Engelmann spruce. They have periodically depleted the dominant and codominant trees, and changed the species composition where subalpine fir is a stand component. Infestations commonly develop in windthrown trees, and spread to standing trees.

Historically, forest administrators have approached the management of spruce beetle populations with a post mortem attitude. Most infestations reached outbreak status and killed substantial numbers of trees before action was initiated. Then attempts were made to control populations through application of insecticides and/or salvage logging of the infested trees. Very few stands received preoutbreak management actions to reduce or eliminate the tree mortality from spruce beetle outbreaks.

While this approach may have been satisfactory 50 years ago, it is unsatisfactory today. The nation is demanding more intensive management and use of the publicly owned forests as well as minimizing these vast tree losses to beetle outbreaks. Public concern is also evident in the increasing involvement of government agencies with the preparation of long-range management plans and environmental impact statements. These reports frequently incorporate information about the effects of spruce beetles on spruce-fir stands and relationships between stand conditions and beetle outbreaks, so that the impact of the beetles can be minimized.

To respond to these land management concerns, forest managers need a method of identifying potential outbreak areas. With such a method, they could direct preoutbreak actions to high-priority stands, and thereby reduce the number as well as the severity of future outbreaks. We believe a suitable stand rating plan can now be generated by integrating existing information scattered in different printed references. These references are Alexander (1967), Knight et al. (1956), Massey and Wygant (1954), and Schmid and Hinds (1974).

Development of the Stand Rating Plan

From Knight et al. (1956, p. 4), we use the first three susceptibility categories: spruce in creek bottoms, better stands of spruce on benches and high ridges, and poorer stands on benches and high ridges. These categories are modified, integrated into Alexander's (1967) site indexes, and listed in table 1

---

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

[2] *Forester, San Juan National Forest, Pagosa Springs, Colorado.*

Table 1.--Risk categories for potential spruce beetle outbreaks for each stand characteristic

Risk category[1]	Physiographic location	Average diameter of live spruce above 10 inches d.b.h.	Basal area	Proportion of spruce in canopy
		Inches d.b.h.	*Ft^2*	*Percent*
HIGH (3)	Spruce on well-drained sites in creek bottoms	>16	>150	>65
MEDIUM (2)	Spruce on sites with site index of 80 to 120	12-16	100-150	50-65
LOW (1)	Spruce on sites with site index of 40 to 80	<12	<100	<50

[1] Number in parentheses indicates arbitrary value to be used in calculating stand priority, and is used only for convenience.

as physiographic locations. The new susceptibility categories become (1) spruce on well-drained sites in creek bottoms, (2) stands on sites with an index of 80 to 120, and (3) stands on sites with an index of 40 to 80. Since spruce on well-drained sites in creek bottoms could be included in the better-than-average sites, the separation of this category may seem unjustified. Because numerous infestations appear to have originated near creek bottoms, we feel this separation is valid. The latter two categories of Knight et al. (1956) pertain to the species composition of the stand, and therefore fit more appropriately in Schmid and Hinds' (1974) characteristic of percentage of spruce in the canopy.

Information on tree diameters is drawn from Massey and Wygant (1954), and unpublished data gathered by Schmid and Hinds. Massey and Wygant (1954, p. 13-14) indicated that the average diameter of the infested trees in the White River outbreak decreased from 21 to 17 to 15. As the outbreak began to terminate, the average diameters of living trees was about 13 inches. Unpublished information from Schmid and Hinds' study indicates that the average diameter at breast height (d.b.h.) of the spruce prior to the outbreak was about 16 inches when only trees above 10 inches d.b.h. were considered. Thus, the diameter information is subdivided into three categories: above 16 inches, 12 to 16 inches, and less than 12 inches.

Finally, the stand basal area and percentage of spruce in the canopy is derived from Schmid and Hinds (1974). This latter category in the rating plan also includes information from the tree susceptibility priorities of Knight et al. (1956).

Determining Risk Ratings for Particular Stands

Most forest managers will have information on these four stand characteristics available from their stand compartment files. It is then a simple matter to compare the actual stand information with the risk value in table 1. For example, the manager compares the site data with the risk categories of the physiographic location characteristic and classifies the stand as high, medium, or low risk (3, 2, or 1 rating) for that particular characteristic. He does this for each characteristic and then adds these rating values together. The total becomes the stand risk value which is used to classify the stand as having a high, medium, or low outbreak potential.

To calculate the rating for a hypothetical stand, assume these characteristics: (1) stand on a site with an index of 100, (2) average d.b.h. of the spruce of 17 inches, (3) basal area of the stand equals 155 ft^2 per acre, and (4) 70 percent of the canopy is spruce. Comparing these characteristics to the risk ratings in table 1, values of 2, 3, 3, and 3 are obtained for the respective characteristics. Adding these together gives a value of 11. The stand risk value of 11 is then translated into a potential outbreak rating:

Stand Risk Value	**Potential Outbreak Rating**
11-12	High
7-9	Medium
4-5	Low

The value of 11 gives the stand a high rating. If the value should be 4 or 5, the stand would receive a low rating; 7 to 9 would give it a medium rating.

Any arrangement of the different combinations of the four characteristic ratings shown below will give the risk value in parentheses:

Low (4-5)	**Medium (7-9)**		**High (11-12)**
1,1,1,1	1,3,2,1	2,2,2,1	3,3,3,3
1,1,2,1	1,3,3,1	2,2,2,2	3,2,3,3
	3,2,1,2	3,2,1,3	
	2,2,3,2		

Other Factors to Consider

There are two obvious voids in the system—one between the low and medium categories, and one between the medium and high categories. We believe these are "intermediate" areas where the rating of a stand legitimately falls between two more definitive categories. For example, a set of stand characteristics rating 2,1,2,1 or any combination of those values results in a stand risk value of 6:

Intermediate (6)	**Intermediate (10)**
1,1,3,1	3,3,3,1
2,1,2,1	3,3,2,2

Since half of the values are medium risk and the other half are low risk, the stand is midway between a low and medium outbreak rating. Should it rate low or medium? We believe it is intermediate, not distinctly in either category and needs further examination. Some sequential sampling plans for insect populations have similar voids, and the population is simply assigned to the next higher category. This solution could be used with this system, but we purposely left these voids because we believe they provide an ideal opportunity for the forest land manager and forest entomologist to work together, use their professional judgment, and derive an accurate stand rating.

We also recognize that the four stand characteristics in our method represent only a fraction of the factors that could be used. The forest manager may have information on windthrow potential, diameter growth rate, etc., from his own experience or from other published sources (such as Alexander 1973, 1974) which he can also consider in deciding whether the stand should be given a higher or lower rating. It is in this area where good experience and professional judgment are most beneficial.

Forest managers will ask "What size stand can be rated under this system?" In answering this question, we must first define a stand. We did so by paraphrasing the definition used by the Resource Inventory Project of Region 2, USFS (Forest Service Handbook): "A stand is a tree community possessing sufficient uniformity as regards timber type, age class, risk class, vigor, stand-size class and stocking class as to be distinguishable from adjacent communities and thus form a silvicultural unit." The rating system obviously works whether an area is 10,000 acres or 100 acres, as long as each area can be considered a stand. If an area does not meet the definition, the rating plan is not applicable.

Resource Inventory Projects in the Central Rockies are classifying the spruce-fir forests; stands in Colorado range in size from 40 to 200 acres. Unfortunately, some areas in the Central Rockies have yet to be delineated into stands so that areas of 10,000 acres or more, comprised of many stands, have not been classified. What can the forest manager do to circumvent this problem, and gain some type of rating for his stands? Two alternatives exist. First, apply the plan to the most susceptible part of the total acreage, and use the rating for the whole compartment. Since large areas such as drainages would probably be comprised of stands with high to low potential outbreak conditions, the total acreage would receive a high rating. This would lead to many areas with high ratings, and eliminate the value of the plan. In the second alternative, the land manager could apply the system to each of the different stands within the unit, derive an outbreak rating for each, and then average the ratings for the entire unit. This alternative is better than the first, but still does not fully utilize the system. Both alternatives compromise the system to the point where its usefulness is greatly reduced.

The system logically seems to conflict with the management objective of timber production. Since large spruce in stands of more than 65 percent spruce in the canopy and 150 ft^2 of basal area per acre constitute a high potential outbreak condition, their removal should lower the outbreak potential of the stand. However, their removal eliminates the major source of lumber. We recognize this conflict but suggest that the intent of the rating system is to identify the outbreak potential of each unmanaged stand, rather than to tell the manager how to manage. The manager decides whether to cut or leave such trees. He can leave the stand uncut, but he does so realizing that those trees are carried under high risk.

As mentioned previously, this system originates from several different sources not from a definitive study with the rating system as its objective. It has not been field tested, and therefore will probably be refined as it is used. Despite these disadvantages, we feel it provides the forest manager with another valuable tool for managing spruce forests and beetle populations.

Literature Cited

Alexander, Robert R.
1967. Site indexes for Engelmann spruce. USDA For. Serv. Res. Pap. RM-32, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Alexander, Robert R.
1973. Partial cutting in old-growth spruce-fir. USDA For. Serv. Res. Pap. RM-110, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Alexander, Robert R.
1974. Silviculture of subalpine forests in the Central and Southern Rocky Mountains: The status of our knowledge. USDA For. Serv. Res. Pap. RM-121, 88 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Knight, F. B., W. F. McCambridge, and B. H. Wilford.
1956. Estimating Engelmann spruce beetle infestations in the Central Rocky Mountains. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Stn. Pap. 25, 12 p. Fort Collins, Colo.

Massey, C. L., and N. D. Wygant.
1954. Biology and control of the Engelmann spruce beetle in Colorado. U.S. Dep. Agric. Circ. 944, 35 p.

Schmid, J. M., and T. E. Hinds.
1974. Development of spruce-fir stands following spruce beetle outbreaks. USDA For. Serv. Res. Pap. RM-131, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Agriculture—CSU, Fort Collins

ruary 1976

U S D A FOREST SERVICE
RESEARCH NOTE RM-310

OREST SERVICE
S. DEPARTMENT OF AGRICULTU

CKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A New Compact Pollinator

Michael R. Barnhart[1]

A simple and inexpensive pollinator was designed which is compact, waterproof, nonclogging, and requires only small quantities of pollen. It was used successfully in 1974 and 1975 for pollinating Scotch pine in a breeding program at the USDA Forest Service Shelterbelt Laboratory, Bottineau, N.D.

Keywords: Pollination, tree breeding, genetics.

Pollinators in current use are usually constructed with a one-way rubber bulb to force air into the pollen chamber and pollen out of it. Reines and Green (1956) attached the rubber bulb directly to the pollen chamber, while Perry (1954) attached it to a short length of glass tubing. Forbes (1974) fitted a bent piece of glass tubing inside the pollen chamber. Their pollinators are bulky, however, do not properly mix the pollen with air, and tend to plug frequently.

Our Scotch pine breeding program required a simple, compact, reliable, and inexpensive pollinator that could use small quantities of pollen and produce a desirable pollen-air mixture. We have used the pollinator described below in a controlled-pollination Scotch pine breeding scheme for two field seasons. We have found it to be completely satisfactory, with none of the shortcomings of other models.

The materials used in construction of the improved pollinator are simple and inexpensive. The pollen chamber is a polyethylene squeeze wash bottle (fig. 1a) with a screw cap (fig. 1b). The pollen passes through a polyethylene hose and nozzle (fig. 1c) and then through a disposable 18-gage hypodermic needle (fig. 1d) glued to the end of the nozzle.

Wash bottles from Nalge Company, which include the hose and nozzle, were used. The plastic rubber glue (Duro Plastic) and hypodermic needles were purchased from local hardware and drug stores. It is important that the glue remains flexible when dry. Total cost of materials per bottle is only 60 cents, and about 3 minutes are required to assemble each pollinator.

Assembling the pollinator is simple. Insert the tubing through the cap and into the wash bottle. Tighten the cap to make a tight, waterproof seal. With a single-edge razor blade, cut off the nozzle 9 mm from its base (dotted line in fig. 1c). Spread a thin film of plastic rubber glue around the outside of the nozzle. Slip the base of the hypodermic needle over the nozzle, being careful not to clog it. The glue takes several hours to dry.

This pollinator has several advantages:

1. It is well sealed and waterproof because the 6 mm hose passes through a 5 mm hole in the screw cap (fig. 1b, c).
2. The resilient polyethylene bottle walls respond to the slightest pressure.
3. It is inexpensive, compact, light, and easy for the operator to control during pollination.
4. It handles small quantities of pollen.
5. The operator can see through the bottle and hose to observe pollen movement and control hose depth accordingly.

---

[1] *Forestry Research Technician, located at the Shelterbelt Laboratory, Bottineau, in cooperation with North Dakota State University-Bottineau Branch and Institute of Forestry. Station's central headquarters maintained at Fort Collins in cooperation with Colorado State University.*

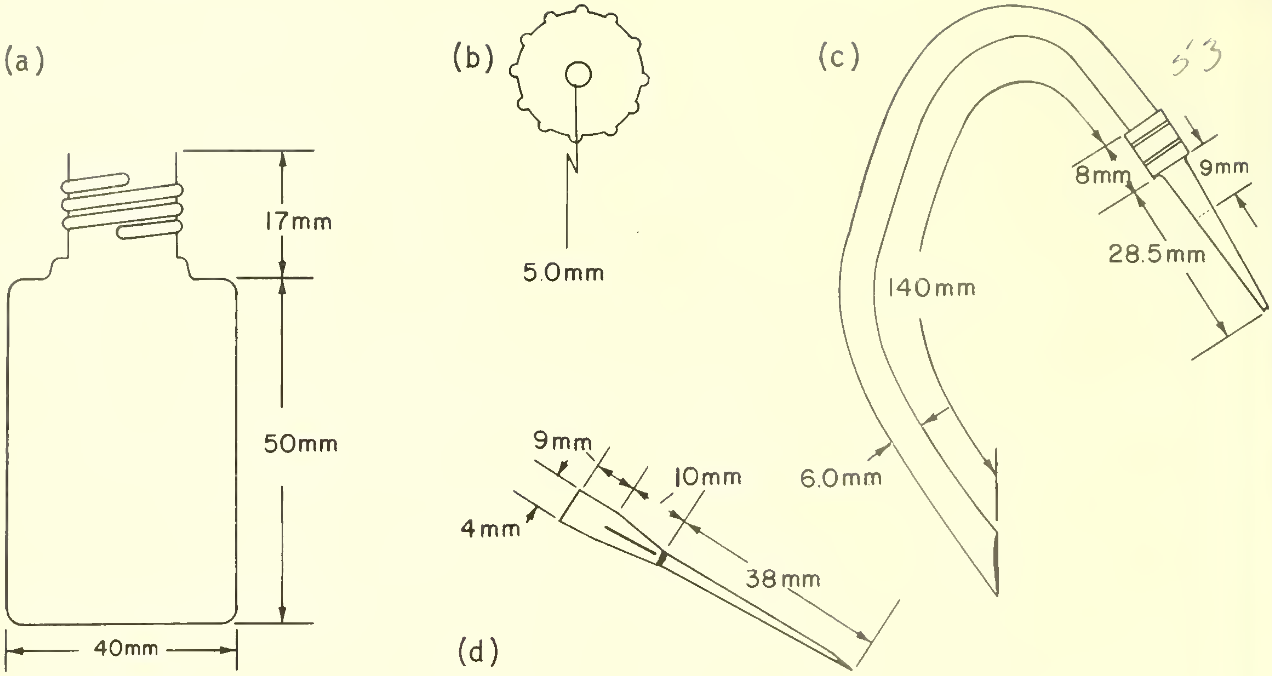


Figure 1.—Scale drawing of components of the improved pollinator: (a) polyethylene squeeze wash bottle; (b) bottle cap with top opening 1 mm smaller than hose; (c) hose and nozzle; and (d) disposable hypodermic needle.

The improved pollinator is used in the field much like other pollinating devices. Pour some pollen in the bottle; the amount is not important as long as the hose opening is immersed in the pollen. Tighten the cap on the bottle top. To inject, tilt the bottle forward at a 45-degree angle, puncture the protective bag surrounding the flower, and squeeze quickly but slightly (fig. 2). This will force an adequate quantity of pollen through the needle.

When not in use, the hypodermic needle should be forced into a urethane foam Dispo plug to prevent contamination of pollen and for safety. These plugs are quicker to use and less likely to slip off than a plastic syringe sheath.

Figure 2.—Improved pollinator being used to pollinate Scotch pine conelets.

Literature Cited

Forbes, C. Donovan.
1974. Black walnut controlled-pollination techniques. Tree Planters' Notes 25(3):9-11.
Perry, O. Thomas.
1954. Controlled pollination of pine species in North America. J. For. 52(9):666-671.
Reines, M., and T. James Green.
1956. A syringe for pine pollination. J. For. 54(9):598.