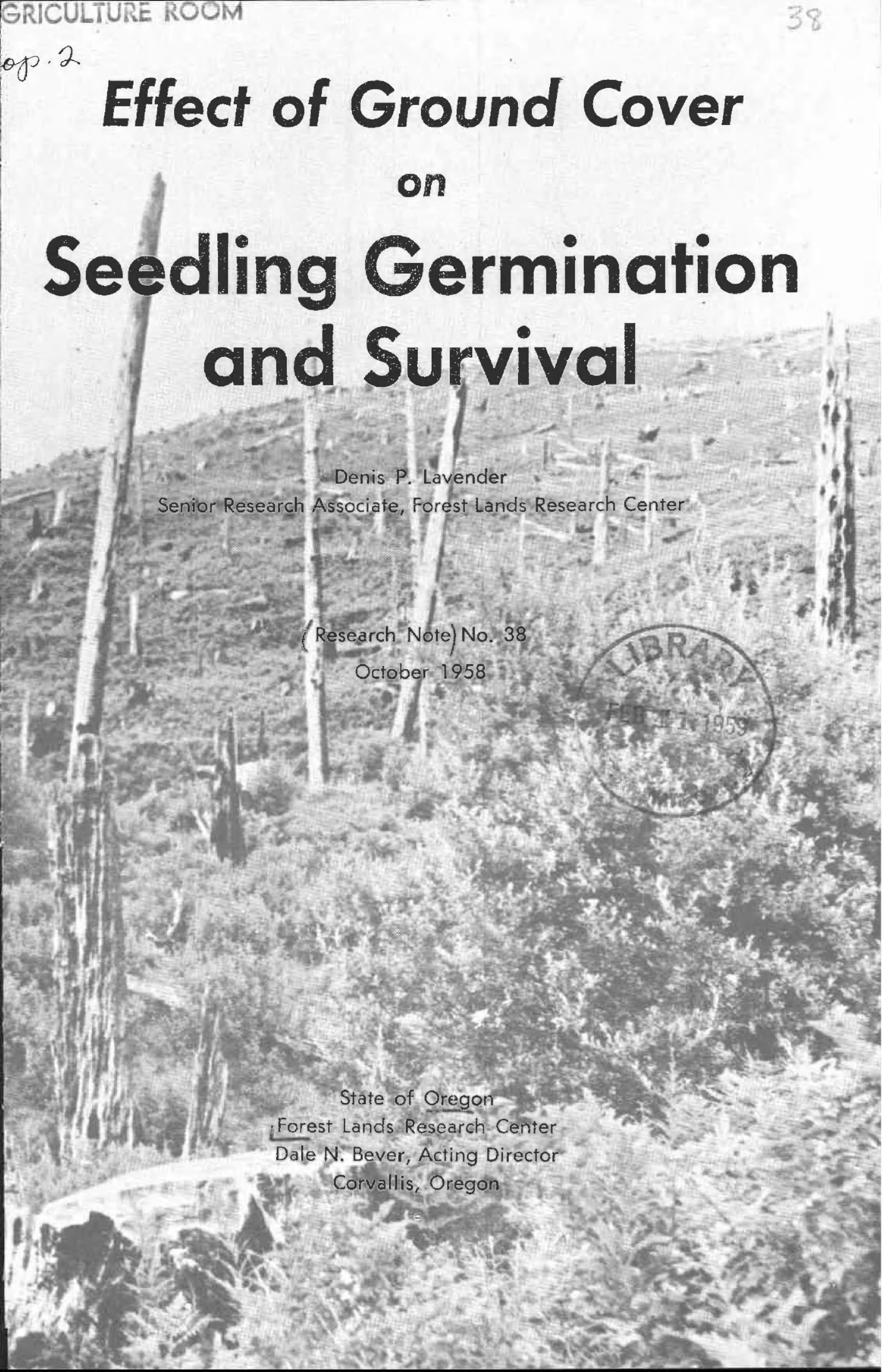

Effect of Ground Cover on Seedling Germination and Survival

Denis P. Lavender
Senior Research Associate, Forest Lands Research Center

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State of Oregon
Forest Lands Research Center
Dale N. Bever, Acting Director
Corvallis, Oregon

Forest Lands Research Center

. . . Its Purpose

Develop the full potential of Oregon's timber resource by:

- increasing productiveness of forest lands with improved forest practices.
- improving timber quality through intensified management and superior tree selection.
- reducing losses from fire, insects, and diseases—thus saving timber for products and jobs.

Keep development of the forest resource in harmony with development of other Oregon resources.

. . . Its Current Program

Seed production, collection, extraction, cleaning, storage, and germination.

Seedling production, establishment, and survival for new forests.

Growth and development of trees, quality of growth, and methods of thinning and harvesting to grow improved trees.

Study of forest fire behavior and fire weather to prevent fires.

Insect pests and their control, to save trees.

Disease control and prevention in Oregon forests.

Mammal damage and the controls to help regrowth.

Soils and their relationship to growth.

Development of improved forests through selection and breeding.

Effect of Ground Cover on

Seedling Germination and Survival

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Summary

Moderate to heavy ground cover typical of the eastern two-thirds of Oregon's Tillamook Burn does not necessarily limit the success of direct seeding projects. Neither the mechanical barrier of fallen leaves from deciduous shrubs nor the competition of growing vegetation appear to affect seriously the establishment of seedlings from seed.

Previous aerial seeding projects in the burn have avoided areas where low vegetation or the leaf litter from deciduous shrubs and trees was heavy.

High quality, vigorous seed, combined with effective control of seed-eating mammals, sufficient moisture, and favorable exposure is quite likely to result in successful reforestation attempts on areas supporting a ground cover similar to that found in the eastern two-thirds of the Tillamook Burn.

The area chosen for this study was devastated by four major fires between 1933 and 1951, sweeping over land previously covered with a Douglas fir forest. These fires eliminated natural seed sources for the bulk of the acreage.

Cover intensity in the experimental area varied from light (0-33% of ground surface covered by living plant material), to medium (33-66%), to heavy (66-100%). The overall experimental design checked each of these types for effect on seed germination and seedling survival and included double checks in the laboratory. Results indicated that while herbaceous cover may tend to delay germination, it does not always affect final germination percent nor total seedling survival.

Seed for the research project was collected in the fall of 1953 in the North Santiam River drainage at an elevation of about 3,600 feet. The Douglas fir cones were dried, seed extracted and stored at 0°F. until fall of 1954 when it was cleaned further and some seeds randomly selected for germination tests. The seedlot showed a viability of 91%.

For the purpose of the experiment, seed-eating mammals on the area were forestalled by protective "hoods" of galvanized sheet metal rings and ¼-inch hardware cloth. Each of these was designed to accommodate the ten Douglas fir seeds which were simply scattered over the enclosed soil surface.

Devices for measuring temperature and moisture conditions were installed around the experimental

area and provided a general measure of the environment. While the micro-climates immediately around individual seedlings could not be accurately measured, they did seem to function actively in determining actual germination dates. Since the 1955 growing season was characterized by a cold, moist spring and a cool, relatively dry summer, soil temperature was not a limiting factor, but available moisture did seem to exert considerable influence. With a very dry August and September, it was especially interesting to note that the surviving seedlings (dug up in late September) had root systems clearly superior to those that had died.

In this experiment a northerly exposure proved much more desirable for seedling survival than other exposures. These data pertain to the ecological factors studied and are not applicable to greatly different plant communities.

Introduction

Major fires swept over a large portion of the Coast Range of northwestern Oregon in 1933, 1939, 1945, and 1951 devastating an area originally covered by a fine stand of Douglas fir (*Pseudotsuga menziesii* [Mirb.]). This burned area is known as the "Tillamook Burn." Much of the 350,000 acres has been burned two or more times. The succession of four fires left no source of natural seed for most of the area. If this land is to be reforested, it will have to be done by artificial means. Handplanting of coniferous nursery stock and direct seeding, either by helicopter or by hand-operated seeders, are two reforestation methods currently employed.

Planting requires no control of seed eaters and the most favorable microsites can be stocked with relatively large seedlings. Planting, however, is very expensive and slow. In contrast, direct seeding is rapid and much less expensive.

Success of direct seeding is dependent upon efficient control of seed-eating mammals and seed beds favorable for germination and survival. Past surveys have attempted to evaluate effects of vegetation upon seed germination and seedling survival. The project described herein was designed to evaluate these effects as accurately as possible.

The broad objective was to provide a practical guide for reforestation work in the Tillamook Burn and in other areas with similar soil and cover types and to increase our knowledge of Douglas fir seedling ecology.

The plant cover on the portion of the Tillamook Burn sampled varies from very light on some microsites to heavy on others. The terrain is rugged. Slopes of any direction or steepness may be found. The field experiment was designed to compare the effects of different cover intensities on the four major exposures, north, south, east, and west, upon the germination of seeds and the establishment of Douglas fir seedlings.

The greenhouse study, investigating the effects of vegetative debris upon Douglas fir seed germination, was designed to supplement and facilitate the interpretation of field data.

Seed used in study

In 1953 the seeds used were collected from the west slope of the Oregon Cascade Mountains at 3,600 feet elevation. The cones were dried at temperatures of from 85°F. to 110°F. The seeds were extracted by hand and cleaned on a Clipper fanning mill. They were stored at 0°F. until the fall of 1954, when they were further cleaned until the seed lot was 98.25% sound. Six hundred seeds selected at random proved to have a viability of 91%. This is somewhat above that (70-85%) of most Douglas fir seed and is at least partly responsible for the high field germination. This high germinative vigor may also be one of the reasons for the extremely high percent of germinants which lived through to the conclusion of the project. In 1956 the viability had dropped to 89%. However, these seeds still produced 50% more seedlings in the field than did a 1955 lot which germinated 83% in the laboratory.

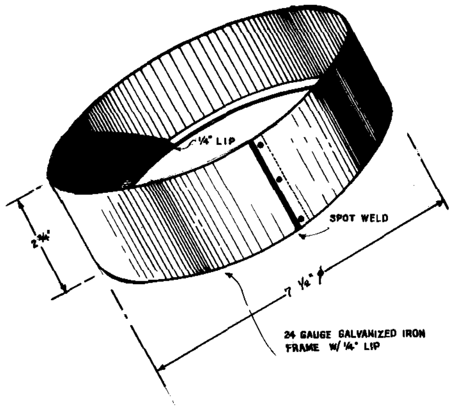

Figure 1. Diagram of galvanized steel ring used to protect seed spots.

Protection from seed-eating mammals

Field experiments with tree seed germination and survival in the Pacific Northwest must be protected from the depredations of the ubiquitous white-footed deer mouse *Peromyscus* spp. and other seed-eating mammals. The apparatus designed for this purpose consisted of galvanized sheet steel rings (figure 1) forced into the soil until the sides were approximately ¼-inch above the soil surface, with a hood of ¼-inch hardware cloth approximately cut eight inches high pegged down over the ring (figure 2).

Weather observations

Temperature- and moisture-measuring devices were installed in the experimental area. The variations in soil moisture and temperature which occur in an area even as small as 7½ inches in diameter make accurate measurement of the meteorological factors of the miscrosite of each seedling impractical. For this reason the data provided by the instruments on each of the four slopes and cover types can be regarded as a mean. The individual seedlings in any seed spot may have been exposed to temperature and moisture stresses more or less severe than the data obtained from the instruments.

Maximum-registering mercury thermometers were employed to measure soil surface temperatures. These were read once each week. During the winter and spring of 1956, William P. Lowry, research meterologist, Oregon Forest Lands Research Center, and the author compared the temperatures recorded by thermometers with those obtained from thermocouples under varying conditions. The temperatures recorded by the thermometers were approximately 2°F. lower than those of the thermocouples.

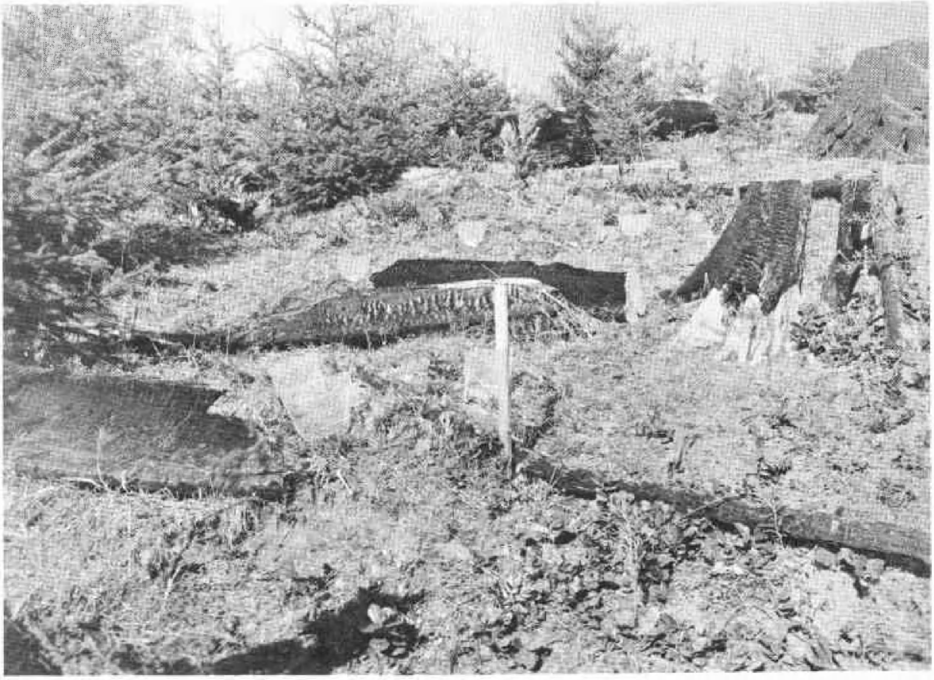

Figure 2. Sample seed spots with protective hoods on West Plot 8, May 27, 1955. Coniferous reproduction is the result of a planting experiment.

Figure 3. "Tempscribe" installation on West Plot 8, May 27, 1955.

Bacarach 7-day tempscribes were used to record ambient temperatures. These instruments were housed in shelters on the north side of logs or stumps (figure 3).

Fiberglas soil moisture units containing the electrode sandwich and equipped with 6-foot lead-in wires were installed at the surface of the soil and at the 3- and 10-inch levels. These units were "read" once a week with the Colman soil moisture ohmmeter.

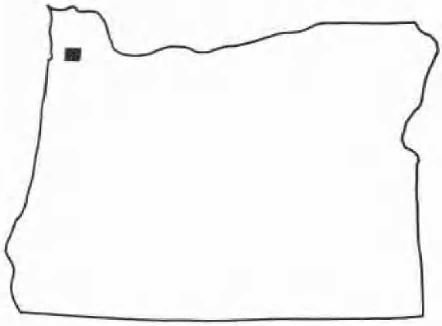

Figure 4. Black square marks location of experimental area.

Location and topography of the experimental area

The study plots were located in a rectangular area, near the center of the Tillamook Burn, (45°30′ north latitude, 123°30′ west longitude) (figures 4 and 5). The elevation of this area varies from 500 to 2,800 feet above mean sea level. The topography of the area is that of a dissected plateau and includes broad, flat ridges and sharp, narrow valleys.

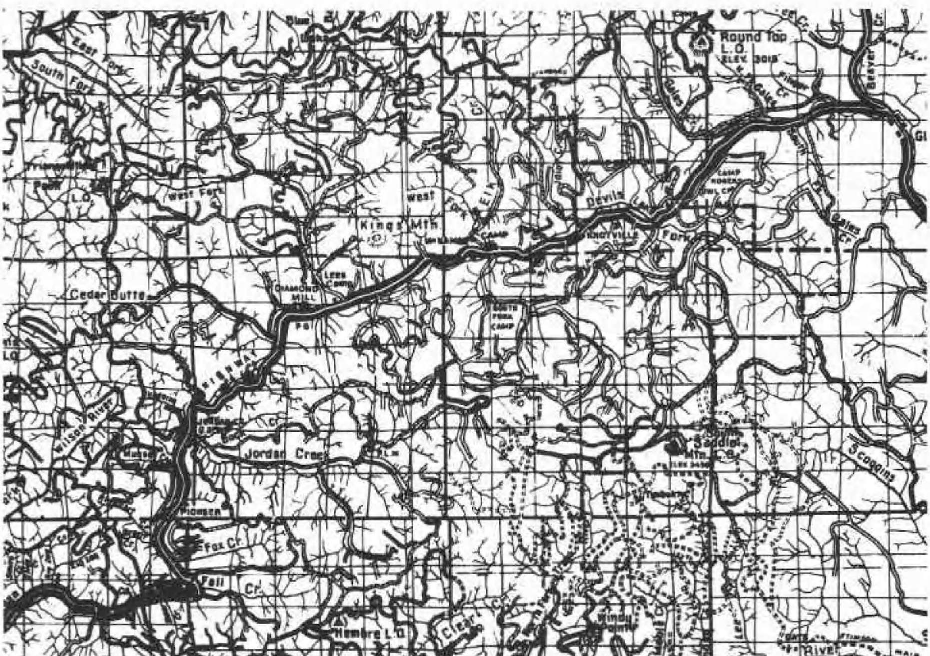

Figure 5. Detail of the portion of the Tillamook Burn where the study was carried out.

Vegetation

Most of the Tillamook Burn has a cover similar to the vegetation found in the Oregon Cascades at comparable altitudes. The following plant species are found in the experimental area:

HERBACEOUS

(Annual and Perennial)

Scientific name	Common name
Achlys triphylla	Vanillaleaf
Agrostis exarata Trin.	Western bentgrass
Aira caryophyllea L.	Silver hairgrass
Anaphalis margaritacea var. *occidentalis* Greene	Pearly everlasting
Anthriscus vulgaris (L.) Pers.	Bur-chervil
Campanula scouleri Hook.	Scouler's campanula
Cerastium L. sp.	
Chrysanthemum leucanthemum L. var. *pinnatifidum* Lec. and Lam.	Oxeye-daisy
Cirsium lanceolatum (L.) Scop.	Common thistle
Clintonia uniflora (Schult.) Kunth.	One-flowered Clintonia
Coptis laciniata Gray.	Western goldthread
Cornus canadensis L.	Dwarf dogwood
Deschampsia Beauv. sp.	Hairgrass
Disporum smithii (Hook.) Piper	Large-flowered fairybells
Elymus L. sp.	Ryegrass
Epilobium angustifolium L.	Fireweed
Epilobium L. sp.	Willowherb
Festuca myuros L.	Rattail fescue
Galium L. sp.	Bedstraw
Gnaphalium L. sp.	Cudweed
Hieracium albiflorum Hook.	White-flowered hawkweed
Holcus lanatus L.	Velvetgrass
Hypericum perforatum L.	Common St. Johns-wort
Hypochaeris radicata L.	Hairy Cats-ears
Lotus corniculatus L.	Birdsfoot trefoil
Lotus micranthus Benth.	Small-flowered lotus
Lotus stipularis Greene var. *subglaber* Ottl.	Thicket lotus
Lupinus oreganus Hel.	Oregon lupine
Lupinus rivularis Dougl.	Riverbank lupine
Luzula campestris (L.) DC. var. *multiflora* (Ehr.) Celak	Common woodrush
Luzula parviflora (Ehr.) Desv.	Small-flowered woodrush

Scientific name	Common name
Mitella ovalis Greene.	Oval-leaved mitrewort
Oxalis oregana Nutt.	Oregon oxalis
Plantago major L.	Common plantain
Poa L. sp.	Bluegrass
Prunella vulgaris L.	Heal-all
Rumex acetosella L.	Red or sheep sorrel
Sanicula (Tourn) L. sp.	Snakeroot
Scrophularia californica C. and S.	California figwort
Smilacina racemosa (L.) Desf.	False Solomons-seal
Stachys rigida Nutt.	Rigid hedge nettle
Streptopus amplexifolius (L.) DC	Large twisted-stalk
Taraxacum officinale L.	Dandelion
Trientalis latifolia Hook.	Broad-leaved starflower
Vancouveria hexandra (Hook.) Morr. and Dene	Inside-out flower
Verbascum Thapsus L.	Mullein
Viola (Tourn.) L. sp.	
Xerophyllum tenax (Pursh.) Nutt.	Beargrass

FERNS

Scientific name	Common name
Pteridium aquilinum (L.) Kuhn. var. *pubescens* Underw.	Western brakefern

BRUSH AND SHRUBS

Scientific name	Common name
Amelanchier florida Lindl.	Western serviceberry
Arctostaphylos columbiana Piper	Hairy manzanita
Berberis nervosa Pursh.	Long-leaved Oregon grape
Gaultheria shallon Pursh.	Salal
Rubus parviflorus Nutt.	Thimbleberry
Rubus spectabilis Pursh.	Salmonberry
Rubus vitifolius C. and S.	Western dewberry or Training blackberry
Sambucus glauca Nutt.	Blue elderberry
Symphoricarpos mollis Nutt.	Creeping snowberry
Vaccinium parvifolium Smith	Red huckleberry

Figure 6. Typical "light" cover. Photograph taken on North Plot 3, September 23, 1955.

Experimental design

The cover density was estimated in three classes: light, 0-33% of the ground surface covered by living plant material (figure 6); medium, 33-66% of the ground surface covered by living plant material (figure 7); and heavy, 66-100% of the ground surface covered by living plant material (figure 8).

This study was designed primarily to determine the effects of such cover upon germination and survival of Douglas fir seedlings. Accordingly, six areas of each cover type were located for each major exposure. In most areas two or three of the cover classes were located on a single hillside. For each replicate of each type of cover a set of three protected seed spots was installed as the sample unit. Each of the three seed spots received one of the following preseeding treatments:

Mineral. Ground surface within the ring scraped bare to mineral soil. This was a check or control seed spot.

Undisturbed. Neither living nor dead organic material within the ring was disturbed prior to seeding. (This procedure simulated seeding after leaf fall).

Disturbed. Dead organic material was removed prior to seeding and replaced after seeding in a close approximation to the original arrangement. (This sub-treatment simulated seeding before leaf fall.)

Ten seeds were placed in each seed spot, randomly scattered over the area within the protective ring.

Thus the experimental design contained four exposures (NSEW); three covers (light, medium, and heavy); three preseeding treatments (mineral, undisturbed, disturbed) combined factorially with six replications for a total of 216 individual seed spots.

Experimental procedures

Limitations of time and equipment made it impossible to visit all plots every week to record meteorological

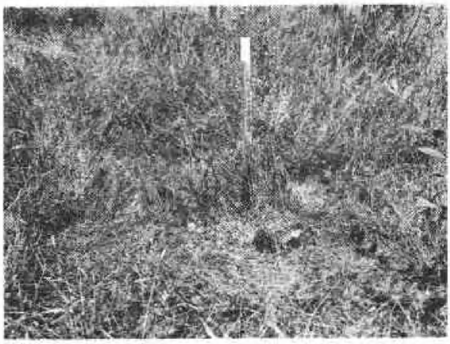

Figure 7. Typical "medium" cover. Photograph taken on South Plot 3, September 23, 1955.

Figure 8. Typical "heavy" cover. Photograph taken on East Plot 15, September 23, 1955.

data; therefore, the field plots were divided into two classes: 1) noninstrumented plots; and 2) instrumented plots.

Most of the plots had no soil moisture- or temperature-registering devices. These plots were visited once every three or four weeks. Germination or mortality occurring subsequently to the previous examination was noted together with the condition of the living seedlings.

Temperature- and soil moisture-measuring equipment was installed at only one replicate for each major exposure. Four areas, each of which contained plots of light, medium, and heavy cover, were selected. Three soil moisture units were installed at each seed spot, one at the soil surface, one at the three-inch level, and one at the ten-inch level. In addition, one unit was installed at the soil surface immediately adjacent to each of two seed spots to provide a means of measuring the effects of the sheet steel rings on soil moisture. The units were installed in the fall to allow ample time for establishment of proper contact between units and soil.

One maximum thermometer was placed on the soil surface in each seed spot. In addition, one thermometer was placed on the soil surface immediately adjacent to each of two seed spots to provide a means of measuring the effects of the hardware cloth hoods on the soil temperature. All thermometers were placed so the plane of the soil surface bisected the thermometer bulb (figure 9).

The four instrumented areas were visited weekly from April 4th until the termination of the field experiment in October of 1955. Data recorded on the weekly inspections included a description of the seedlings together with

Figure 9. Illustrates typical placement of thermometers. Wires on right hand side of seed spot lead to soil moisture block buried at the soil surface.

readings of the soil units and thermometers. In addition, the ambient temperature records from the Tempscribe installed on each exposure were collected each week.

On June 1st, the hoods were removed from all instrumented seed spots originally containing organic debris. This provided 12 pairs of screened and unscreened seed spots to measure the effects of the hardware cloth hood on maximum soil temperatures and on seedling survival.

Greenhouse study

During the course of previous years' studies on seeding with Douglas fir the author had noted examples of germinated seeds unable to force their radicles through partially decayed leaves. A. Koroleff, in published material and in correspondence with the author, indicates the serious problem hardwood leaves present to satisfactory stocking of forest lands in eastern North America.

The greenhouse experiment was designed to determine whether the physical impedance presented by layers of dead organic material was sufficient to prevent successful germination of

Figure 10. Typical hardwood cover flat. Light layer of peat moss utilized to keep leaves moist. Photograph taken April 12, 1955.

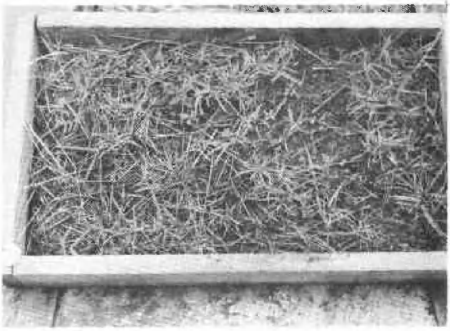

Figure 12. Typical grass cover flat. Photograph taken April 12, 1955.

Douglas fir seed when other physical factors were favorable. Accordingly 14 $2\frac{1}{2}$ x 12 x 19-inch greenhouse flats were filled with thoroughly mixed Hembre silt loam. This Tillamook Burn soil is in the Brown Latosol great soil group and is a deep, friable silt-loam developed on weathered basalt.

The organic litter was arbitrarily divided into three types: hardwood (*Quercus oregoni, Acer circinnatum, Alnus rubra, Acer macrophyllum, Rubus parviflorus*, and *Rubus spectabilis*); fern (*Pteridium aquilinum* var. *pubescens*); and grasses (*Festuca Myuros, Poa* sp., *Agrostis exorata Holcus lanatus*, and *Aira caryophyllea*). Figures 10, 11, and 12 illustrate these three types.

Four seed flats were provided to test each of the three cover types. A layer of dead organic material sufficient to just obscure the surface of the soil visually was placed in these twelve flats. In addition, a second layer approximately equal to the first was added to half the flats. Thus two flats were covered with a single layer of organic material of each of the three types; and two, with a double layer. The soil surface of the last two of fourteen flats was left bare to serve as a control (figure 13).

Three hundred seeds were spaced equally over the surface of each flat. Half the seeds were planted below the single layer, and half on the single layer in each flat with only one layer of

Figure 11. Typical fern cover flat. Photograph taken April 12, 1955.

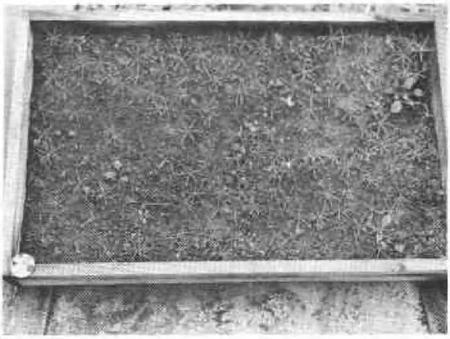

Figure 13. Control flat. Photograph taken April 12, 1955.

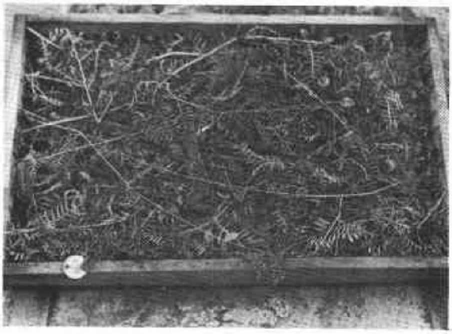

Figure 14. Flat with a single layer of fern cover. Photograph taken April 12, 1955.

Figure 15. Same flat as that shown in figure 14. Photograph taken June 29, 1955. Major herbaceous species present include velvetgrass, silver hairgrass, and sheep sorrel.

organic cover. Where two layers of organic cover were placed in a flat, one-third of the seeds were planted on the soil; one-third between the layers; and one-third on top of both layers. Random selection was used to locate the various planting techniques within each flat. This procedure was followed to insure equal numbers of seeds in all possible positions relative to the cover at the initiation of the study.

The flats were placed in steel pans which permitted watering from below once a week. This procedure was fol-

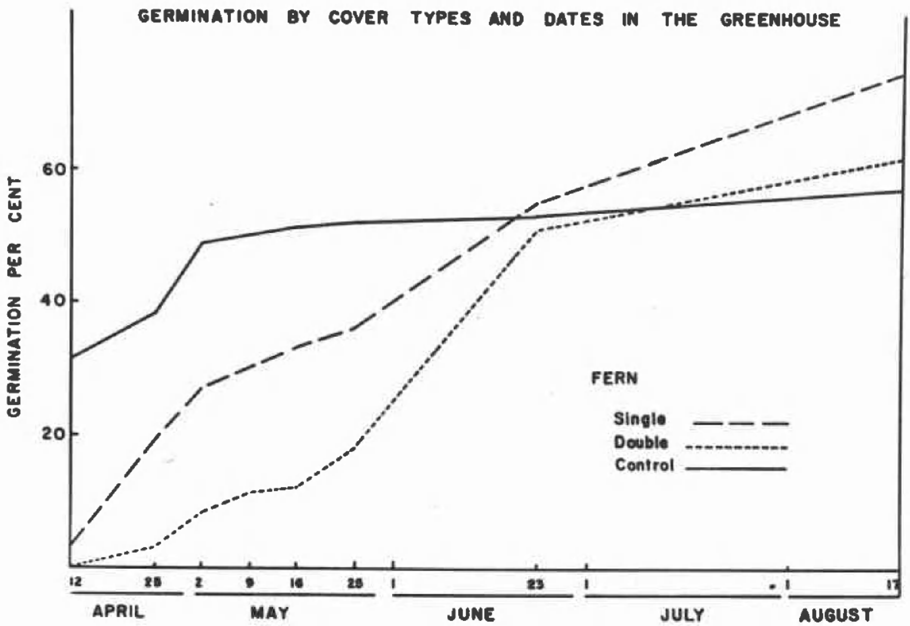

Figure 16.

lowed to avoid disturbing the layers of cover during watering and to insure uniform moisture in all the flats.

The flats were inspected and watered once a week from the date of seeding until this phase of the study was terminated on July 29, 1955. After planting, the flats were treated with "fermate" to kill damping off fungi.

No attempt was made to control the growth of herbaceous cover plants. A comparison of figures 14 and 15 will show the extent living herbaceous cover developed during the study.

Early in August all seedlings, living and dead, were removed from each flat and tallied. The results of this final examination together with the results of the earlier greenhouse examinations are shown in figures 16, 17, and 18.

Analyses of the data presented in figures 16, 17, and 18, and table 6 indicate that the organic litter on the surface of the seed flats significantly reduced the germination of Douglas fir seed until the latter part of June (or until about two months after initial germination on mineral seed beds). Had this occurred under field conditions, it is entirely possible that this two-month delay in germination would result in much greater mortality, as the seedlings would not have developed their root systems before the normal summer drought. Although some differences exist between the effects of the different litter types and densities, none is significant.

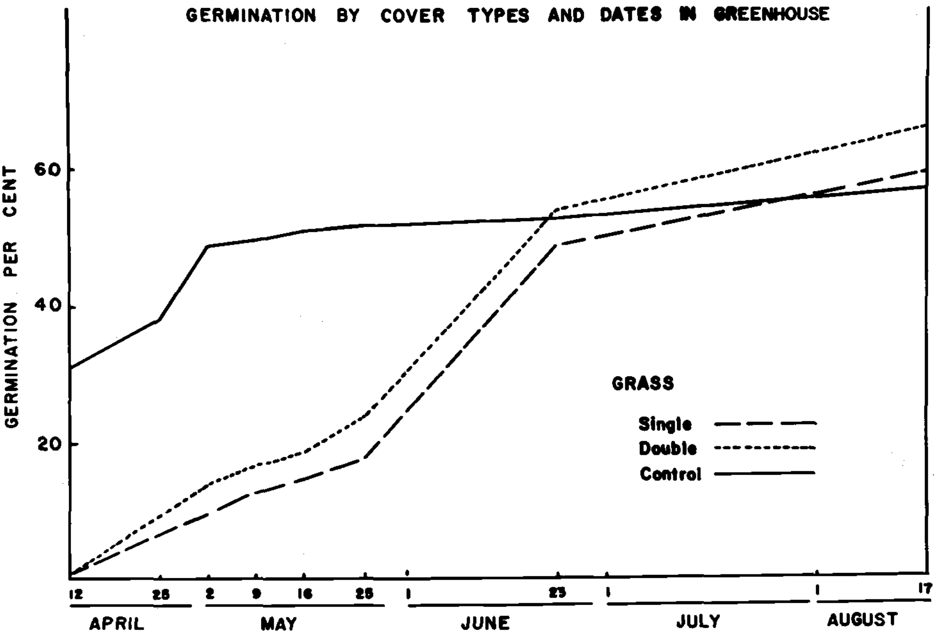

Figure 17.

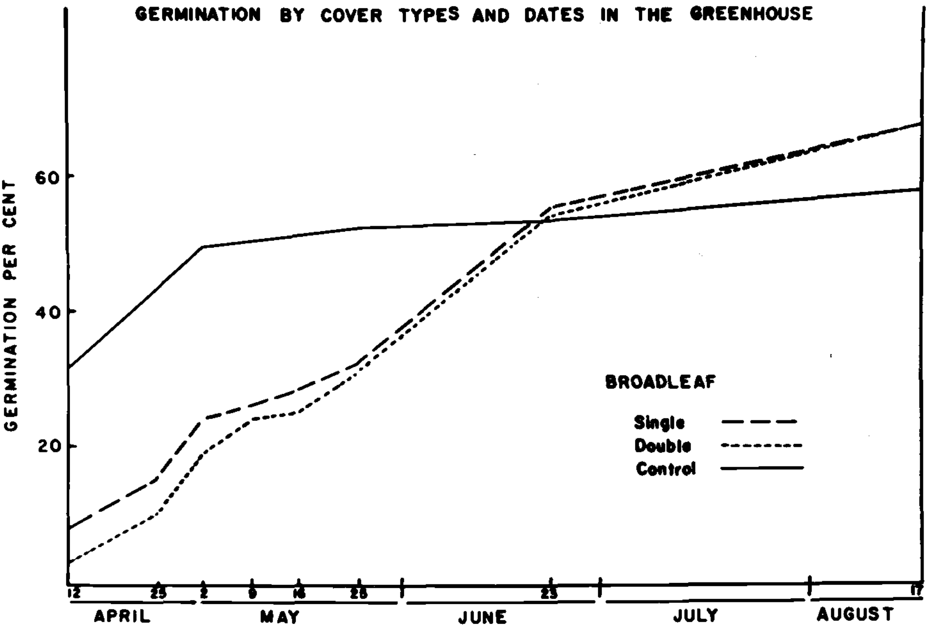

Figure 18.

Results

Tables 1-5 present a summary of the germination and survival data for each factor studied.

Only the "exposure" treatment was significant. The interactions are all significant; therefore no statement as to favorable cover or seeding conditions may be made for all exposures.

Effect of screen hoods on soil surface temperature

Experience in other regions indicates that the use of screened seed spots results in increased germination and survival of coniferous seedlings. Schopmeyer, C. S., and Helmers, A. E., found that the use of screens appeared to reduce the mortality of seedling Engelmann spruce (*Picea engelmanni* [Parry] Engelm.), ponderosa pine (*Pinus ponderosa* Dougl.), and western white pine (*Pinus monticola* Dougl.) in the northern Rocky Mountains. In the same region, Miller, C. I., found it necessary to leave the screen caps over ponderosa pine and white pine seedlings for a year to prevent depredations by mice and other rodents. Fowells, H. A., and Schubert, G. H., report that the germination and survival of ponderosa pine, sugar pine (*Pinus lambertiana* Dougl.), Jeffrey pine (*Pinus jeffreyi* Grey et Balf.) and white fir (*Abies* spp.) were increased under screen caps in California even when the rodent population was low. Krauch, H., noted that newly germinated Douglas fir seedlings in unscreened seed spots in Arizona were clipped by mice shortly after emerging. The same author indicates that the screen reduces soil temperature and

ANALYSIS OF VARIANCE

Source of variation	D.F.	Sum of squares	Mean square	"F"	Tab. "F"
Total	202				
Exposure	3	1,212.97	404.32	13.79	3.91**
Cover	2	101.77	50.88	1.73	3.05 n. s.
Seeding condition	2	164.13	82.06	2.80	3.05 n. s.
Exp. x cover	6	1,643.05	273.84	9.34	2.92**
Exp. x seeding condition	6	1,478.45	246.41	8.40	2.92**
Cover x seeding condition	4	344.67	86.17	2.94	2.40*
Exp. x cover x seeding condition	12	2,231.95	193.50	6.60	2.29**
Error	167	4,898.06	29.33		

** Significant at 1% level.
* Significant at 5% level.
n. s. Nonsignificant.

Table 1. NUMBER OF SEEDLINGS ON ALL EXPOSURES

	Degree of cover			Seedbed condition			Total
	light	medium	heavy	mineral	disturbed	undisturbed	
Germinants							
Total alive	287	343	315	293	349	303	945
Total dead	215	184	147	196	163	187	546
Total	502	527	462	489	512	490	1,491
Total possible germinants	650	700	680	660	680	690	2,030
Germination percent	77	75	68	74	75	71	73
Mortality percent	43	35	32	40	32	38	37
No. of living seedlings/100 seeds placed	44	49	46	44	51	44	47

Table 2. NUMBER OF SEEDLINGS ON NORTH EXPOSURE

	Degree of cover			Seedbed condition			Total
	light	medium	heavy	mineral	disturbed	undisturbed	
Germinants							
Total alive	91	132	103	106	118	102	326
Total dead	41	19	11	31	19	21	71
Total	132	151	114	137	137	123	397
Total possible germinants	170	180	180	170	180	180	530
Germination percent	78	84	63	81	76	68	75
Mortality percent	31	13	10	23	14	17	18
No. of living seedlings/100 seeds placed	54	73	57	63	65	56	62

Table 3. NUMBER OF SEEDLINGS ON WEST EXPOSURE

	Degree of cover			Seedbed condition			Total
	light	medium	heavy	mineral	disturbed	undisturbed	
Germinants							
Total alive	64	88	66	64	76	78	218
Total dead	40	38	37	50	33	32	115
Total	104	126	103	114	109	110	333
Total possible germinants	130	160	150	150	140	150	440
Germination percent	80	79	69	76	78	73	76
Mortality percent	38	30	36	44	30	29	35
No. of living seedlings/100 seeds placed	49	55	44	43	54	52	50

Table 4. NUMBER OF SEEDLINGS ON EAST EXPOSURE

	Degree of cover			Seedbed condition			Total
	light	medium	heavy	mineral	disturbed	undisturbed	
Germinants							
Total alive	63	67	67	51	83	63	197
Total dead	58	61	28	48	41	58	147
Total	121	128	95	99	124	121	344
Total possible germinants	170	180	140	150	170	170	490
Germination percent	71	71	68	66	73	71	70
Mortality percent	48	47	29	48	33	48	43
No. of living seedlings/100 seeds placed	37	37	48	34	49	37	40

Table 5. NUMBER OF SEEDLINGS ON SOUTH EXPOSURE

	Degree of cover			Seedbed condition			Total
	light	medium	heavy	mineral	disturbed	undisturbed	
Germinants							
Total alive	69	56	79	72	72	60	204
Total dead	76	66	71	67	70	76	213
Total	145	122	150	139	142	136	417
Total possible germinants	180	180	210	190	190	190	570
Germination percent	81	68	71	73	75	72	73
Mortality percent	52	54	47	48	49	56	51
No. of living seedlings/100 seeds placed	38	31	38	38	38	32	36

Table 6. NUMBER OF GERMINANTS IN GREENHOUSE FLATS*

Type of cover	Date							
	4/12	4/25	5/2	5/9	5/16	5/25	6/23	8/17
Mineral	187	228	292	302	308	314	321	344
Single fern	16	117	163	163	177	216	332	444
Double fern	0	19	49	65	75	108	308	370
Single grass	4	20	62	76	89	107	292	351
Double grass	5	35	83	101	113	133	**	399
Single broadleaf	48	92	147	158	171	191	332	403
Double broadleaf	17	58	114	142	148	186	326	403

* Table lists total number of germinants recorded for each date. Total possible for each cover type is 600.
** No count made on this date.

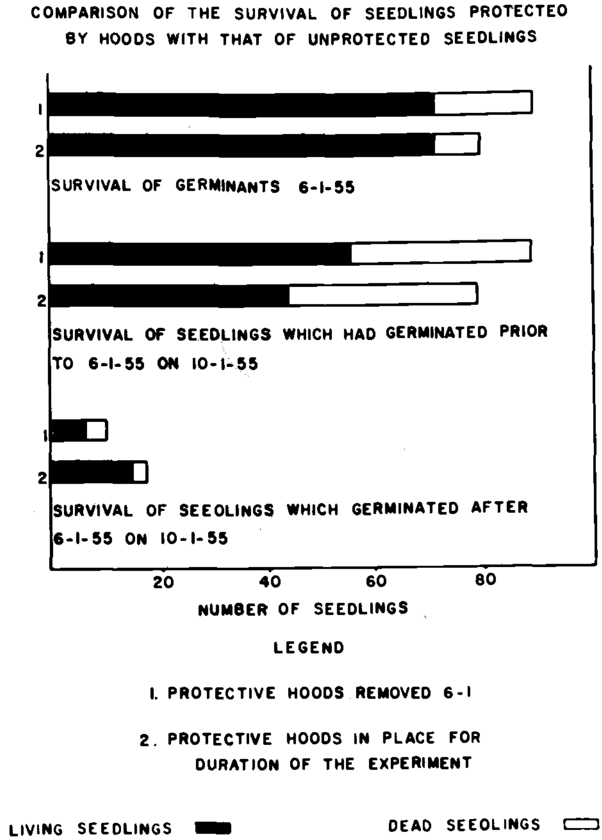

Figure 19.

mortality of the second year seedlings.

In spite of this unanimous evidence of the favorable effect of seed caps upon the survival of coniferous seedlings, statistical analysis of the data presented graphically in figure 19 failed to indicate that survival of seedlings under screen was significantly higher than that of the unprotected seedlings. The survival of the seedlings alive on June 1 in the seed spots not screened subsequent to that date was significantly greater than that of similar seedlings in screened seed spots. Since seed spots were randomly selected, they should have been representative of the conditions existing during the entire experiment. No seedling was more than four weeks old at the time the hoods were removed, and an examination of the maximum temperature records for the unscreened thermometers prior to June 1 shows that only on the southerly exposures were potentially lethal temperatures recorded and even here 120°F. was recorded only once. It is safe to assume that, with possible exception of the south slopes, the hoods increased the survival of the seedlings only by preventing animal damage.

Figure 20 presents the average weekly maximum temperatures noted

RELATIONSHIP OF AVERAGE MAXIMUM TEMPERATURES ON SCREENED AND UNSCREENED PLOTS

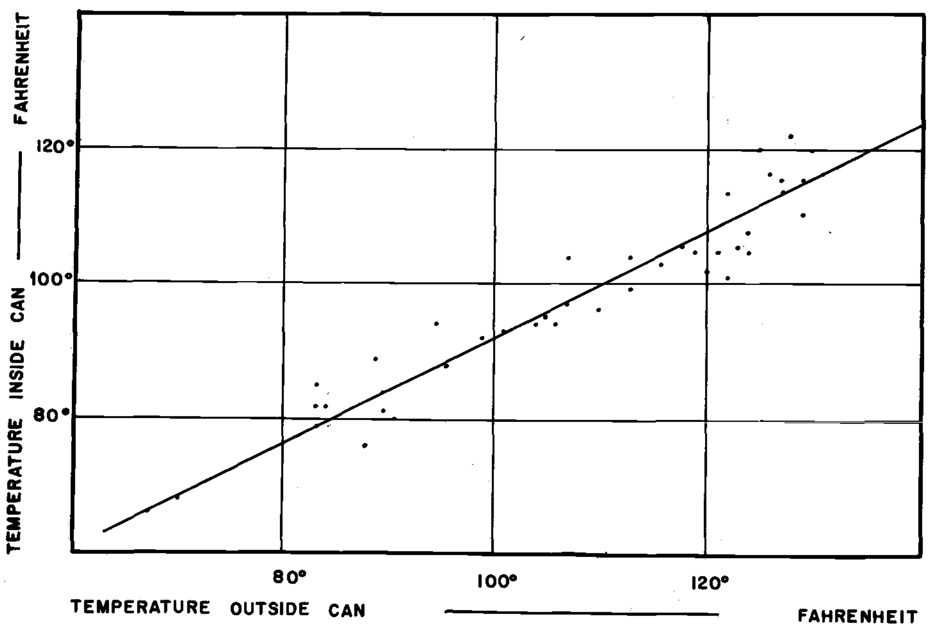

Figure 20.

on the paired screened and unscreened thermometers located in the plots with the soil surface scraped bare and in the 12 pairs of plots described above. This chart clearly shows that the screens do reduce the surface soil temperatures. This difference is due at least partly to the compaction of herbaceous growth by the screen. Fowells and Arnold report the average maximum temperatures inside a cone of 4-mesh 20-gauge hardware cloth 10 inches high and 10 inches in diameter to be 12.2°F. less than comparable maxima outside of the cone. Laboratory trials by the author showed that the hood reduced soil temperature by 13.0°F. when the true soil temperature reached 177°F.

Effect of soil surface temperatures

The problem of the effect of extreme temperatures upon the tissues of plants has been the subject of numerous investigations during the past century. The results of only a few studies directly concerned with Douglas fir seedlings will be reviewed here.

In California, Baker found that, under controlled laboratory conditions, soil surface temperatures in excess of 151°F. were fatal to all Douglas fir seedlings. His equipment included containers of soil in which coniferous seedlings had germinated and a source of radiant heat. Temperature measurements within the seedlings and in the layer of dry sand spread over the moist soil were made with thermocouples. He found that maximum temperatures within the sand exceeded those inside the seedlings by as much as 17°F. The age of the treated seedlings is not given; however, the stems are described as being succulent. This condition obtains with Douglas fir until the

RELATIONSHIP OF AVERAGE MORTALITY WITH AVERAGE WEEKLY MAXIMUM TEMPERATURES FOR ALL EXPOSURES

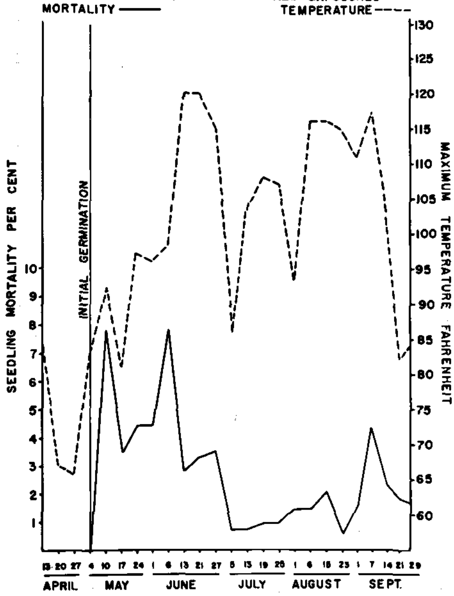

Figure 21.

seedlings are from 8 to 10 weeks old.

In Colorado, Roeser arranged Douglas fir (Rocky Mt. variety) through holes in a board so the roots were in water, and then placed a ¼-inch layer of heated sand on the board and around the stems of the seedlings. Five minute exposure to sand at temperatures of from 146°F. to 154°F. was fatal to all seedlings from 4 to 11 weeks old.

In Washington, Isaac observed that under natural conditions soil temperatures of 125°F. were injurious and those of 137°F. were fatal to Douglas fir seedlings 5 to 10 days old. Resistance to heat injury increased as seedlings grew older . Soil surface temperatures of 147°F. failed to damage 11-week-old seedlings.

Hunt and Chilcote report Douglas fir seedlings were able to survive surface soil temperatures in excess of 160°F. during the first growing season. And Clarkson states that the critical period for heat damage is during the first few weeks after germination.

The consensus of the investigators concerned with this problem is that the lethal temperature varies with the moisture content and the physical structure of the soil and with the age and size of stem of the coniferous seedling. Work with other species has shown that in general the duration of exposure also affects the maximum temperature a given plant can withstand, but this relationship has not been determined for Douglas fir.

In the study reported here, maximum thermometers were arranged in the manner illustrated in figure 9. The bulbs were placed so they were bisected by the plane of the soil surface. The soils in the experimental plots were light-colored silt and clay loams with very little humus.

Field examinations revealed no evi-

RELATIONSHIP OF MORTALITY WITH AVERAGE WEEKLY MAXIMUM TEMPERATURES ON EASTERLY EXPOSURE

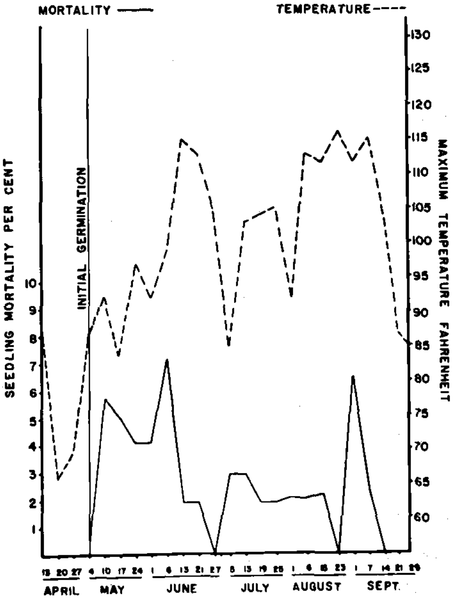

Figure 22.

dence that seedling mortality was due to heat damage. However, laboratory trials with seedlings from the same seed lot showed that heat damage is exceptionally difficult to identify, even in the laboratory where conditions for examination are ideal. This is especially true of lignified seedlings. Thirty 10-week-old seedlings were subjected for 10 minutes to air temperatures from 140°F.—160°F. Ninety percent of these seedlings died, but only four showed any signs of heat damage on the stem prior to death. The remaining seedlings appeared healthy for some time after exposure, but gradually withered. After two months they had the appearance of drought-stricken seedlings. Evidence of positive heat damage on all save the very youngest seedlings is even more difficult to detect under field conditions, especially if the examination of seedlings is made up to thirty days after exposure to high temperatures. Figure 21 shows the lack of relationship between total seedling mortality and maximum soil temperatures for each examination date. Figures 22 to 25 show the relationship for the four principal exposures.

Very little correlation between dates of maximum temperature and mortality can be seen. This apparent lack of correlation may be due partially to the delayed effect of high temperature, as pointed out by the laboratory experiments. The seedling mortality in the individual seed spots equipped with maximum thermometers varied from 0 to 80%. The average maximum temperatures for the duration of the study varied from 80°F. in one of the seed spots on the northern exposure to 111° F. in seed spots on the southerly and westerly exposures. When the mortality occurring in the individual seed spots is plotted over the average maxi-

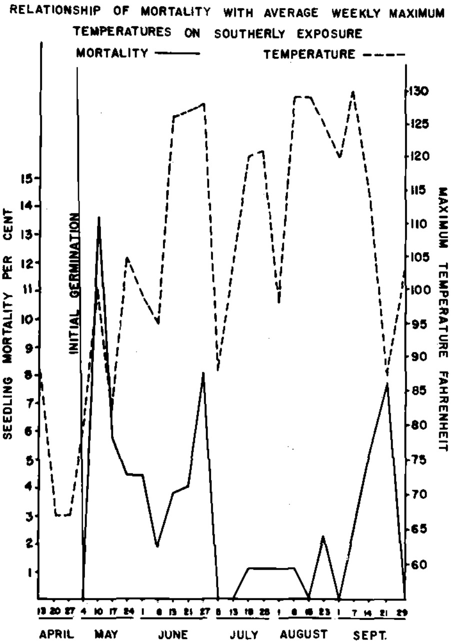

Figure 23.

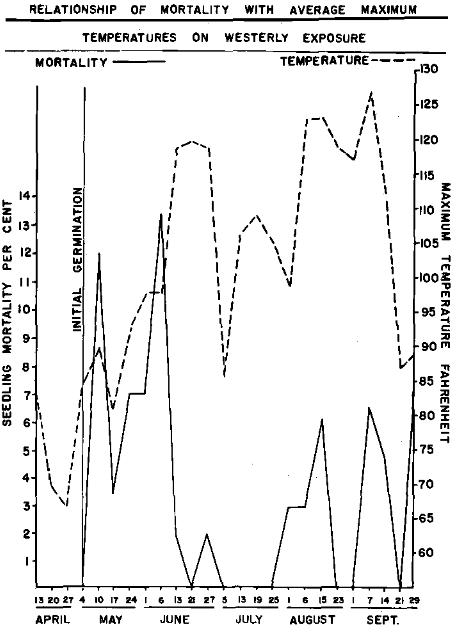

Figure 24.

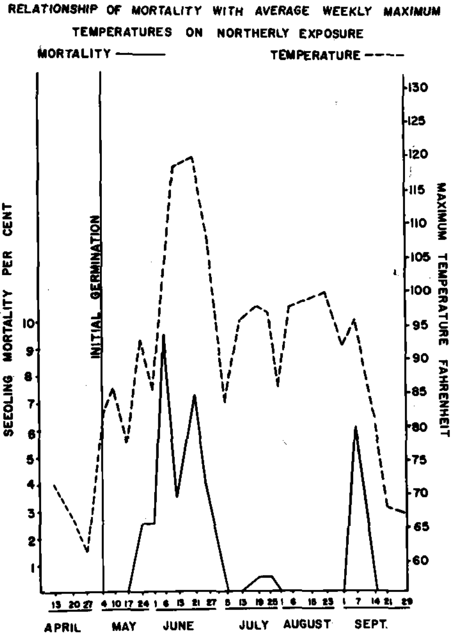

Figure 25.

mum temperatures of these same seed spots, no correlation is noted. It would appear that, for the growing season of 1955, which was characterized by a cold, moist spring, and a cool, relatively dry summer, soil temperature was not a limiting factor for seedling survival in much of the Tillamook Burn.

Effect of steel rings on soil moisture

There appears to be a slight tendency for soil within seed spots to be drier than the soil immediately outside the sheet steel rings. Since these rings cannot affect the vertical movement of soil moisture, their slight drying effect is probably the result of impeding lateral moisture movement. In any event, the slight drying of the seed spots was not sufficiently pronounced to affect the germination of the seeds. Since the condition extended to a depth of only two inches, it is improbable that it had any serious effect upon seedling survival.

Soil moisture and seedling survival

Adequate soil moisture is a vital factor in the survival of coniferous seedlings on cut-over and burned-over forest lands. Unfortunately, soil moisture is difficult, if not impossible, to measure accurately in the immediate microsite of a seedling when the soil moisture percent approaches the wilt point (when it is no longer available to plants). It was believed that the wilt point was reached when the soil moisture percent dropped to approximately

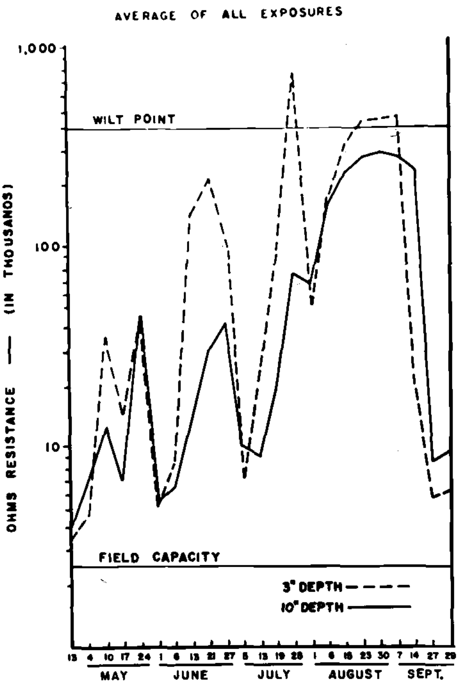

Figure 26.

20% in the Hembre silt loam involved in this study.

Soil blocks were installed within seed spots in hope that roots of germinating seedlings would grow around them. Laboratory calibration demonstrated, however, that soil moisture could vary from 9% to 33% within a distance of 6 inches.

Figures 26 to 31 summarize soil moisture data and seedling mortality data from seed spots equipped with soil moisture blocks. Graphs show that soil moisture dropped below the wilt point for only a short period during the summer. Isaac suggests that drought losses during periods when soil moisture measurements indicate a moisture level above wilt point may be due in part to variation in moisture-holding capacity between the sampling point and the roots of the seedlings. The data presented in this report appear to confirm this hypothesis.

The graphs show some correlation between periods of low soil moisture and seedling mortality in August and early September. The failure of the data, however, to point out the causal factors in seedling mortality strongly indicates that such information can be obtained only through basic physiological research.

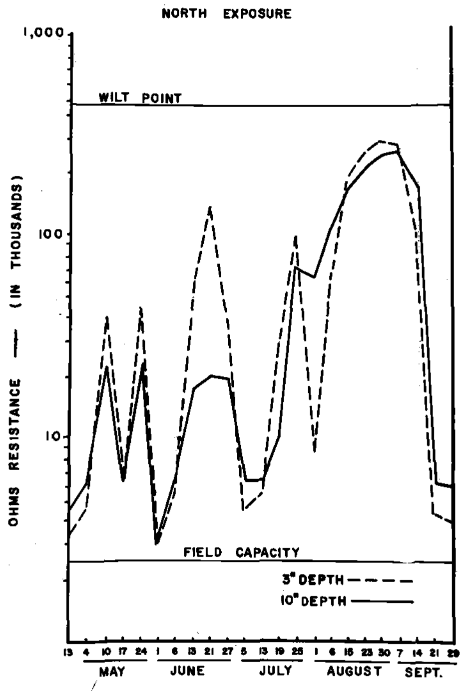

Figure 28.

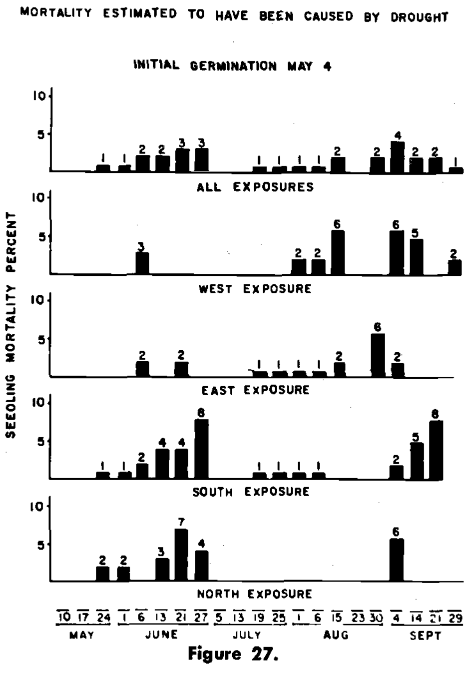

Figure 27.

Climatic conditions

Since heat-caused seedling mortality in any season is due primarily to the maximum temperatures, the weather in 1955 is compared in figure 32 with that of previous years on the basis of maximum daily temperatures. The data was recorded by the U. S. Weather Bureau Station in Forest Grove. There is a definite correlation, however, between the daily maxima recorded there and those obtained from the Oregon State

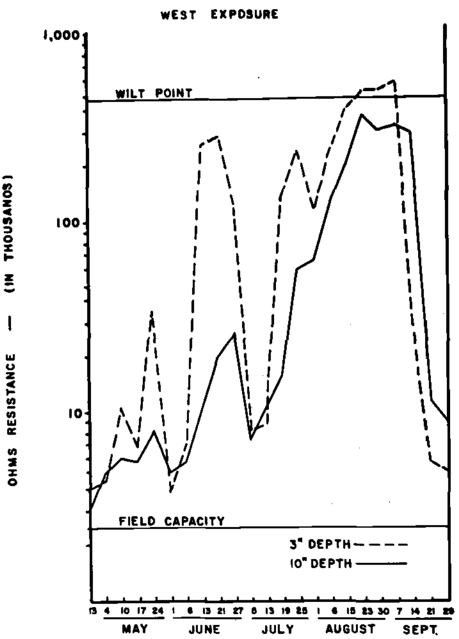

Figure 29.

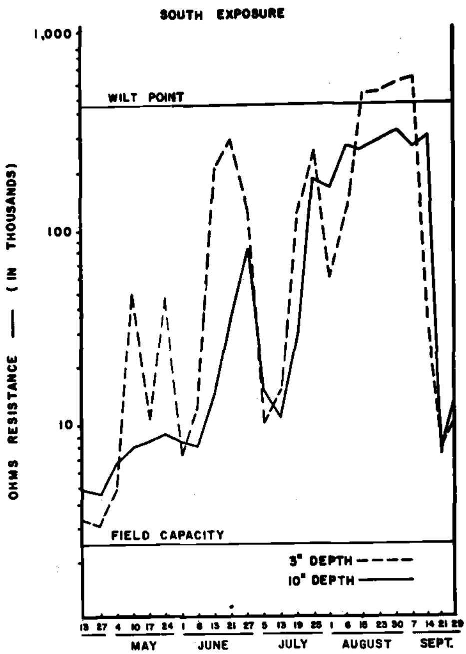

Figure 30.

Board of Forestry Station in the Tillamook Burn (figures 33 to 35). Since many more years of data were available from the Forest Grove station, it was decided to use these readings to establish the relationship of 1955 weather with that of other years. An examination of figure 32 will show that the year 1955 was one of the coolest years of the past decade. The average maximum temperature of April was nearly six degrees lower in 1955 than it was for the same period in 1954. This difference is reflected in the germination dates of Douglas fir seed. In 1954, considerable germination occurred in April; while in 1955, initial germination was not noted until the first week in May. Although the average maximum temperatures in 1955 were cooler than the mean for the decade 1947-1956, the records for only three other years list higher temperatures than those occurring in September 1955. The highest temperature of the decade occurred in July 1956 (109°F.). Observations were made of the effects of this extreme temperature upon Douglas fir seedlings during a similar study and no signs of heat damage were detected.

Bates and Roeser state ". . . in nature it is probably the momentary maximum temperature which determines the degree of injury. It is also in agreement with results obtained in 1919, which showed that seedlings surviving one severe exposure were in no danger from a repetition of the same thing." If this is true, the high temperatures of June and September of 1955 must have produced as severe a heat stress as occurred during the decade.

The period of May through the middle of September in 1955 was the sec-

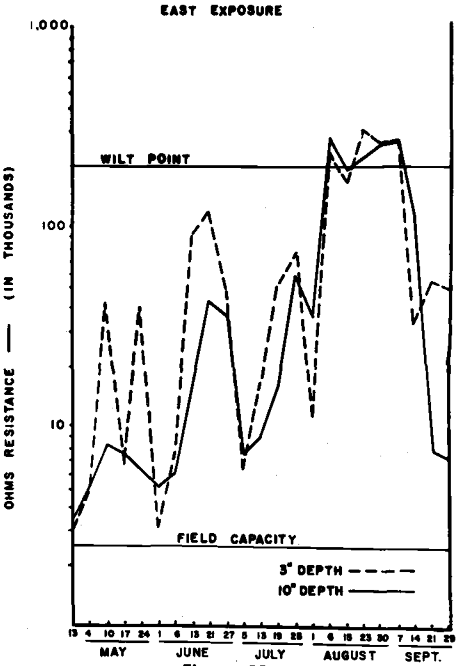

Figure 31.

ond driest period in the decade. From July 28 until September 13, 1955, a period of 47 days, there was no measurable precipitation in the burn. This was the longest period of drought in the decade.

Root development and seedling survival

During the last week of September 1955, all the experimental equipment was removed from the area prior to the hunting season. Several of the seed spots were dug carefully and the soil washed off the seedling roots. Figures 37 to 41 illustrate the root development of both surviving and dead seedlings. Since all the dead seedlings had succumbed within a month prior to the date of the photograph, and since the entire soil mass was extremely dry until the latter part of that period, it would appear that the same differences in root development between dead and surviving seedlings existed when seedlings died. Parker states: "When, however, the entire soil mass dries down to levels near the ultimate wilting point, the root seems to become dormant, or at least to cease growth." The pictures show the clear superiority of the root systems of the surviving seedlings. The importance of vigorous root development to seedling survival is further emphasized when it is realized that the dead seedlings were not weaklings, but were sufficiently vigorous to survive until the last part of the growing season. These data are in agreement with those of the numerous workers cited by Parker.

Since the longest recorded rainless period in the Tillamook Burn occurred in August and September, it is felt that the surviving seedlings demonstrated sufficient drought resistance to survive the driest year in this area.

All the seedlings in each of the preceding five figures were removed from the same seed spot, and all the seedlings, living or dead, that were found at the time of final examination, appear in the photograph. Representative seed spots were dug up on each slope. The only criterion for a seed spot's selection was the presence of both living and dead seedlings. Except for this one attribute, the seed spots chosen for photography represented a random sample of the whole population of experimental seedlings.

Effect of germination date on seedling survival

Most of the plots were not checked frequently enough to permit recording an accurate sequence of all germination (the first examination of a seed spot

RELATIONSHIP OF DAILY MAXIMUM TEMPERATURES IN 1955 WITH CORRESPONDING TEMPERATURES FOR YEARS 1947 THROUGH 1956 (EXCLUDING 1955) RECORDED BY FOREST GROVE WEATHER STATION

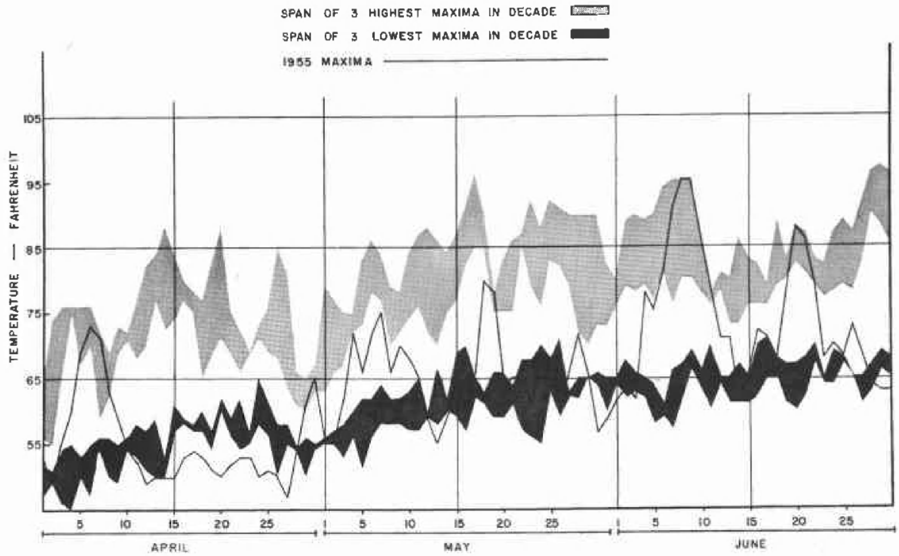

Figure 32a.

RELATIONSHIP OF DAILY MAXIMUM TEMPERATURES IN 1955 WITH CORRESPONDING TEMPERATURES FOR YEARS 1947 THROUGH 1956 (EXCLUDING 1955) RECORDED BY FOREST GROVE WEATHER STATION

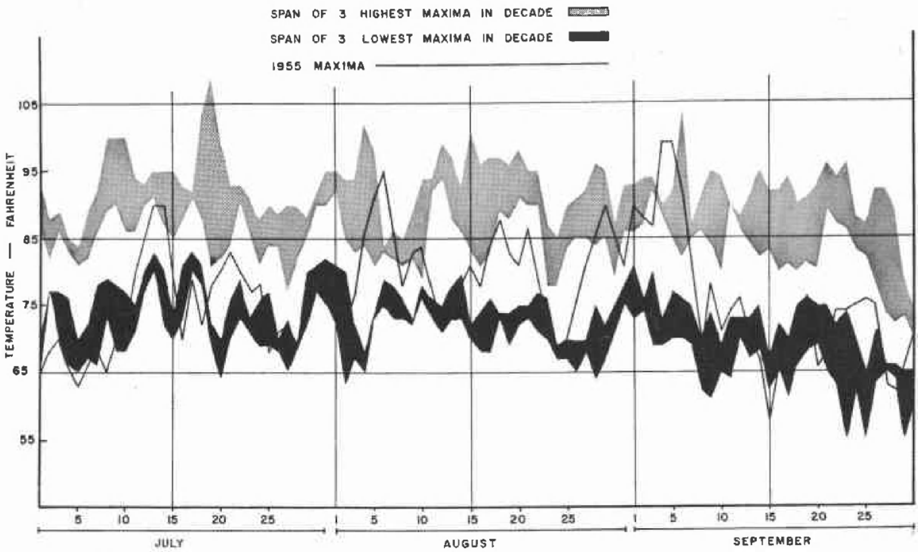

Figure 32b.

A COMPARISON BETWEEN MAXIMUM AIR TEMPERATURES AT FOREST GROVE AND IN THE TILLAMOOK BURN AT 1000' ON A FLAT

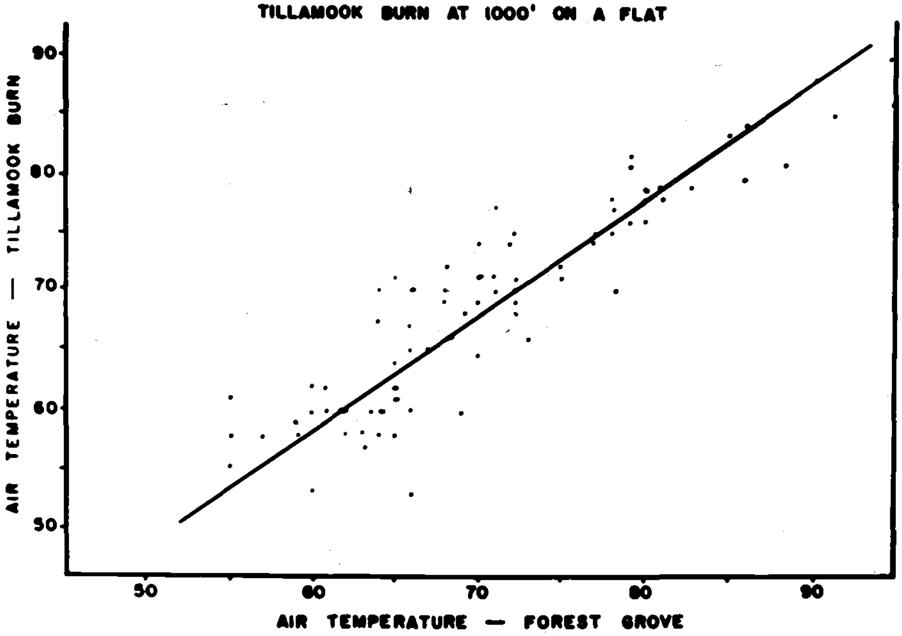

Figure 33.

A COMPARISON BETWEEN MAXIMUM AIR TEMPERATURES AT FOREST GROVE AND IN THE TILLAMOOK BURN AT 2200' ON A SOUTH EXPOSURE

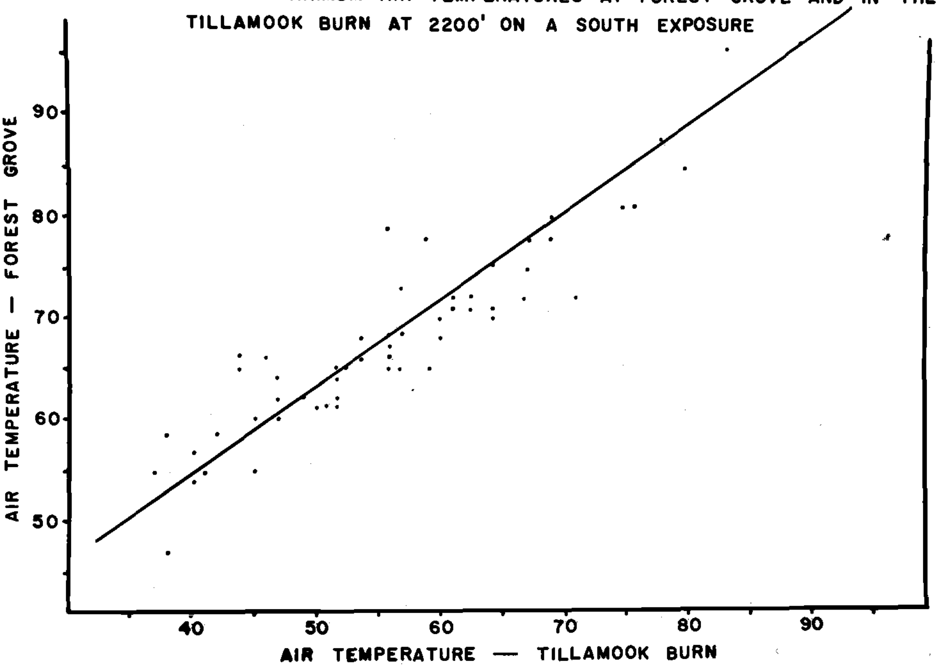

Figure 34.

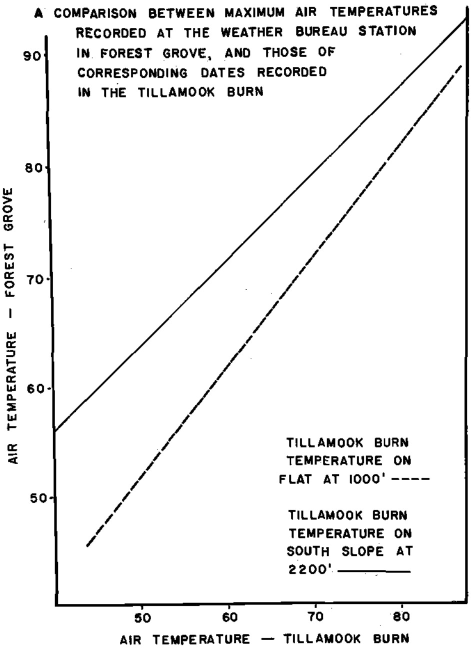

Figure 35.

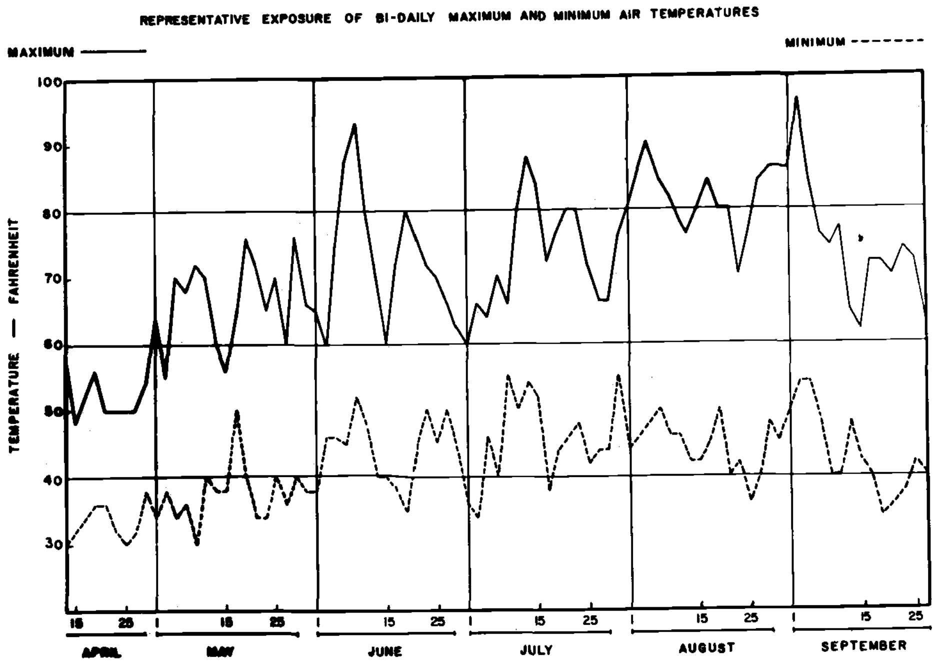

Figure 36. Temperatures recorded for 1955 by Tempscribe as shown in figure 3.

usually fell in the middle of the germination period for that seed spot). It was noted that, on the seed spots checked weekly, full field germination was completed in less than one month subsequent to the initial germination. Inasmuch as most plots were checked only once a month, the germination was frequently completed before the second check.

The seeds were scattered randomly over the surface of the soil within the seed spots. Therefore, it is possible that the germination date of a given seed might reflect the influence of the microsite rather than of the inherent vigor of the seed.

An earlier report by the author stresses the importance of rapid, early germination of seed to successful seeding. The data presented here should not be construed as contradicting this belief, as this experimental seed lot did demonstrate a vigorous germination. Had the germinative vigor of the seeds been less, it is very probable that many more would have failed to germinate, and thus the number of surviving seedlings would have been correspondingly reduced.

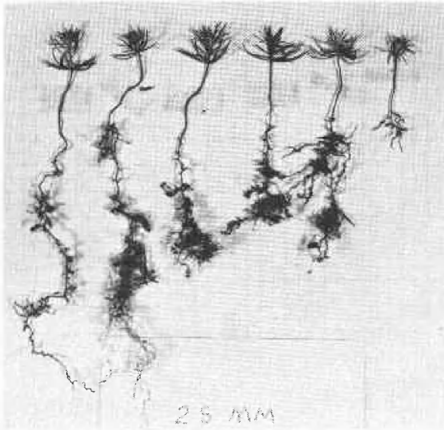

Figure 38. Seedlings were removed from a seed spot on a southerly exposure on September 26, 1955. The two seedlings on the right were dead, the others alive when dug up. The cross section paper in the background of figures 37-41 has four squares to the inch.

The germination dates of the seedlings were compared on a seed spot basis in an attempt to equalize the effects of the microsite. That is, the seedlings of seed spot "A" were listed in order of germination dates and assigned appropriate ranks. Those of seed spot "B" were listed in order of

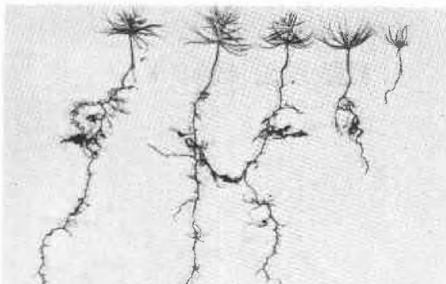

Figure 37. These seedlings were removed from a seed spot on a northerly exposure on September 26, 1955. The seedling on the right was dead, and the others alive on this date.

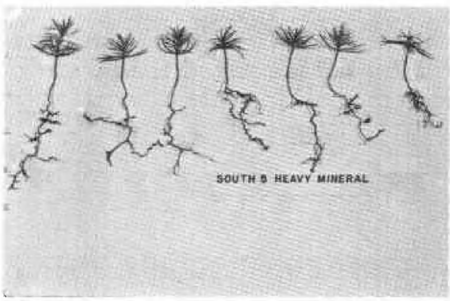

Figure 39. Seedlings removed from a seed spot on a southerly exposure on October 6, 1955. Seedling on the right died during the second week in September; the remaining plants were alive.

their germination, etc. The survival datum for each seedling was recorded and two summations of these resulting data were prepared: (1) for all the seed spots in the experiment and (2) a second for all plots visited weekly.

The summation of data for the entire experiment shows the earliest seedlings to have a survival of 64%; the later germinants, 67%. A slightly larger difference is shown by the totals of the instrument plots. Here the early germinants had a 53% survival, while the later seedlings had a 61% survival. Neither of these differences is statistically significant.

Similar work conducted in the summer of 1956 showed a 61% survival of the early germinants and 49% for the later germinants. A chi-square test showed this difference to be statistically significant.

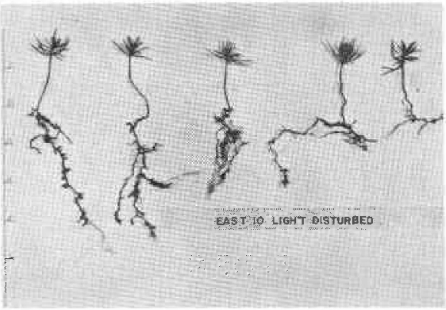

Figure 40. Seedlings removed from an easterly exposure on October 6, 1955. Seedling on right died after September 1; the remaining seedlings were alive when dug up.

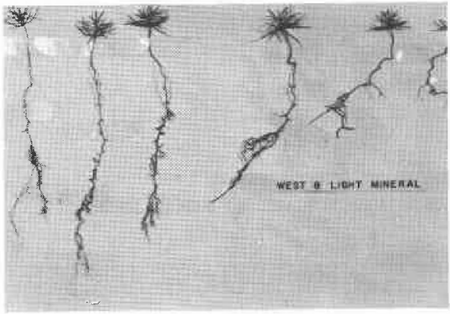

Figure 41. Seedlings removed from a westerly exposure on October 6, 1955. The two seedlings on the right died after September 1; the remainder were alive when excavated.

Conclusions

The following conclusions can be made as a result of this study:

1) On the portion of the Tillamook Burn which supports the degree and type of herbaceous cover described earlier in this report, density of herbaceous plant cover does not affect the germination of Douglas fir seeds nor the survival of the seedlings.
2) The condition of the seed bed does not affect the germination of Douglas fir seed nor survival of the Douglas fir seedlings. In the greenhouse, a single layer of herbaceous cover was sufficient to retard seed germination for two months. Such retardation was not noted in the field. In general, however, there was little organic litter present in the field plots.
3) Northerly exposures are more favorable to germination and survival than are the southerly. The different seed beds and cover types did not maintain a constant relative degree of favorableness from one exposure to another.
4) The greater part of the mortality of seedlings in 1955 appeared to be due to lack of moisture rather than excessive heat. Inasmuch as 1955 was a dry but relatively cool year, losses due to heat may be more important in most years than the data indicate.
5) Date of germination did not affect seedling survival.
6) The germination and survival of seedlings studied in this project were much higher than similar data obtained from operational seeding projects. This was due probably to three factors: (1) high quality, vigorous seed; (2) excellent seed-eating mammal control; and (3) the relative ease of locating seedlings resulted in greater accuracy.

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RUSSEL GETTY	Bureau of Land Management
GEORGE H. BARNES	School of Forestry
D. L. PHIPPS	State Forester

The Forest Protection and Conservation Committee, established in 1953, administers research funds and approves research projects. Present members are:

SIDNEY LEIKEN	Western Forest Industries Association
A. C. ROLL	Member at Large
WALTER F. MCCULLOCH	School of Forestry
ELIOT JENKINS	West Coast Lumbermen's Association
FREEMAN SCHULTZ	Western Pine Association
R. M. KALLANDER	Administrator