RESULTS AND DISCUSSION

Plant Communities

Only two non-arboreal communities, T-3 and T-4 were described. Since only the non-arboreal vegetation contiguous to the Lost Forest was sampled. In both Eckert's (60) and this study, sagebrush is the dominant plant although in the Lost Forest area the associated grass is Sitanion hystrix rather than Stipa sp, Festuca idahoensis or Agropyron spicatum. Eckert also described Artemisia tridentata var. arbuscula as the dominant element of one community while this shrub appeared only in the arboreal communities in the Lost Forest area. Type T-4, Lake Bed sage, in the Lost Forest study contained some stands where the dominant shrub was A. cana rather than A. tridentata. However these stands were on severely disturbed soils and are probably not climax. In both studies, epiphytes were the most common plants of the understory. Eckert's Artemisia tridentata - Festuca idahoensis community, superficially resembles the Lost Forest Festuca idahoensis community but the latter has an overstory of Juniperus occidentalis and Pinus ponderosa.

Dyrness (59) describes six separate communities, all of them arboreal. In all these Purshia tridentata is the only plant other than Pinus ponderosa, found in both study areas in sufficient quantities to be used in characterizing communities. Dyrness's study shows the cover in his study areas to be much heavier than that of the Lost Forest. Species found by Dyrness are also more mesic as could be expected since the mean elevation is approximately twelve-hundred feet higher than in the Lost Forest and the rain-fall is approximately twice that of the latter area.

The eight plant communities studied in and adjacent to the Lost Forest are described in the following sixteen tables (Tables 5-20). For most of the communities the only plants which occurred with sufficient regularity within each community were those which were used as basis for original stratification. With the exception of the Idaho fescue in the T-5, "Idaho Fescue" zone the only plants which occurred with sufficient frequency, coverage or constancy to characterize a community were either trees or shrubs. This again is to be expected where the unstable nature of the soil is considered. The larger perennial shrubs and trees are not as susceptible to complete domination by the shifting sands as the smaller short-lived species.

The Idaho fescue and the bitter brush communities appear relatively stable and have the appearance of being climaxes. The T-0, "Dense Ponderosa Pine" community is

Table 5

CHARACTERISTICS OF T-O, DENSE PONDEROSA PINE COMMUNITY: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare Ground	45.89	92.05	100.00
Litter	34.70	97.10	100.00
Stipa thurbiana	.69	3.73	100.00
Poa secunda	.41	2.54	50.00
Lichen	.33	1.16	66.67
Small early annuals	.28	.87	100.00
Bryophytes	.17	2.46	100.00
Agropyron cristatum	.16	.29	83.33
Sitanion hystrix	.13	.71	83.33
Lupinus sp. (Tourn.) L.	.07	.45	100.00
Oryzopsis hymenoides (R. & S.) Ricker	.06	1.16	33.33
Stipa comata	.06	.79	16.67
Eriogonum ovalifolium Wats.	.04	.12	100.00
Achillea lanulosa	.04	.29	100.00
Townsendia florifer (Hook.)	.03	.54	66.67
Eriophyllum lanatum (Pursh.) Forbes	.03	.17	33.33

Table 6

CHARACTERISTICS OF T-0, DENSE PONDEROSA PINE COMMUNITY: SHRUBS AND TREES

Species	Coverage By Hgts.	Coverage All Hgts.	Frequency By Hgts.	Frequency All Hgts.	Constancy
Artemisia tridentata		0.77%		44.84%	100.00%
0-6"	0.11		13.80		
6-24"	0.43		20.40		
24" +	0.23		21.70		
Chrysothamnus nauseosus		0.58		38.30	100.00
0-6"	0.07		8.80		
6-24"	0.43		19.20		
24" +	0.08		3.80		
Purshia tridentata		0.20		9.17	66.67
0-6"	T		3.30		
6-24"	0.05		1.20		
24" +	0.15		0.80		
Artemisia tridentata arbuscula		0.50		20.00	33.33
0-6"	0.12		6.40		
6-24"	0.31		12.10		
24" +	0.07		5.40		
Purshia tridentata		0.20		9.17	66.67
0-6"	T		3.30		
6-24"	0.05		1.20		
24" +	0.15		0.80		
Leptodactylon pungens (Torr.) Nutt.		0.11		0.50	50.00
0-6"	0.04		2.50		
6-24"	0.07		2.80		
24" +	--		--		

Table 6 (Continued)

Species	Coverage By Hgts.	Coverage All Hgts.	Frequency By Hgts.	Frequency All Hgts.	Constancy
Chrysothamnus viscidiflorus		0.01%		3.75%	33.33%
0-6"	0.01		0.30		
6-24"	--		4.20		
24" +	--		--		
Pinus ponderosa		4.36		0.02	83.33
Juniperus occidentalis		0.34		T*	50.00

*Trace

Table 7

CHARACTERISTICS OF T-1 OCCASIONAL PINE AND JUNIPER COMMUNITY: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare Ground	55.27	93.40	100.00
Litter	23.83	95.88	100.00
Bryophytes	4.80	2.68	100.00
Lichens	0.66	1.00	100.00
Townsendia florifer	0.45	0.25	66.67
Stipa comata	0.42	2.08	50.00
Sitanion hystrix	0.33	1.54	100.00
Oryzopsis hymenoides	0.32	2.29	100.00
Achillea lanulosa	0.17	0.16	66.67
Early annuals	0.17	1.17	83.33
Erigonum ovalifolium	0.07	0.45	100.00
Poa secunda	0.07	0.33	50.00
Agropyron cristatum	0.04	0.25	50.00
Eriophyllum lanatum	0.03	0.25	83.33
Erigeron filifolius (Hook.) Nutt.	0.03	0.21	66.67
Carex rossii Bott.	T	T	16.67

Table 8

CHARACTERISTICS OF T-1, OCCASIONAL PINE AND JUNIPER COMMUNITY: SHRUBS AND TREES

Species	Coverage By Hgts. %	Coverage All Hgts. %	Frequency By Hgts. %	Frequency All Hgts. %	Constancy %
Chrysothamnus nauseosus		1.68		50.00	100.00
0-6"	0.23		2.41		
6-24"	1.06		45.00		
24" +	0.34		25.00		
Artemisia tridentata		0.83		33.80	100.00
0-6"	0.12		4.58		
6-24"	0.33		17.50		
24" +	0.38		10.00		
Leptodactylon pungens		0.40		15.00	100.00
0-6"	0.09		10.42		
6-24"	0.30		19.15		
24" +	0.01		3.75		
Artemisia tridentata arbuscula		0.31		15.81	66.67
0-6"	0.07		2.32		
6-24"	0.22		4.58		
24" +	0.02		7.50		
Chrysothamnus viscidiflorus		0.06		6.25	50.00
0-6"	0.03		1.67		
6-24"	0.03		2.91		
24" +	0		1.67		
Purshia tridentata		0.02		1.25	16.67
0-6"	0		0.00		
6-24"	0.01		0.83		
24" +	0.01		1.67		
Artemisia cana		0.01		0.42	16.67
Tetradymia glabrata Gray		0.01		1.25	50.00
Pinus ponderosa		1.34		T	16.67
Juniperus occidentalis		2.14		0.01	33.33

Table 9

CHARACTERISTICS OF T-2, JUNIPER--LOW SAGE COMMUNITY: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare Ground	55.15	100.00	100.00
Liter	7.80	100.00	100.00
Bryophytes	9.59	5.16	100.00
Lichen	2.56	5.81	100.00
Stipa thurberiana	0.96	0.87	83.33
Sitanion hystrix	0.82	1.25	83.33
Stipa comata	0.23	0.91	33.33
Early annual plants	0.22	0.46	50.00
Oryzopsis hymenoides	0.20	1.50	66.67
Erigonum ovalifolium	0.10	0.20	66.67
Lupinus sp.	0.10	0.08	16.67
Erigeron filifolius	0.06	0.25	83.33
Poa secunda	0.03	0.20	33.33
Agropyron cristatum	0.02	0.08	16.67
Eriophyllum lanatum	0.02	0.20	33.33
Achillea lanulosa	0.01	0.08	33.33
Townsendia florifer	0.01	0.16	33.33

Table 10

CHARACTERISTICS OF T-2, JUNIPER--LOW SAGE COMMUNITY: SHRUBS AND TREES

Species	Coverage By Hgts. %	Coverage All Hgts. %	Frequency By Hgts. %	Frequency All Hgts. %	Constancy %
Artemisia tridentata arbuscula		1.40		15.81	83.33
0-6"	0.13		6.25		
6-24"	1.01		36.75		
24" +	0.26		27.12		
Chrysothamnus viscidiflorus		1.04		6.25	83.33
0-6"	0.39		16.25		
6-24"	0.64		40.00		
24" +	0.01		3.33		
Chrysothamnus nauseosus		0.60		50.00	66.67
0-6"	0.20		6.25		
6-24"	0.29		14.31		
24" +	0.11		11.67		
Artemisia tridentata		0.51		33.80	100.00
0-6"	0.16		4.56		
6-24"	0.24		13.63		
24" +	0.11		12.50		
Leptodactylon pungens		0.33		15.00	83.33
0-6"	0.16		4.17		
6-24"	0.21		4.17		
24" +	0.01		2.08		
Phlox diffusa Benth. var.		0.31		4.56	33.33
0-6"	0.31		4.56		
6-24"	--		--		
24"	--		--		
Artemisia cana		0.03		3.33	16.67
0-6"	0.01		0.42		
6-24"	0.02		0.84		
24" +	--		--		
Juniperus occidentalis		5.97		C	0
Pinus ponderosa		0.92		C	00.67

Table 11

CHARACTERISTICS OF THE PONDEROSA PINE--BITTER BRUSH COMMUNITY T-OBB: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare Ground	44.03	75.05	100.00
Litter	49.17	90.00	100.00
Bryophytes	0.72	3.00	100.00
Oryzopsis hymenoides	0.19	0.29	83.33
Lichens	0.18	0.29	50.00
Poa secunda	0.11	0.87	83.33
Festuca idahoensis	0.10	0.50	50.00
Sitanion hystrix	0.09	0.79	83.33
Early annuals	0.09	1.03	33.33
Erigeron filifolius	0.09	0.28	66.67
Elymus triticoides	0.04	0.29	50.00
Poa nevadensis	0.04	0.12	33.33
Townsendia florifer	0.04	0.28	83.33
Eriophyllum lanatum	0.03	0.33	66.67
Achillea lanulosa	0.02	0.20	50.00
Agropyron cristatum	0.02	0.08	33.33
Stipa thurberiana	0.01	0.17	33.33
Calamagrostis rubescens Buckl.	T	0.18	33.33
Psoralea lanceolata Pursh.	T	0.12	16.67

Table 12

CHARACTERISTICS OF THE BITTER BRUSH (PURSHIA TRIDENTATA) T-OBB COMMUNITY: TREES AND SHRUBS

Species	Coverage By Hgts. %	Coverage All Hgts. %	Frequency By Hgts. %	Frequency All Hgts. %	Constancy %
Purshia tridentata		3.79		56.28	100.00
0-6"	0.02		2.04		
6-24"	0.38		20.40		
24" +	3.39		40.00		
Leptodactylon pungens		0.21		12.08	66.67
0-6"	0.03		5.00		
6-24"	0.18		6.25		
24" +	T		0.83		
Chrysothamnus viscidiflorus		0.09		7.50	33.33
0-6"	0.05		T		
6-24"	0.03		7.18		
24" +	0.01		6.67		
Artemisia tridentata arbuscula		0.06		4.58	16.67
0-6"	0.01		0.50		
6-24"	0.04		1.75		
24" +	0.01		1.25		
Chrysothamnus nauseosus		0.03		3.33	83.33
0-6"	0.00		00.42		
6-24"	0.01		00.83		
24" +	0.02		4.58		
Artemisia tridentata		0.01		2.50	16.67
0-6"	0.00		0.42		
6-24"	T		0.83		
24" +	T		4.68		
Pinus ponderosa		4.50		0.01	100.00
Juniperus occidentalis		1.00		0.01	66.67

Table 13

CHARACTERISTICS OF THE T-3 UPLAND SAGE COMMUNITY: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare ground	54.19	95.75	100.00
Litter	8.04	62.50	100.00
Bryophytes	20.99	4.37	100.00
Sitanion hystrix	1.50	3.92	100.00
Stipa comata	1.50	1.70	33.33
Small early annuals	.92	2.21	83.33
Psoralea lanceolata	0.69	2.13	50.00
Poa secunda	0.33	1.08	50.00
Lichen	0.27	0.88	66.67
Eriophyllum lanatum	0.22	0.33	66.67
Festuca idahoensis	0.18	.67	16.67
Agropyron cristatum (var.)	0.17	0.13	16.67
Oryzopsis hymenoides	0.06	0.25	33.33
Townsendia florifer	0.05	0.25	16.67
Erigonum ovalifolium	0.03	0.12	33.33

Table 14

CHARACTERISTICS OF THE UPLAND SAGE
T-3 COMMUNITY: SHRUBS

Species	Coverage By Hgts. %	Coverage All Hgts. %	Frequency By Hgts. %	Frequency All Hgts. %	Constancy %
Artemisia tridentata		11.23		82.00	100.00
0-6"	.13		4.56		
6-24"	.11		5.83		
24" +	10.99		79.65		
Chrysothamnus viscidiflorus		1.10		31.90	83.30
0-6"	.03		1.67		
6-24"	.37		5.49		
24" +	.70		16.67		
Leptodactylon canescens		.29		13.3	66.67
0-6"	.06		2.50		
6-24"	.15		8.33		
24" +	.08		.21		
Phlox diffusa var.		.09		2.92	33.33
0-6"	.09		3.75		
6-24"	T		T		
Chrysothamnus nauseosus		.09		.18	33.33
0-6"	.06		.06		
6-24"	.02		.02		
24" +	.01		.01		
A. tridentata arbuscula		.06			33.33
0-6"	.02		6		
6-24"	.03		2		
24" +	T		1		
Tetradymia canescens D.C.		T		T	
0-6"	T		T		
6-24"	T		T		

Table 15

CHARACTERISTICS OF T-4 LAKE SAGE COMMUNITY: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare Ground	50.70	95.00	100
Litter	10.10	54.00	100
Bryophytes	6.42	22.95	100
Muhlenbergia asperifolia (Nees & Mey.) Paradt.	1.76	2.60	67
Sitanion hystrix	1.74	2.06	67
Agropyron dasystachyum (Hook.) Scribn.	.81	2.20	83
Lichens	.49	.88	83
Psoralea lanceolata	.28	1.33	50
Stipa comata	.23	1.90	50
Erigeron filifolius	.07	.04	17

Table 16

CHARACTERISTICS OF T-4 LAKE SAGE COMMUNITY: SHRUBS

Species	Coverage By Hgts. %	Coverage All Hgts. %	Frequency By Hgts. %	Frequency All Hgts. %	Constancy %
Artemisia tridentata		3.96		34.8	87.5
0-6"	.10		8.3		
6-12"	.53		25.7		
12" +	3.28		29.2		
Artemisia cana		3.83		39.6	87.5
0-6"	.02		0.2		
6-12"	.08		7.1		
12" +	3.73		33.3		
Chrysothamnus nauseosus		3.32		72.8	100.0
0-6"	.06		6.3		
6-12"	.86		32.5		
12" +	2.40		51.7		
Chrysothamnus viscidiflorus		2.85		33.3	100.0
0-6"	.23		8.3		
6-12"	.73		16.5		
12" +	1.89		25.0		
Leptodactylon pungens		.12		5.8	33.3
0-6"	.01		0.1		
6-12"	.08		4.6		
12" +	.03		0.1		
Tetradymia canescens		.07		2.9	33.3
0-6"	.04		0.1		
6-12"	.03		1.7		
12" +	--		0.4		

Table 17

CHARACTERISTICS OF T-5 IDAHO FESCUE COMMUNITY: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare ground	67.55	87.55	100.0
Litter	14.07	23.33	100.0
Bryophytes	5.50	2.70	100.0
Festuca idahoensis	4.48	5.77	100.0
Stipa thurberiana	.84	.83	67.7
Small annuals	.32	3.80	100.0
Sitanion hystrix	.30	1.33	100.0
Stipa comata	.30	.04	33.3
Poa secunda	.13	.46	100.0
Lupinus (sp.)	.11	.79	87.5
Eriophyllum lanatum	.06	.33	33.3
Eriogonum ovalifolium	.05	.38	100.0

Table 18

CHARACTERISTICS OF T-5 IDAHO FESCUE COMMUNITY: SHRUBS AND TREES

Species	Coverage %	Frequency %	Constancy %
Artemisia tridentata var. arbuscula	0.64	0.22	83.3
A. tridentata	0.55	0.08	66.7
Chrysothamnus viscidiflorus	0.45	0.11	33.3
Tetradymia canescens	0.14	0.07	50.0
Leptodactylon pungens	0.06	0.02	50.0
Phlox diffusa var.	0.05	0.01	16.7
Chrysothamnus nauseosus	T	0.83	33.3
Juniperus occidentalis	7.1	0.02	83.3
Pinus ponderosa	0	0.0	0.0

Table 19

CHARACTERISTICS OF PONDEROSA PINE-DUNE T-6
COMMUNITIES: GRASS AND FORBS

Species	Coverage %	Frequency %	Constancy %
Bare ground	30.02	95.00	100.00
Litter	36.23	85.72	100.00
Bryophytes	0.60	1.00	100.00
Sitanion hystrix	0.17	1.58	100.00
Poa secunda	0.11	0.50	83.33
Oryzopsis hymenoides	0.08	0.79	66.67
Early annuals	0.05	0.54	66.67
Calamagrostis rubescens	0.05	0.12	33.33
Lupinus sp.	0.05	0.45	50.00
Stipa thurberiana	0.04	0.25	16.67
Psorallea lanceolata	0.02	0.12	33.33
Stipa comata	0.02	0.41	50.00
Townsendia florifer	0.02	0.12	33.33
Achillea lanulosa	0.02	0.20	50.00

Table 20

CHARACTERISTIC PONDEROSA PINE-DUNE T-6
COMMUNITIES: SHRUBS AND TREES

Species	Coverage By Hgts. %	Coverage All Hgts. %	Frequency By Hgts. %	Frequency All Hgts. %	Constancy %
Leptodactylon pungens		0.45		25.19	83.33
0-6"	0.05		7.08		
6-24"	0.40		20.00		
24" +	0		1.67		
Tetradymia glabrata		0.35		1.25	66.67
0-6"	0.00		0.00		
6-24"	0.09		0.42		
24" +	0.26		1.25		
Purshia tridentata		0.27		2.40	66.67
0-6"	0.00		1.25		
6-24"	0.26		1.25		
24" +	0.00		4.58		
Artemisia tridentata		0.31		8.33	66.67
0-6"	T		0.83		
6-24"	0.03		5.62		
24" +	0.28		3.33		
Chrysothamnus nauseosus		0.74		8.33	66.67
0-6"	0.01		0.83		
6-24"	0.06		5.00		
24" +	0.67		2.92		
Chrysothamnus viscidiflorus		0.04		7.92	50.00
0-6"	T		0.83		
6-24"	0.03		3.33		
24" +	0.01		3.75		
Pinus ponderosa		4.06		0.02	100.00
Juniperus occidentalis		0.46		0.00	66.67

also climax as far as the overstory is concerned. The understory vegetation, however, is again characterized by considerable variation due to shifting sands.

The "Upland Sage" community appears relatively stable where the ratio of dead sage to live sage is concerned. It is probably not a true climax in the association although as indicated in Tables 11, 12, 13, 14 it dominates the site. As Poulton (135) postulates, Artemisia tridentata is probably a subordinate member of most of the associations in which it occurs and without grazing pressure or other disruption it will give way to competing climax grasses. Figure 35 shows the dominance of Idaho fescue in the Lost Forest "Idaho Fescue" community over other understory vegetation. Artemisia tridentata is almost entirely absent in the Idaho fescue stand association except where it appears as fragments of a sagebrush stand. Figure 36 shows an area approximately twenty-five miles north of the Lost Forest. This area has been fenced and grazing restricted to the summertime. The grass is Agropyron spicatum. Nearby lands upon which early seasonal grazing is practiced are dominated by Artemisia tridentata.

Poulton (135) has suggested the possibility of using the ratio of dead Artemisia to live Artemisia as an index to the shrub's status in a stand. He does not claim that the data from his few macroplots establish a typical ratio.

Figure 35. Festuca idahoensis stand with fragment of sagebrush stand.

Figure 36. *Agropyron spicatum* restored to dominance over *Artemisia tridentata* by regulated grazing 25 miles north of Lost Forest.

They do indicate a trend. He found that the mean ratio for a relatively stable stand based on frequency is 0.378. For an increasing stand it was 0.028.

The ratio for a decreasing stand is 1.415. Table 21 shows the status of live to dead Artemisia in the Lost Forest. These ratios are based on coverage data rather than frequencies. Although Poulton used frequency data for his ratios, this was not feasible in the Lost Forest area. Many sites there contain large numbers of young Artemisia plants which have succumbed to drought while older plants continue to thrive. The use of frequency data in this case would require a subjective elimination of large numbers of young plants and seedlings from the data. For this reason coverage was used since it provided a more objective criteria. The criteria appear to be applicable to the Artemisia elements in most of the Lost Forest communities. Table 21 indicates that in only the T-0 and T-2 communities is the sage decreasing. In all others it is either stable or increasing.

When viewing the Lost Forest for the first time, trees appear to dominate all other vegetation. This external appearance is not borne out by coverage data. As can be seen in Tables 5 to 20, the shrubs, forbs and grasses afford approximately the same amount of cover in the forest types. Shrub cover in the sage type is considerably greater

Table 21

STATUS OF *ARTEMISIA TRIDENTATA* BY VEGETATION TYPES

Type	Ratio dead/alive	Status
T-6 Pine-sand dunes	0	Not yet established
T-5 Idaho fescue	0	Very little but stable
TOBB Pine-bitter brush	0	Very little but stable
T-1 Pine-juniper	.129	Increasing
T-4 Lake bed sage	.176	Increasing
T-3 Upland sage	.190	Stable
T-0 Dense pine	.612	Senescent
T-2 Juniper-low sage	.706	Senescent

Table 22

TREE-STEM BASAL AREA FOR ARBOREAL COMMUNITIES

Community	Sq. ft./acre		
	Pine	Juniper	Total
T-6 Ponderosa pine dunes	78.4	7.9	86.3
T-5 Idaho fescue	5.8	48.4	54.2
TOBB Bitter brush-pine	33.4	10.2	43.6
T-0 Dense pine	32.3	5.4	37.7
T-1 Occasional pine-juniper	13.3	21.0	34.3
T-2 Juniper-low sage	7.1	9.6	16.7

than tree cover in the arboreal zones.

The only plants other than the epiphytes showing a high constancy throughout all communities were Sitanion hystrix and Artemisia tridentata, Chrysothamnus nauseosus and Leptodactylon pungens. Constancies of these and other plants are shown in Table 23.

The only plants showing high fidelity were Muhlenbergia asperifolia and Agropyron dasystachyum which were both limited to the T-4 Lake Sage area. Erigonum ovalifolium was the only other plant showing any indication of fidelity for a community or group of communities. It was not found in the Lake Sage, Ponderosa Pine - Dune or Bitter Brush and Pine communities. It had a high constancy for the remaining communities (Table 23).

During the second summer a number of small dead annuals were found in most of the plots examined. These were not noted the previous year. Most of these plants were unidentifiable but were recorded and shown in the community description tables as early annuals. They were probably the result of the heavy May precipitation in 1960 which was followed by weather extremely favorable for germination. The subsequent hot dry weather destroyed them before maturity.

The status of the arboreal species is, like that of the other plants, determined to a great extent by the

Table 23

CONSTANCY OVER ALL COMMUNITIES

Species	Constancy %
Bryophytes	100
Sitanion hystrix	91
Artemisia tridentata	79
Chrysothamnus nauseosus	73
Leptodactylon pungens	66
Lichens	58
Chrysothamnus viscidiflorus	58
**Juniperus occidentalis*	58
**Pinus ponderosa*	56
Poa secunda	56
Early annuals	54
Townsendia florifer	54
Oryzopsis hymenoides	48
Eriogonum ovalifolium	46
Artemisia tridentata var. *arbuscula*	42
Eriophyllum lanatum	40
Stipa thurberiana	40
Stipa comata	35
Lupinus sp.	33
Erigeron filifolius	33
Agropyron cristatum	25
Tetradymia canescens	23
Festuca idahoensis	21
Achillea lanulosa	20
Psoralea lanceolata	17
Purshia tridentata	17
Phlox diffusa var.	12
Agropyron dasystachyum	10
Calamagrostis rubescens	8
Muhlenbergia asperifolia	8
Elymus triticoides	4
Poa sp.	4
Carex rossii	4

*Based on the six arboreal communities only shifting sands. This is particularly true of reproduction. Reproduction occurs readily in a few particularly favorable microsites but not at all in most of the forest (Figure 37). In twenty-four 50' x 100' macroplots established in the six arboreal communities there were only eight ponderosa pine seedlings found. In these same plots there were sixteen juniper seedlings. All of the pine seedlings were under gray rabbit brush plants.

The ponderosa pine stands are very sparse when evaluated by commercial forest standards. Meyer (122) "Yield of Even-Aged Stands of Ponderosa Pine" shows that for stands of two-hundred years the normal basal area for the poorest site is ninety square feet per acre. The highest mean basal area for any strata in the Lost Forest was that found in the T-6, Ponderosa Pine-Dune community. It was only 78.4 square feet per acre. The Ponderosa-Pine-Dune sites were selected for vegetation analysis because they were occupied by relatively dense stands of pine trees and therefore do not reflect density of the over-all stands. However one macroplot (50' x 100') located on a deep sand dune included a dense close-growing group of ponderosa pine which measured fifty-three square feet of basal area. This is 461 square feet per acre which is considerably higher than the highest mean value given by Meyer (122) for the best ponderosa pine sites. (These were also the

Figure 37. Ponderosa pine reproduces well in favorable sites.

tallest trees in the forest; one was 115 feet high).

Table 22 shows stem basal-areas for all the arboreal communities. Only two arboreal communities appear to have the appearance of a true climax. These are the T-OBB ponderosa pine-bitter brush zone and the T-5 Idaho fescue zone. The most distinct plant community is that of T-4 or "Lake Sage." It is the only one containing plants of high fidelity and also contains the fewest numbers of species. The sage, its principal vegetative criterion, is to a large extent Artemisia cana rather than Artemisia tridentata or A. tridentata var. arbuscula as found in the other communities. (Tables 5 to 20). Its characteristics would probably be even more distinct were it not for invasion of wind eroded areas by Chrysothamnus nauseosus and C. viscidiflorus.

The vegetation of the Lost Forest and vicinity is in a state of flux because of the continuous movement of the surface sands. Only two communities are relatively stable at the present time. These are T-OBB Ponderosa Pine-Bitter Brush and the T-5 Juniper-Idaho Fescue associations.

Excessive grazing could have a considerable effect upon the plant communities. In fact, it probably did since historical evidence indicates a fairly heavy usage, particularly in the period before 1920. The greater distance to water may account for the fact that two relatively undisturbed communities still exist in the eastern end of the forest. These areas may not have received as high a grazing pressure as those closer to the water supply.

It is doubtful that even heavy grazing could have as profound an effect upon vegetation as the constantly shifting sands or the long dry period during the 1920's and the 1930's. A large number of ponderosa pine trees died during this drought period and at present are being replaced by seedlings at the foot of the small sand dunes. Most of the trees which died during the drought period were within the communities designated as T-1 "Occasional Pine and Juniper," T-2 "Juniper-Low Sage," and T-5 "Idaho Fescue."

Recent harvesting of ponderosa pine in the forest has had considerable impact upon the vegetation. This is particularly noticeable around mill sites. Of much more extensive effect has been the numerous skid trails established during the harvesting operation. None of these forces are of the magnitude of natural influences existing in the forest.

Crested wheat grass has been seeded in the skid trails and around portable mill sites where it appears to be maintaining itself. It does not appear to compete well with native species on undisturbed sites.

The lack of species fidelity in most types, in addition to the high over-all constancy of most species, Table 23) reflects the instability of the vegetation complexes. This is particularly true of the smaller plants. The macroplots were subjectively located to include the species which had been selected as characteristic of an arbitrarily chosen soil-vegetation strata. Fragments of other smaller vegetative elements were present, absent or distributed more in accordance with the vagaries of sand erosion and movement. For these reasons, the statistics pertaining to ostensibly dominant plants e.g. ponderosa pine-bitter brush, indicate merely how well these species define the original strata. The balance of the vegetation reflects the stability and variability of the soil, the continuous movement of the sands and other disturbances.

Figure 38 shows the distribution of the soil-vegetation types adjacent to and within the Lost Forest. Over the underlying soil types indicated on the figure are imposed small sand dunes too numerous to permit mapping.

Soils - The Lost Forest is on the Boundary between the Brown and the Sierozem (93) zone. Soils in the immediate area of the forest if classified according to currently accepted nomenclature should be placed among the Regosols which are formed from unconsolidated parent materials other than alluvium. Regosols normally have weakly developed

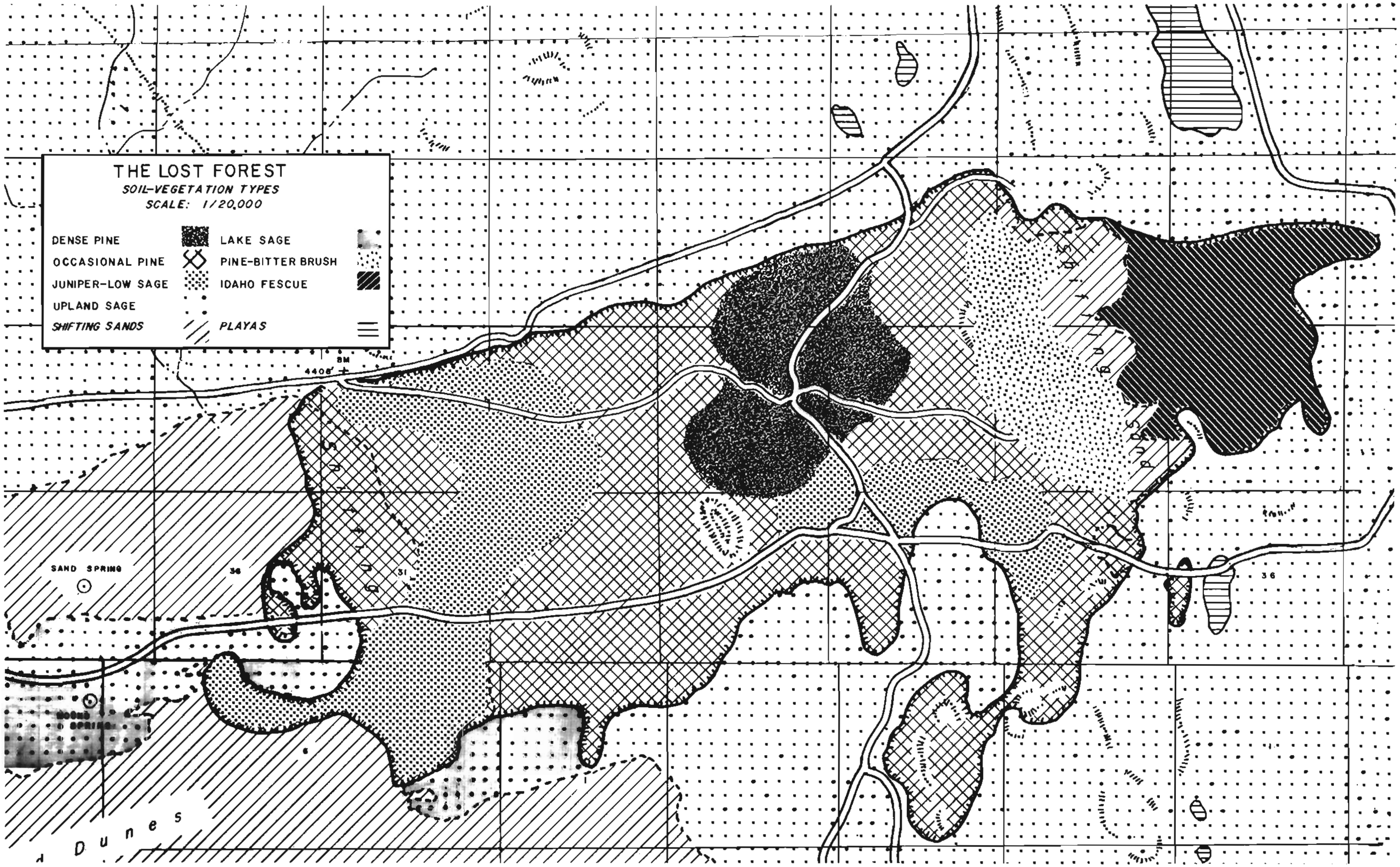


Figure 38. Plant communities. Scale 1" = 1 mile

horizons or none at all. Lost Forest soils display horizons upon exposure of their cross-sections but these are usually not the result of normal development.

Most of the horizons are totally unrelated from the standpoint of soil genesis. The horizons for the most part are the result of lake sediments, aeolian deposits and alluvial materials deposited in the pluvial and post-pluvial lakes by streams. The timing of these deposits has produced a polyglot pattern of sedimentary strata; some of which have undergone soil forming processes in place. Many such soils have been covered later with aeolian sands and still another soil forming process has begun. This picture has been further confused by lake levels which varied as much as several hundred feet in depths during the glacial and post-glacial period. Low precipitation and temperature have slowed the soil forming process which might otherwise have obscured the nature of the varied parent materials. For these reasons characterization of the soils by conventional description of profiles is not applicable and soil strata must be referred to by their parent materials or by their depths.

One exception to the above is the well-defined caliche layer which underlies most of the soils. This strata is very distinctive and well-defined but to determine whether it is a product of soil genesis or is the result of fluctuating lake levels was not within the scope of this study. The absence of zones in soils at some elevations which are above the pluvial lake levels indicate that the latter may be the case.

Parent Materials Parent materials of the Lost Forest soils are lake sediments, pumice, basalts, pyroclastic breccia and sands. In some areas a mixture of all five may be found; in others only the sands are significant.

On the old lake bed the surface six to ten inches is primarily of sand including much fine pumice and some diatoms from eroding portions of the bed of Fossil Lake. The second layer one foot to 2.5 feet is composed primarily of pumice and diatoms. At from three feet to six feet a layer of coarser sand is found.

Along the multiple shores, which represent many levels of the pluvial lakes, water-worn coarse fragments of basalt are found. These areas are conspicuously barren of vegetation (see barren areas in aerial view Figure 12). Most of the plants which do grow there are able to survive only because of a shallow topping of fine sand and silt which has been deposited by the winds. These coarse gravelly soils are found in the T-2 or Occasional Pine and Juniper community.

Another distinct soil type, although very limited in area, is that formed from the weathering pyroclastic breccia outcropping in the south central portion of the forest (figure 14). It supports a number of a fairly thrifty pine trees and the usual sage, rabbit brush and juniper. It is uniform to considerable depths but appears to retain moisture only in its upper levels. The root system depicted in Figure 39 illustrates this characteristic.

Pumice sands from either Mt. Mazama or Newberry Crater or both appear in the surface of nearly all the soils. The fine ash from Mt. Mazama is also found in many localities. It occurs in deposits as much as twelve to sixteen inches deep. The purity, the silt size particles, and the diatom skeletons in the material indicate that it was deposited in a lake of considerable depth (see Figure 33).

The soils of the T-3 (Upland Sage type), are the most uniform of all the soils in the Lost Forest area. They have a high sand content (seventy-five per cent) in all horizons. The soils in the timber type designated T-0, Dense Pine, or "Pine-Coarse Loamy Sand" appear to be similar to those of the upland sage but have a surface horizon consisting of a mixture of fine wind blown sand and coarse basaltic sands. These have a much higher clay content in the second horizons than most of the area on

Figure 39. Shallow ponderosa pine root system on loose deep sand.

Figure 40. Uprooted juniper.

which pine trees are found (see Table 21). The T-1, Occasional Pine and Juniper soils are midway between the T-0 and T-3 soils with regards to both clay content of the second horizon and the fine wind blown sand content of the surface.

Sand dunes of varying depths are found throughout the area occupied by other soils. Wherever these are present the characteristics of the sand completely override the influence of the underlying soil. Some of these dunes are still moving and support no appreciable vegetation. Others have remained fixed for a considerable period of time.

Other dunes previously stabilized are now moving with the persisting winds. Some large areas of the forest are almost completely covered by sand dunes (Figures 11 and 15).

The sands occur in two distinct size classes (see Figure 41). The finer sand includes approximately fifteen per cent pumice sand. The balance of the latter sand is mostly glass and crystalline material with some broken fragments of diatoms. The coarser sand is made up mostly of darker minerals and has no pumice sand. The latter sands are found in the northwestern portion of the forest and for the most part are of fairly recent origin as determined from the poorly rounded fragments.

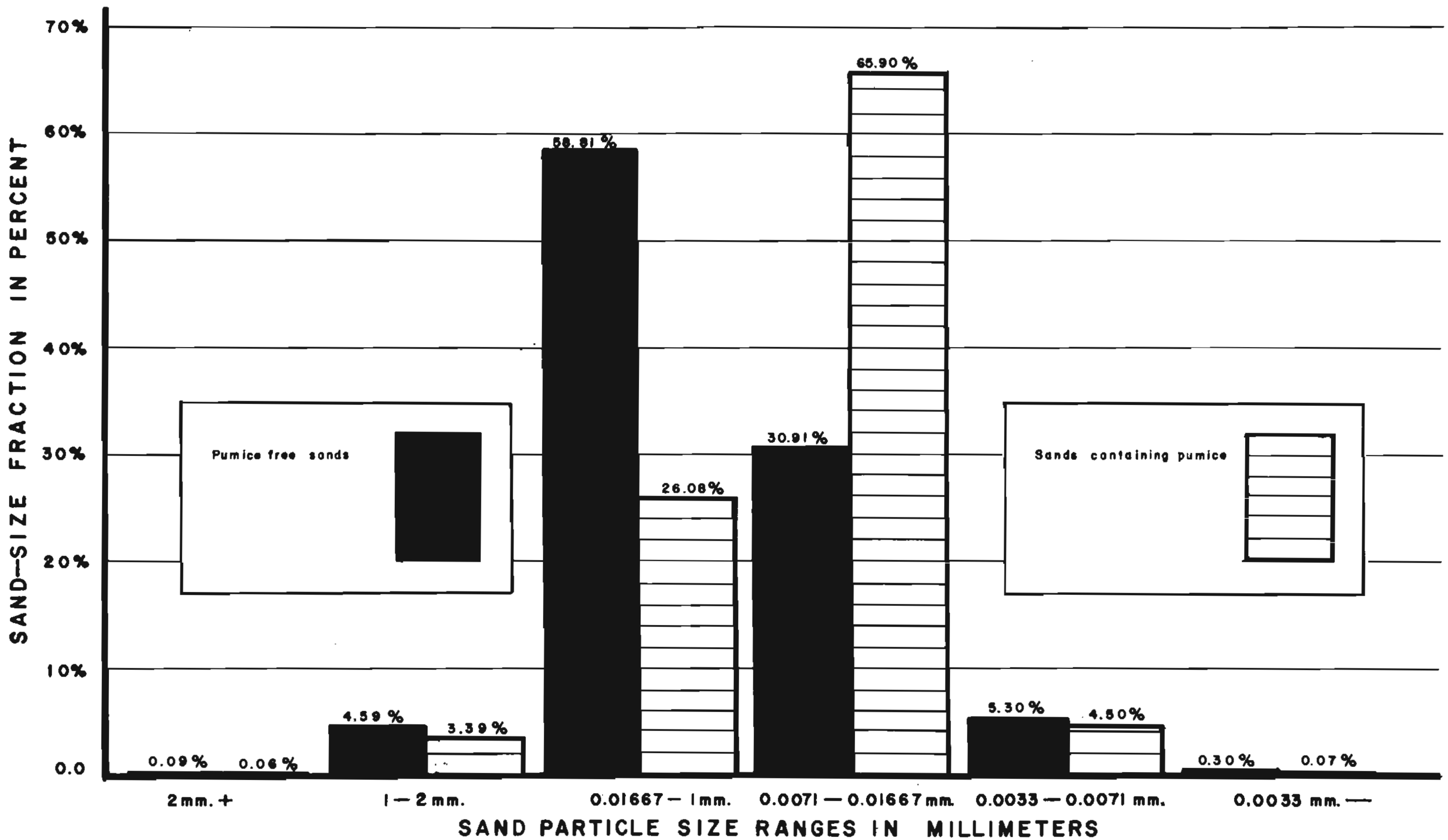
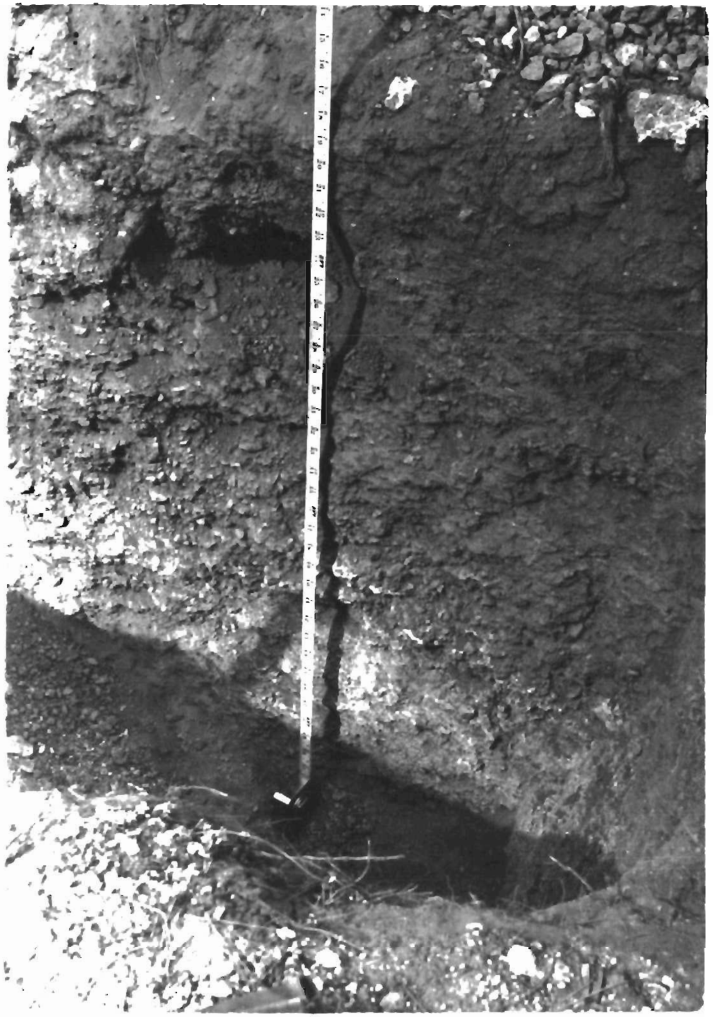


Figure 41. Sand particle sizes.

<u>Caliche</u> - Underlying the soils everywhere in the Lost Forest is a dense deposit of calcium carbonate or caliche. The pan thus formed is almost as hard as the native basalt. In some places it is in an unbroken sheet from a few to several inches in thickness. It is high in sodium salts and is rarely penetrated by the roots of plants. Roots of the pine trees upon descending to this layer proliferate and form massive horizontal systems. (See Root Patterns Figure 57).

Frequently a shallow layer of sand is found above a fossil soil underlain by one of these caliche layers (Figure 42 right). The upper white band in the photograph is paint which marks the bottom of loose, unconsolidated surface material; the lower white marker the top of the fossil soil; the light colored material at the bottom of the photograph is the top of the caliche zone. Figure 42 (left) illustrates the fragmented type of caliche. The upper photograph in Figure 43 also illustrates this phenomenon. Immediately below the latter photograph is shown the platy structure of what appears to be an incipient caliche layer formed in almost pure pumice in the T-4, Lake Bed Sage, type. This latter material contains 23.0 me. of Na per 100 gm.

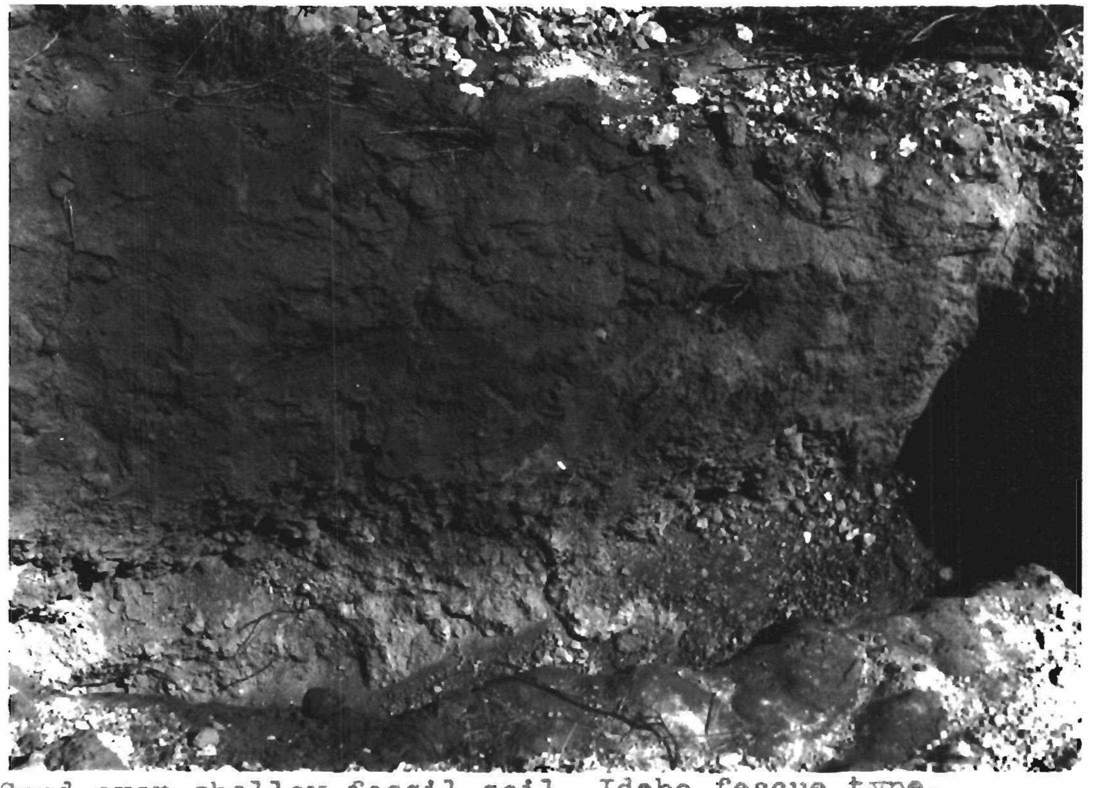
<u>Structure</u> - Except in the caliche layers, structure as



Fragmented caliche

Sand over buried soil.

Figure 42. Some soil profiles.



Sand over shallow fossil soil, Idaho fescue type.

Platy structure of pumice in an incipient caliche zone.

Figure 43. Caliche formations.

commonly thought of in well developed soils is practically non-existent. This is due to the relatively short period of time which the soil forming processes have had to operate and to the overriding influence of shifting sands and changing lake levels.

<u>Other Physical Properties</u> - The texture of some representative soils is shown in Table 24. Also shown are the moisture equivalents and the bulk densities and wilting coefficients of sand soils. Since moisture equivalents of sands are sometimes poor indicators of a field capacity, the two sands listed were also submitted to a 0.1 atmosphere test to obtain an additional estimate of field capacity. This proved to be the 3.99 per cent for the coarser sand and 9.02 per cent for the finer sands. The laboratory 0.1 atmosphere test for the coarse sands also appeared to be inadequate since under field conditions five days after heavy rains and melting snow they contained 5.2 per cent moisture. As for the fine sands, on July 18, approximately eight weeks after the last rain, the mean moisture percentage at the eighteen inch level in a four-foot dune was 10.3 per cent. Two days after an August rain the surface six inches averaged 14.9 per cent. Both the moisture equivalent and the 0.1 atmosphere test appeared to be poor estimates of field capacity of either sands.

Table 24

PHYSICAL CHARACTERISTICS OF REPRESENTATIVE SOILS

Plant Com.	Soil	Depth	% Sand	% Silt	% Clay	Moist. Equiv.	Bulk Density	Wilt. Coef.
T-0 Pine	Sand	Surface	85.9	8.9	5.2	11.6	1.44	* 4.0
	Coarse Coarse Loamy Sand	16"	75.9	10.9	13.2	19.0	1.54	10.3
T-0, BB, Pine Bitter brush	Sand, fine	Surface	93.1	3.1	3.8	9.8	1.56	* 4.0
	Sand, fine	24"	90.0	6.2	3.8	7.6	1.67	* 4.0
T-2, Juniper Low Sage	Sand, fine	Surface	87.6	7.6	4.8	9.7	1.35	* 4.0
	Sand, fine	17"	94.0	2.4	3.6	6.0	1.61	* 4.0
T-3, Upland Sage	Loamy sand	Surface	74.6	17.2	8.2	15.2	1.30	8.3
	Loamy sand	15"	76.4	12.9	10.7	16.0	1.45	8.7
T-4, Lake Sage	Loamy sand	Surface	74.6	21.6	3.8	13.2	1.22	7.2
	Sandy loam	20"	66.4	14.8	18.8	24.5	.37	13.1

*Direct estimate from Oregon State University Soils Department unpublished notes

Soil Chemical Analysis (see Appendix 9) In the upper zones of the soils on which trees are found growing, pH's range from 7.1 to 8.4. The highest pH was in the type which has the poorest pine growth. The lowest pHs are found in the area in which Idaho fescue is the dominating characteristic. The pH of the caliche layer in the Idaho fescue type is only 7.4. In the upland sage zone, alkalies alone would not prohibit tree growth. The pH of the upper levels of both fine and coarser sands are above 7.5. Hydrogen ion concentrations of the sands do not exceed pH 8.0 except at depths of four feet or greater.

The sodium content of the upper portions of most of the soils is well within the tolerable limits for trees. The lower zones, however, show a relatively high content of the base. In the seven to nine inch zone the T-1 "Occasional Pine and Juniper" type has 1.15 me/100g. At thirty inches it is 2.22 me/100g. The caliche in the "Upland Sage" has 12.37 me/100g. The highest is in the caliche zone of the Lake Sage soil which has 23.0 me/100g.

In general, all essential macro-nutrients except nitrogen appear adequate for most plant growth. Nitrogen also appears adequate for tree growth in all soils except pure sand. (See Appendix 9).

Nitrogen percentage in the surface horizons is from 1/5 to 1/6 of that found in the same zone by Dyrness (59) in his study of Ponderosa Pine types on Pumice soils in Lake County. The Upland Sage type (T-3), with the highest nitrogen percentage still was lower than the lowest percentage found by Dyrness in the surface horizons (.099% as compared to 0.105%). The pH values for the soils described by Dyrness were approximately 1.0 units lower than those at similar soil levels in the Lost Forest and vicinity.

Exchangeable potassium, calcium and exchangeable magnesium were considerably higher in the Lost Forest soils than in soils described by Dyrness although the latter showed a slight superiority in phosphorus content. The pumice soils examined by Dyrness also had from about six to twenty-five times more total organic matter in their surface horizons.

Cation exchange capacities of the surface soils in the two study areas are almost identical although in the lower soil levels the Lost Forest soils show a superiority of from approximately three to four times. Since Dyrness did not include Na in his analysis, base saturation cannot be compared for the two areas.

<u>Moving Sand Dunes</u> - Sand, in the form of dunes and sand sheets, is found throughout the forest. Several square miles of shifting sand dunes are found on the adjacent

Fossil Lake bed. Since soils as well as topography are so well characterized by these sands a discussion of their origin, their characteristics and their behavior in dunes is warranted.

Bagnold (15) states that the origin of most sands is in the decomposition of granitic gneisses and granitic rocks. Larger rock fragments are probably broken down to sand size particles by being abraded in streams between surfaces of heavier stones and that rounding is mostly accomplished by wind movement (15). The overwhelming bulk of the sands in the Lost Forest area are of the fine pumice-containing type as previously described. Discussion of movement, therefore, is concerned only with these sands.

The direction of dune movement as postulated by Bagnold (15) is determined by the vector-sum of all winds strong or of moderately strong velocities acting upon them. Thus the ultimate direction of movement is determined by the algebraic sum of the angular velocity of winds. In the Fossil Lake dunes the general direction of movement is North 75° east. The strong winds blow from approximately South 45° West. The changing direction is due to a strong northwest wind which blows for much shorter periods of time than the southwestern component. Evidence that a strong wind blowing at angles of 90° or more from the prevailing wind is involved can be seen in the teardrop and whaleback shape of the dunes (Figures 5 and 8). Bagnold (15) states that such shapes are due to multi-directional winds. Other evidence that additional winds are involved is apparent in the abruptness with which the dune fields terminate on their northern boundaries. This phenomenon is also noted on the northern boundary of the forest where both forest and dunes end abruptly (Figure 44). The latter phenomenon also provides excellent evidence that the existence of the forest is linked primarily to the distribution of sand.

An estimate of the rate of movement of the individual dunes or dune fields can be no more than speculative. There is no way of determining whether sand movement began during early stages of lake recession or later, nor is it possible to determine the rate at which the lake receded. It is reasonable, however, since such large quantities of sands are involved, to assume that the bulk of it most likely came from the dried up bed of a large portion of the lake much as have the dunes today.

There are only two methods available for making an objective estimate of the velocity of these sand fields. One of these involves measurements reported by Bagnold (15). He estimates that individual dunes of 30 meter's high move 10.9 m. or 37' per year; 17 meter's high, 10.8 m. or 36' per year; 11 meter's high, 16.2 m. or 55' per year.

Figure 44. Aerial view north across forest showing lake bed characteristics of terrain and abrupt northern boundary of forest.

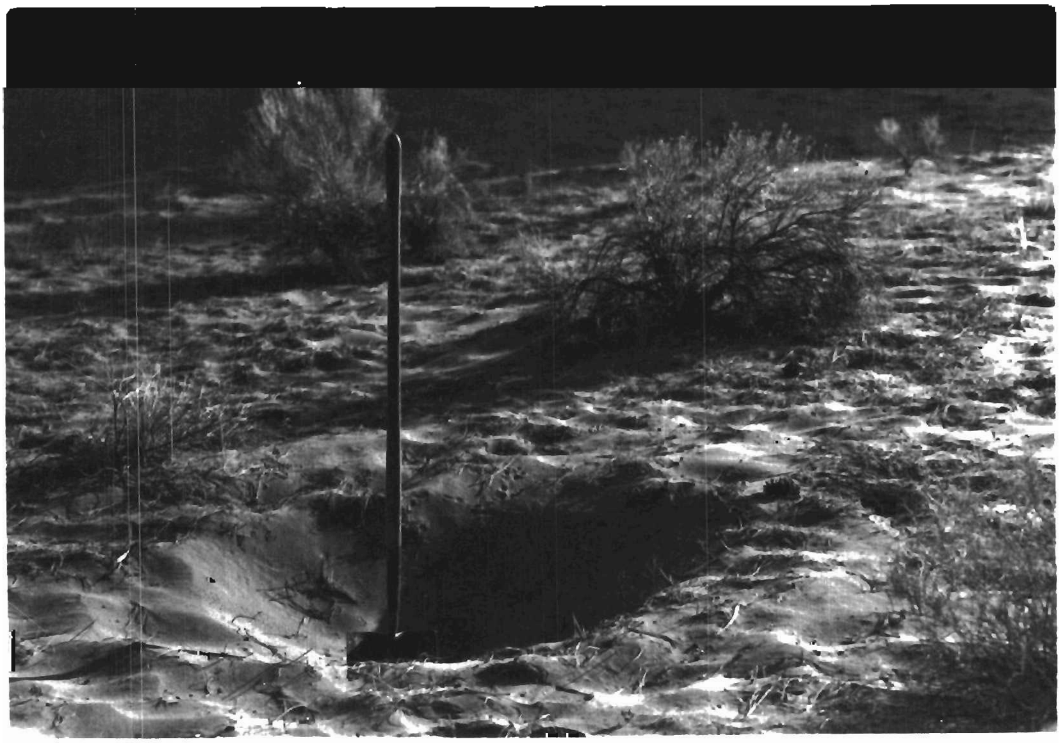
Velocities are based upon winds which persisted for 178 days of the year at 13-22 mph; ninety days at 13-30 miles per hour; thirteen days at 30-35 miles per hour. Assuming that the northeasterly wind vector in the Lost Forest area persisted one fourth of this time and assuming a seventeen meter dune we arrive at an estimate of nine feet-per-year dune velocity. In order to travel the approximately five miles from the present lake site to the east end of the forest it would require 26400/9 feet per year or 2933 years.

Another estimate was made by comparing aerial photographs taken in 1954 with aerial photographs made in 1960 (Figure 15). A mean advance for the large dunes in the east end of the forest was 5.8 feet per year. Using this figure an estimated 4,500 years would be required for advance of the dunes to the east end of the forest. No correction for the effect of slope upon the over-all velocity was made. Neither is there available an objective means by which the retarding effect of vegetation or moisture upon the over-all movement can be taken into account. Although the basis upon which these estimates are made is admittedly weak, each is of the same order of magnitude.

Soil Moisture

The problem of describing moisture relationships is

Evidence of shifting sands in exposed juniper roots.



Deflation one year after removal of one 3" auger core.
Figure 45. Sand movement in Lost Forest.

Figure 46. Junipers killed by encroaching sand.

best solved in an empirical manner. One of the significant factors is the penetration of precipitation into the soil mantle. Retention of the precipitation which has penetrated the soil mantle is also an essential factor in permitting ponderosa pine to survive in a climatic province in which it does not ordinarily exist. Location of available moisture is well illustrated in the lateral development of root system throughout the sand zone with little or no penetration into the fossil soils beneath.

"Sands are sometimes thought to have some miraculous power of drawing water up and from an underground water table to an unspecified heights by capillary attraction." (15) Bagnold (15, p. 245-246) states "there is no evidence whatever for this idea. An experiment showed that if a column of sand either enclosed in a tube or exposed as an open heap is supplied at its base with an unlimited amount of water the surface tension of the grains is unable to cause any moisture to rise higher than 40 cm. at the most." The idea could also be refuted by the fact that such lifting of water could require the expenditure of energy which is not available.

Bagnold states further that the presence of much moisture in sand cannot be accounted for by evaporation from below and recondensation above since this also would require work to be done and that in the case of evaporation and recondensation only thermal changes within the body of the dune could provide energy. He also states that since sand is such a poor conductor of heat even the extreme temperature changes which occur in the desert do not affect appreciably the temperatures to more than 20 cm. below the surface. This compares well with the author's measurements of temperature at 15 cm. depths during the summer of 1959. Although surface temperatures changed from as high as 59°C during the day to as low as -5°C at night, the temperature at the 15 cm. level remained constantly at 21°C.

Bagnold (15) remarks that in reality it is the uniformity of temperature within the dunes which prevents evaporation and thus retains water under the surface. He reports that such moisture may remain under the surface for many years, for water can only evaporate if the air in contact with it is unsaturated with vapor. Further evaporation could not take place as long as the saturated air between the grains remains in place. It is only in the upper 15 to 20 cm. that air is constantly being changed by the expansion and contraction of the air with the changing temperatures. Although Bagnold's explanations appear oversimplified the water retention phenomenon is spectacular in the Lost Forest Fossil Lake dune areas. The upper six to ten inches of sand appears as if freshly oven-

Figure 47. Ponderosa pine 62" in diameter, 93' tall.

Figure 48. Leaf litter over sand.

dried, while a foot or so below the surface cool damp sand can be found even in the most barren appearing dunes.

Underground Moisture - A perched water table or the emergence of underground water over an impervious strata have often been suggested as the sources of water essential for support of pines in the Lost Forest. This idea is given some credence by the shallow form of root systems. To investigate this possibility pits were dug below root zones in several sectors of the forest. Most of the pits were completely extended through an impervious layer into loose, unconsolidated material below. The presence of the impervious layer and the layer of dry unconsolidated material below indicates that moisture does not rise to the root zones from artesian sources.

There are, however, some elements of the perched water table theory at work. The source of the water is not an underground one but is the direct result of precipitation entering the sand dunes in too great quantities for the water to be firmly retained by the sand. Moisture descending to the fossil soil beneath moves outward a few feet over the relatively impervious material in the fossil soil. It is in the zone directly above the impervious materials that optimum development of the roots of pines and other plants occurs. The low moisture content of samples taken below the saturated horizons help to substantiate these conclusions. At the foot of one dune within the forest Juncus were found thriving after a summer rain.

Moisture Relations in Dunes - In 1908, Waring (158) after a visit to Fossil Lake stated that the appearance of pine trees on Pine Ridge (Lost Forest) seemed a unique occurrence and remarked, "It seems closely related to the soil conditions and moisture as affected by the drifting sands from the valley." Waring made no comments as to the mechanisms involved in the phenomenon but he had hit upon the one essential factor which made existence of the pine forest possible. That the pines are fundamentally linked to the movement and development of the sand dunes is particularly apparent in observations of the area from the air. (Figures 6, 12, 15 and 44).

General Moisture Depletion Pattern

The first samples were taken for moisture depletion determinations at nine localities in March 22, 1960, five days after a heavy warm rain which melted the remaining snow. The moisture percentage at the moisture depletion stations was determined again on July 6 and at two-week intervals thereafter until September 26. Immediately after the July 29 samples were taken, a rain of 1.12 inches occurred. On August 1, soil moisture was reassessed. Final measurements were made September 26. The results of soil moisture depletion studies are briefly summarized by vegetation types as follows: (See Figure 49)

T-0 Dense Pine-Coarse Loamy Sand - (Moisture Depletion Plot No. 3)

This soil is a very coarse loamy sand occasionally with a shallow surface layer of pure sand. Although the moisture content of the surface layer was still relatively high two days after the July rain, the examination five days after the rain in March indicates that very little moisture was present in the surface. This indicates fairly efficient absorption and retention of available precipitation. One feature of this soil, which no doubt aids pine growth, is the high clay and silt content of its second horizon.

T-1 Occasional Pine and Juniper - Moisture Depletion Plot No. 2

The moisture profiles two days and again two weeks after precipitation indicate no better permeability or moisture retaining characteristics in these soils than in those supporting less arboreal vegetation. On the contrary, the soil moisture percentage remains considerably lower in the soils of the T-1 community than most of the other soils.

T-2 Juniper-Low Sage - Moisture Depletion Plot No. 5

The vegetation zone characterized by juniper and low sage shows a surface situation somewhat similar to the two sage types except that the moisture conditions in the lower zone appear considerably more favorable than the moisture condition in the T-3 Upland Sage. It is also probable that moisture in lower zone of the T-2 "Juniper Low Sage" soil is more readily available than from the pumice silt of the T-4 Lake Sage area. Considerable puddling was evident immediately after the rain but the rapidly drying surface indicated that most of the loss through evaporation ceased considerably sooner than in the sage types.

T-3 Upland Sage - Moisture Depletion Plot No. 1

Although the unsurfaced roads were sufficiently dry to permit auto travel on March 22, 1960 the surface soil in this vegetational zone was still well saturated. In fact, free water still stood on the surface in some of the low depressions. The skies at the time of observation were clear, the temperature in the low 70's with a strong wind of twenty-five to thirty miles per hour. It was obvious that the moisture loss under these conditions was very rapid.

In March the surface soil moisture exceeded the moisture equivalent by 1.5 per cent. The other horizons were approximately at the moisture equivalent percentage. At no point during the balance of the year did the lower horizons of the "Upland Sage" soils exceed more than one-half the moisture equivalent.

By July 6, although several rains of unknown quantities had occurred early in May, the surface six to eight inches was considerably below the estimated wilting coefficient of sunflower and by July 18 and 29 had reached this point at even lower depths. Between July 29 and August 1, 1.12 inches of rain fell. Again the surface eight inches of soil was well saturated but not as high a moisture percentage as in March. Seven days after the July rain the soil surface still appeared moist particularly in the early morning hours before the rapid evaporation exceeded the upward movement through soil capillaries. Two weeks after the July rain, soil moisture was the same as on July 6 despite the heavy rain. Moisture continued to decrease until the last sample was taken on September 26.

T-4 Lake Sage - Moisture Depletion Sample No. 6

The surface moisture regime of these soils resemble the Upland Sage type. Soil moisture at approximately six inches below the surface was similar to that of the Upland

Sage at the time of examination in March. However, at greater depths the parallel trends disappeared. The lake bed soils have developed upon a partially cemented layer of silt-and-clay sized pumice. This material has a much higher moisture retaining ability than the fine sands and coarse silts in the T-3, Upland Sage community.

Moisture depletion plot 6, (Figure 49), exaggerates the total moisture retention capacity of the pumice zone since the bulk density of this material is approximately .87 grams per cubic centimeter as opposed to 1.45 grams per cubic centimeter at similar depths in the Upland Sage soils.

The rapid loss of moisture from the surface of the soil is apparent for several days after a rain. Figure 32 shows damp soil ten days after the rain of July 29 and 30; in all but two of the ten days which elapsed after the July storm, the weather was characterized by high temperatures and extremely low humidity (7-12%).

That moisture in the pumice layer is retained with great capacity is obvious from the appearance of soil moisture profiles (Figure 49). The pumice layer is well cemented but not entirely impervious to roots. Some sage roots were found to penetrate to depths of 2.5 feet although none extended completely through the layer. This may be due either to the low moisture content or the high salinity of its lower portion (see Appendix 4). In March the sand immediately below the pumice zone had less than two per cent moisture content and remained this way throughout the sampling period.

T-5 - Idaho Fescue

Because of its inaccessibility moisture depletion stations were not established in this zone.

T-6 Ponderosa Pine Dunes - Coarse Sand - Moisture Depletion Plots 4a and 4b

The moisture percentage in the pure, coarse sands remains very low throughout the season. The moisture content was slightly higher than the upper levels eighteen days after the July 29th rain. Figure 49 also indicates that the moisture at the surface was somewhat higher under the trees than on barren dunes. This was due to the reduction of evaporation by the heavy mantle of partially decomposed needles under the trees (Figure 48).

Soil moisture percentages in the coarse sands remain so low throughout the season that survival of pine trees under such conditions appears almost impossible (Figure 49). The bulk density of the coarse sands is not sufficiently different from those of the other soils to change their calculated moisture percentage values in relation to absolute moisture content. Mean bulk density of the fine

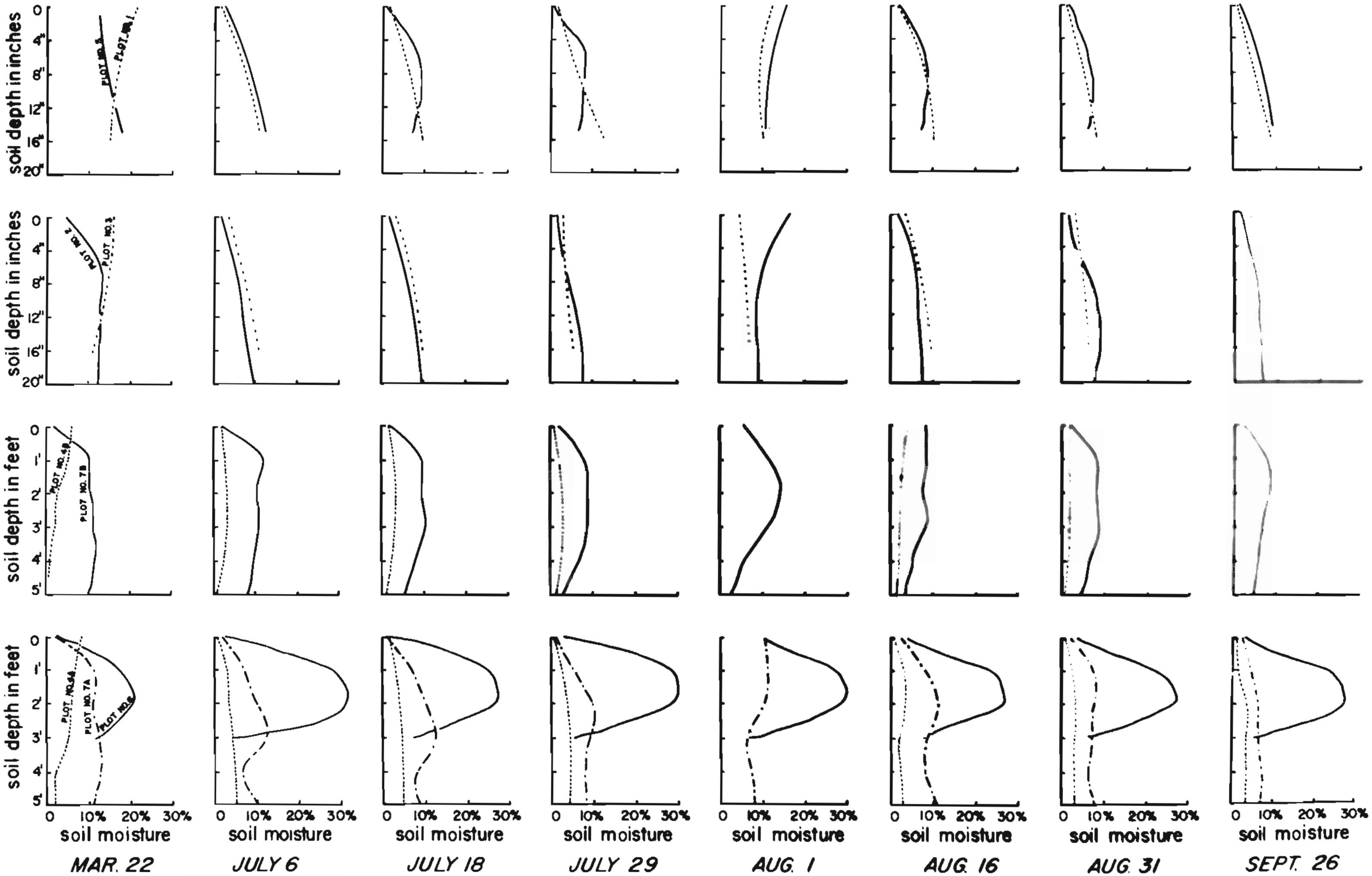


Figure 49. Soil moisture profiles. Plot 1, T-3; Plot 2, T-1; Plot 3, T-0; Plot 4a, T-6 (open); 4b, T-6 (under trees); Plot 5, T-2; Plot 6, T-4; Plot 7a, T-6 (open); 7b, T-6 (under trees).

sands at the moisture depletion sites was 1.39 grams per cubic centimeter and of the coarse sands 1.40 grams per cubic centimeter.

The influence of forest tree cover on the moisture regime can be noted in Figure 49, in the difference between soil moisture in plot A, which was located in the open, and plot 7B which was located under the trees. The difference is characterized by considerably higher moisture content in the open as would be expected. This may be due to interception of precipitation by tree crowns as well as to uptake by roots.

T-6 Ponderosa Pine on Dunes - Fine Sand - Moisture Depletion Plot No. 7a and 7b

As in the coarse sands the surface of the fine sand under the pine trees shows considerably higher moisture content than in the open. This is the result of the thick duff beneath the trees. As in the case of the coarse sands, total moisture was considerably less under the pine trees than in the open. In the deeper portions where sands are not underlain by an impervious fossil soil, moisture content decreased slightly with depth to approximately the five-foot level. Beyond this there was a sharp drop where the sand became too dry to lift with an auger.

Soil Permeability - The results of an experiment to determine the relative permeability of some Lost Forest soils are shown in Figure 50. Differences of greater magnitude, e.g., between T-3 and T-0, T-0 and T-6 etc., appear real and were confirmed by direct observations after rains. Except for the types T-1, "Occasional Pine and Juniper" and T-2 "Juniper Low Sage," the order of permeability is the same as the order of density of the respective pine stands. This exception could be accounted for quite readily by the fact that the "Juniper-Low Sage" is on a soil containing a much higher proportion of gravel than any of the other soils. The gravelly nature of the latter permits rapid loss as well as rapid permeability.

The relatively slight advantage, in permeability which the T-6 "Sand Under Pine" appears to have over the "Barren Dune" may be due to the somewhat lower moisture content of the former. There data, and the direct evidence so apparent following rains, point out the tremendous advantage of unconsolidated sands in admitting and conserving moisture for plant growth. This obviously is one of the essential mechanisms permitting the Lost Forest to survive in so unfavorable a climatic province.

Gray Rabbit Brush Moisture Depletion Study

No real differences were found in the moisture content

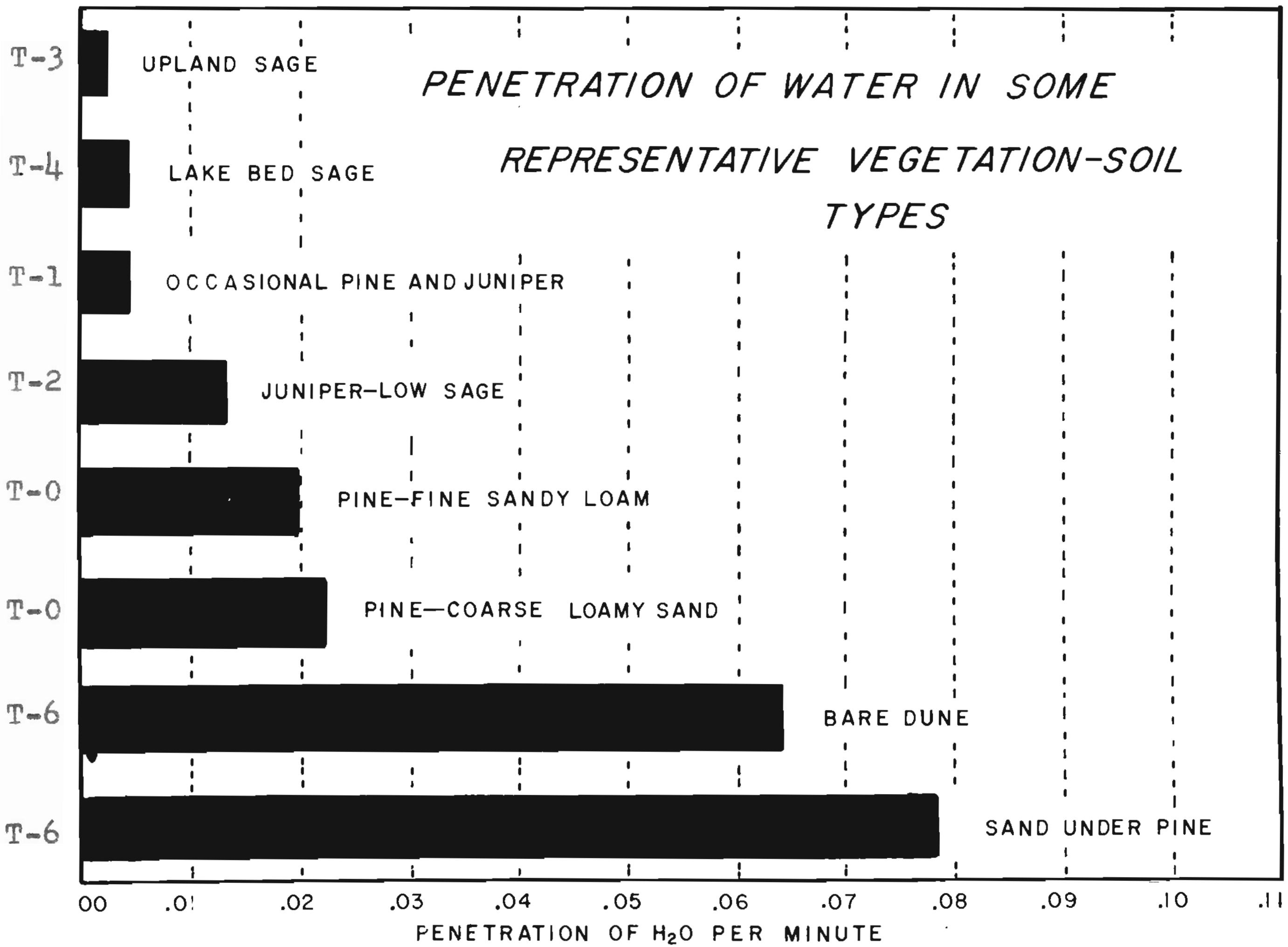


Figure 50. Soil permeability

with respect to directions from the rabbit brush plant (Figure 51). Also, there were no obvious differences in moisture content among the stations at distances of two feet or more from the shrub (Figure 52).

There was a distinct difference between the station immediately under the shrub and the mean of those two feet or more distant from it. The profiles in Figure 52 show mean percentage of soil moisture for July and August for the station immediately under the shrub and the means of the more distant stations. This does not indicate a more favorable moisture regime for the establishment of ponderosa pine since the moisture content is distinctly lower under the shrub at all depths than in the soils more distant. However, on July 6 (Figure 50) the moisture content of surface soil immediately under the shrub was slightly higher than in the more distant stations.

The relationship of moisture content at varying depths was consistent throughout the sampling points except for some minor variations. Figures 51 and 52 portray the details of these relationships. The composite rounded curve of Figure 53 reflects the mean of soil moisture depletion for all depths. This does not fully express the significance of the difference as far as seedling establishment is concerned. Figure 54 shows this much better in the moisture profile "July 6" for "Shrub Station."

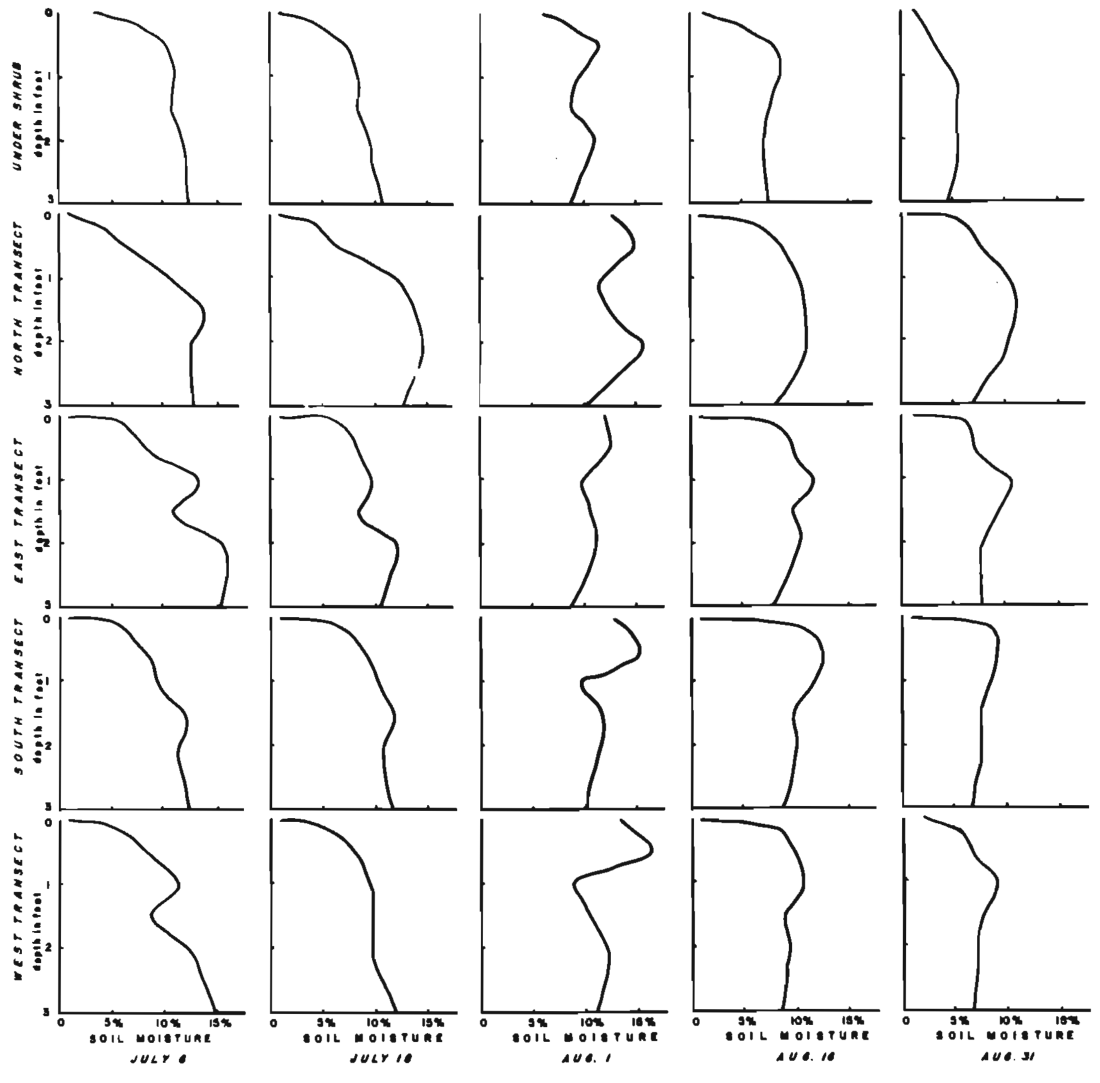


Figure 51. Rabbit brush study, soil moisture profiles by directions.

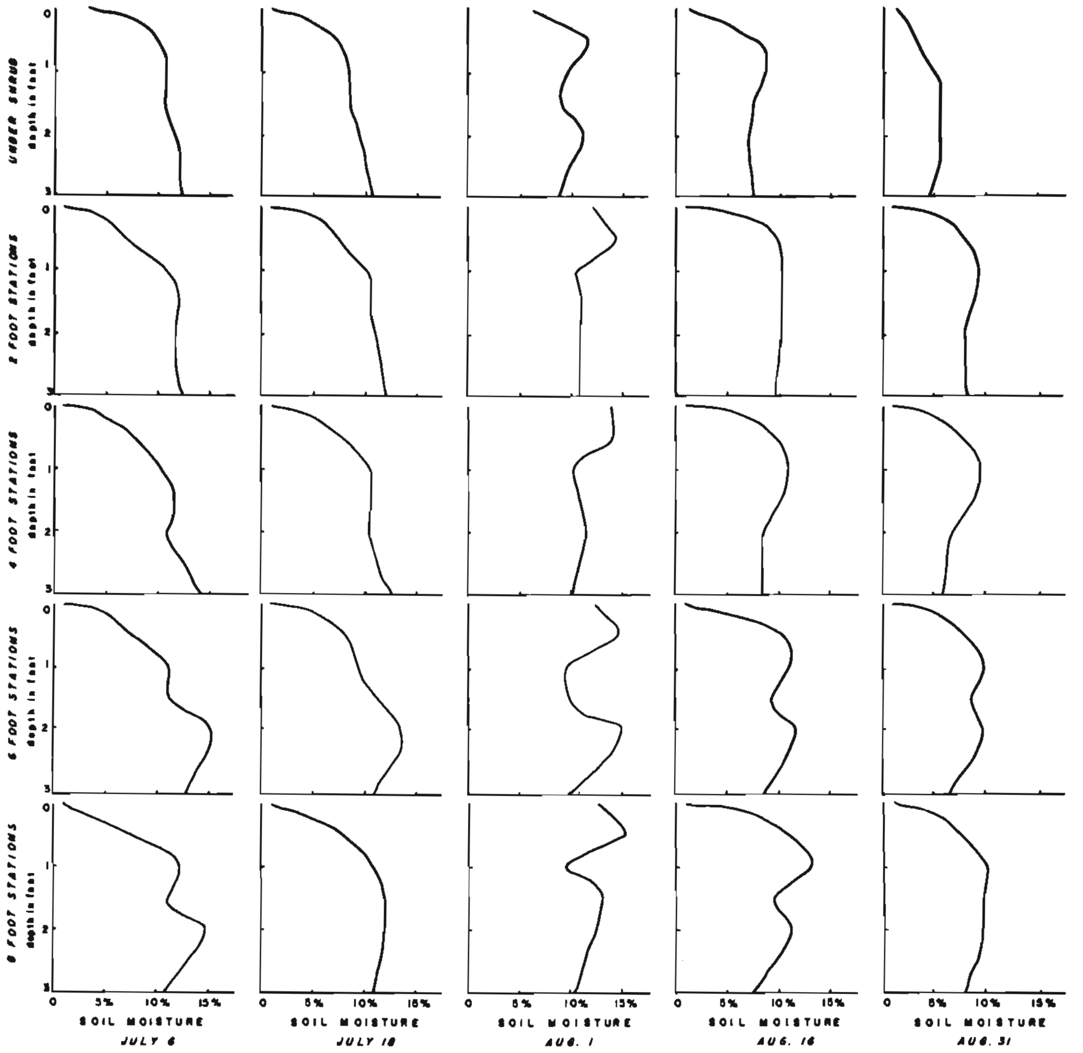


Figure 52. Rabbit brush soil moisture study profiles by distances from shrub.

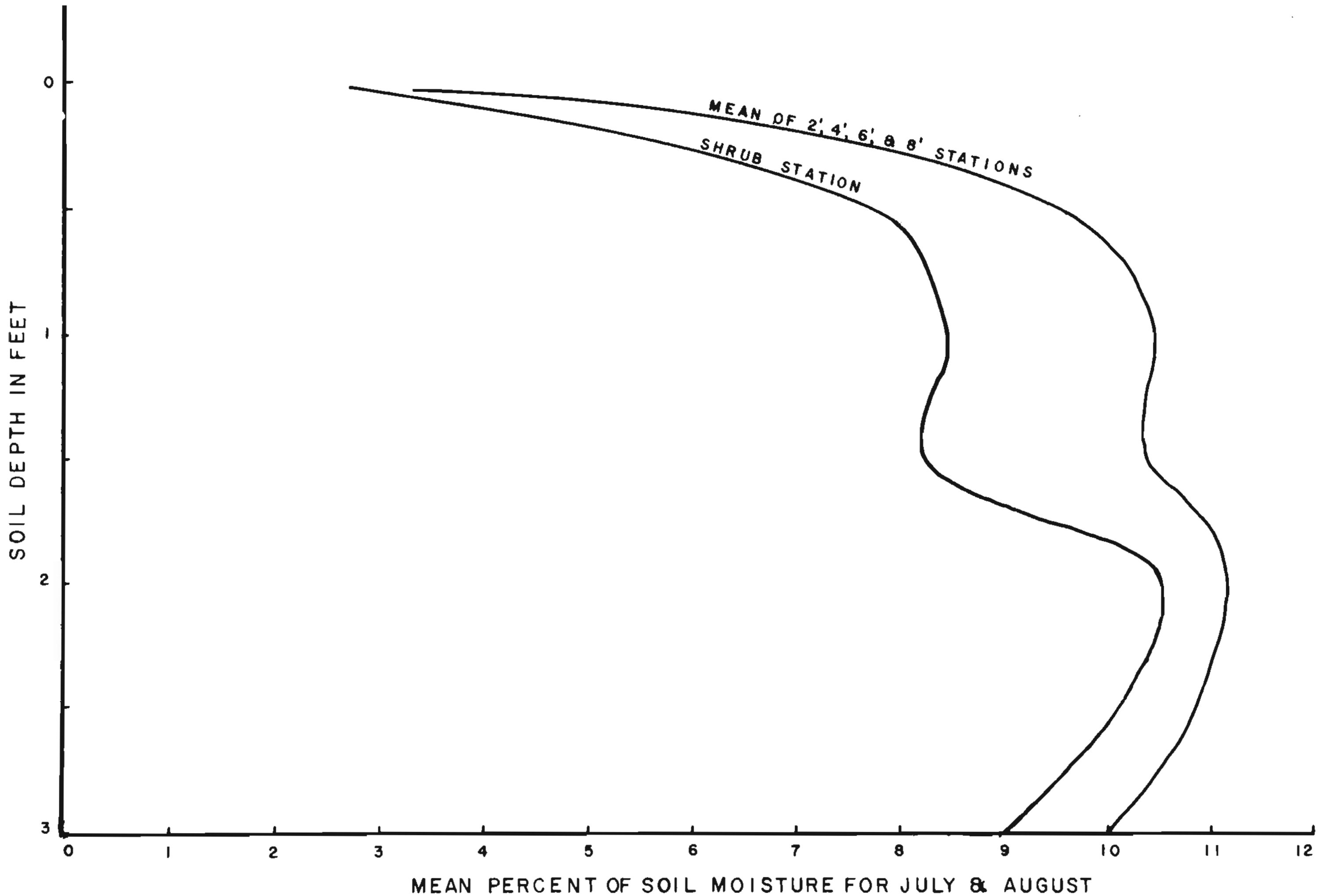


Figure 53. Composite soil moisture profiles for rabbit brush study.

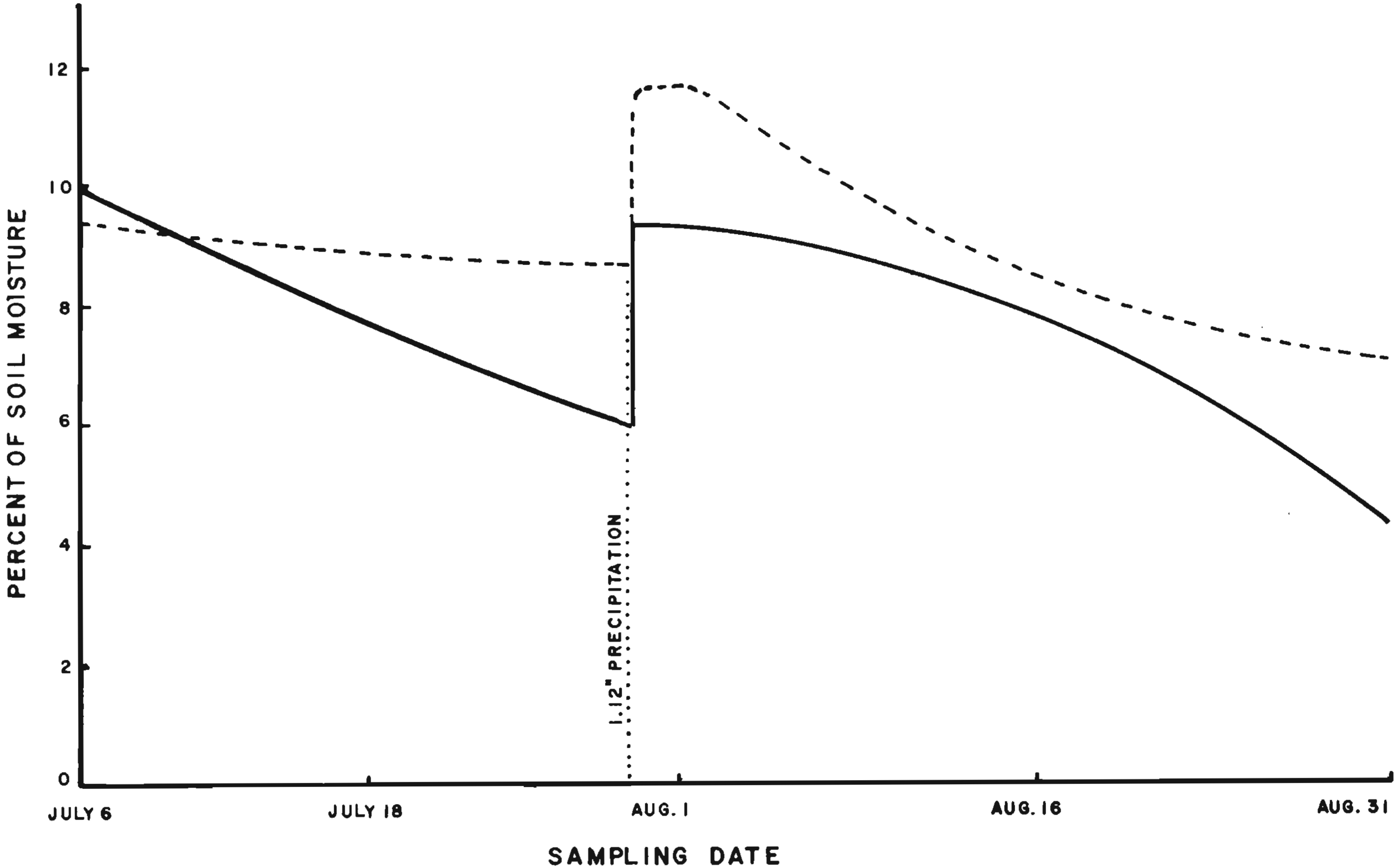


Figure 54. Soil moisture depletion in relation to rabbit brush. Mean of all depths. Broken line--mean of all distant stations, solid line--per cent of H_2O under shrub.

This shows the effect of shade and the light surface litter in preventing the complete loss of available moisture from the surface soil early in the growing season. This could be a significant factor in determining the survival of ponderosa pine seedlings since bare sand exposed to sun, wind and low humidities is reduced in a day or two to near oven dry, moisture content. The slight advantage provided by the moist upper layers of soil when accompanied by a reduction in soil surface temperature, higher humidities, and protection from the wind more than compensate for the somewhat drier soil at lower soil levels under the shrub.

As described in a previous section, gray rabbit brush roots appeared to extend outward for considerable distances in the sand even though soil moisture may be adequate in the immediate area of the plant. Thus water, although less abundant immediately under the shrub is still adequate for survival and growth of ponderosa pine seedlings even after the essential period of germination and establishment.

These rooting characteristics are not found in most of the other shrubs. The one exception is bitter brush. The root system of bitter brush could provide a somewhat similar advantage as far as soil moisture is concerned but until it has completely dominated the site it does not provide the shade and litter which prevents surface evaporation. In any event, ponderosa pine seedlings were not found associated with any of the shrubs other than gray rabbit brush. The dense crown of the rabbit brush also offers considerably more protection from wind than do most of the other shrubs.

It is interesting to see many trees of sapling and pole size, both juniper and ponderosa pine, growing from the clumps of dead rabbit brush which apparently had nortured them (Figure 55).

Depletion of soil moisture throughout the growing season follows the expected pattern as can be observed in Figure 54. In the chart the solid line, which represents moisture conditions directly under the shrub, drops well below the broken line which represents the moisture content at more distant points. The chart also shows that precipitation occurring in storms producing 1.12 inches or less is not as effective immediately under the shrub as in the open. This is due to interception of precipitation by the aerial portions of the plant and by the surface litter. This factor is probably not as significant during the periods when seeds are germinating as are the other favorable influences.

<u>Ponderosa Pine Moisture Depletion Study</u> - Samples were taken on July 6, August 1 and August 31. The results are

Figure 55. Young ponderosa pine growing from crown of gray rabbit brush.

summarized in Figure 56 in which mean moisture percentages for all three depths are plotted with respect to the station from which the data were obtained.

It is significant to note that although the last reported rain occurred in May, the 1.12 inch storm of July 29 raised the moisture percentage above the July 6 level. By August 31 moisture was considerably below the July 6 level. It should be noted that the sand has a higher moisture content directly under each of the two trees than twenty feet away. This is not as might be expected due to protection from evaporation by litter or duff under pine trees since the sand under both trees was devoid of organic litter.

It is probable that the higher moisture content of the sand under the trees after the rains was due to water flowing down the trunk from the crown during the storm. Horizontal rains during the high winds which usually accompany summer rains are intercepted by the crowns and drain off more under the trees than would normally be deposited on the same area in the open. Flow of water down the trunk was observed on several trees during the storm of July 29, 1960.

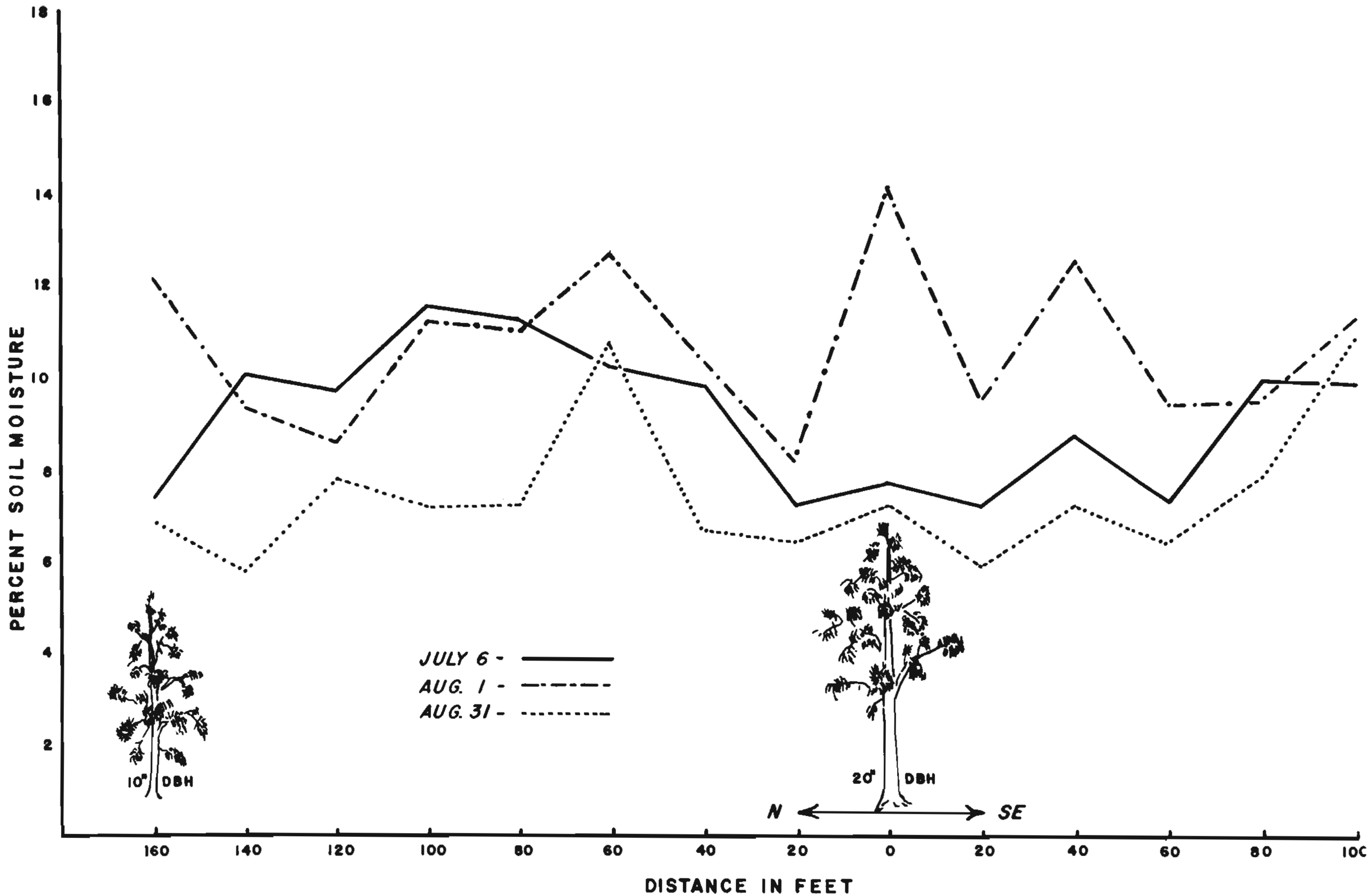


Figure 56. Soil moisture (at mean of 1, 2 and 3 foot depths) in relation to ponderosa pine trees.

Soluble Salts and Water

One factor which has not been discussed is the effect of the soluble salts on the water uptake of the plants. The non-forested soils in the study area are considerably higher in total salts than the forested soils, at least in their upper zones. Kelley (107, p. 114) states that soluble salt content of the soil water greater than .5 per cent affects the water uptake of plants. This is due primarily to an increase on the osmotic pressure of the soil solution.

Some significance may be found in the fact that ponderosa pine roots penetrate the caliche zone in the T-O "Coarse Loamy Sand" soils while in other areas root penetration ceases at the surface of the caliche (Figure 57). For example, the sodium content of the T-O - "Coarse Loamy Sand" caliche is only 0.87 me/100 gm. while some of the others have from 3.21 me/100 gm. to 23 me/100 gm. (appendix 9). Only an analysis of salts in the soil solution could determine their significance in preventing the growth of trees on non-forested soils. This could involve an extensive sampling since salt content is extremely variable in alkaline soils.

Summary of Moisture Relationships - The critical characteristics of the Lost Forest soils with respect to their

A

Shallow soil over caliche.

B

Two layer root system.

C

Two layer root system.

D

Grown on loose sand.

Figure 57. Ponderosa pine root adaptability.

water relationships is their ability to permit rapid penetration of the infrequent precipitation and to retain it against the influence of high water vapor gradients.

For the most part the moisture absorption and retention characteristics of the soils are determined by the amount and location of more or less pure sand covering the older fossil soil or lake sediments. Although the sands are unable to retain great quantities of water on a percentage basis they frequently exist in sufficient depths to permit a large over-all water retaining capacity. As a shallow layer over less penetrable soils they act as an excellent mulch which readily admits precipitation and restricts evaporation.

The total amount of water retained by the fine sands common to the Lost Forest can be estimated from the three constants: bulk density, permanent wilting percentage and field capacity. The mean bulk density for the sand at the site of the fine sand moisture depletion experiments was 1.39. A conservative estimate of field capacity is 14.9 per cent (taken from the moisture content at eighteen inches depth in a four foot-deep dune eight weeks after the last rain). The wilting coefficient for fine sand is estimated at 4 per cent (127).

Total water storage available to plants

= (Bulk density) (Depth) (Field capacity--wilting coefficient)

$= (1.39)(12)(14.9-4.0) = 1.8$ inches

Water storage in the topmost six inches of fine sand must be discounted since moisture is rapidly depleted from most of this zone by evaporation. Each additional foot of sand, can store 1.8 inches. Thus a five and one-half foot dune will retain approximately nine inches of precipitation. This is considerably more than the net moisture which could be expected from a year's rain and snow in the Lost Forest. The advantage of sand as a surface mulch becomes even more significant when it overlies fossil soils with higher moisture holding capacities thus providing a one-way path for percolating rain and snow waters. This advantage is further enhanced by the high moisture content of the sand-fossil soil interface. In some situations six to eight inches of sand was found to be completely saturated. It was on the periphery of one such site that rushes were found growing. These situations were rare but conceivably could occur more frequently if additional precipitation were available.

Impact of Land Use

The effect of harvesting poles, firewood and sawlogs within the forest has made some changes in the overstory, particularly in the portions most heavily cut, but appear to have made no profound changes in the understory vegetation except near portable mill sites. Disturbance of the soil by loggers, ranchers and the U. S. Army on battle maneuver have left conspicuous evidence of disturbance but when compared to the effects of shifting sand dunes these are negligible.

Overgrazing and attempts at farming abetted by drought have caused considerable erosion from portions of the bed of Fossil Lake immediately to the west of the forest. This has resulted in a new series of sand dunes encroaching upon the western end of the forest.

Overgrazing within the forest may have accelerated wind erosion and may have caused a change in understory vegetation. The stable Idaho fescue community in the eastern end of the forest has remained relatively undisturbed probably because of a differential grazing pressure brought about by the greater distance from the only water supply and a partial barrier provided by a series of large sand dunes.

In the adjacent areas not affected by shifting sands, the heavy early grazing practiced in the early 1900's may have caused a change from the Agropyron spicatum to the present dominant grass, Sitanion hysterix, as has happened in other areas, but there is no direct evidence to support such a conclusion.

Root Patterns of Common Species

Numerous uprooted pine trees are found throughout the forest. These trees have succumbed to drought, insects or other agencies. As soon as small root and rootlets have decayed, trees are easily tipped over by wind. Although the system of fine roots has been destroyed, the more massive roots remain to provide distinctive patterns which characterize soil conditions at the site. Many of the roots are semi-permanently preserved by a heavy impregnation with resin (Figure 57). The tremendously varied root patterns of the ponderosa pines indicate their great ability to adapt to varied soil conditions. Figure 57 shows examples of adaptation to different sites and adaptation by individual trees to root growth conditions at different depths.

Juniper trees are seldom uprooted in the manner of the pine trees, but their root systems are very susceptible to uncovering by persistent winds. A few seedlings of both ponderosa pine and juniper were excavated to determine root patterns during the seedling stage. Specimens of big sage, bitter brush, and rabbit brush were also excavated.

One juniper tree approximately eighteen inches in diameter was uprooted by road building equipment and is shown in Figure 40.

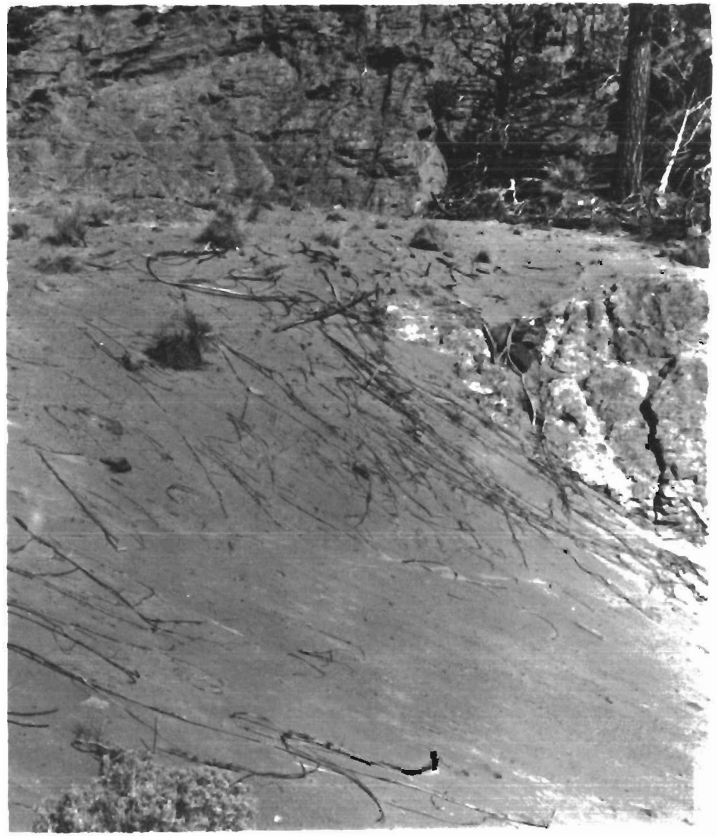


Figure 58. Wind exposed roots of ponderosa pine.

Climatic Observations 1959-1960

Summer maximum temperatures approximating 100°F occurred several times during the author's residence in the Lost Forest. Summer minima falling below freezing are common particularly in June and in August. Temperatures did not remain much below freezing for extended periods during the night (see Figure 59). On July 28, 1959 a temperature of 23°F was recorded. It was sufficiently cold to freeze Russian thistles growing on sand dunes in the western portion of the forest (Figure 32).

The effect of such temperatures on newly germinated seedlings is not known since none of the 1959 germinants were found. However, several seedlings of 1958 origin which had been previously under observations were not harmed. Some of these seedlings were in depressions which could have served as frost pockets so that it is apparent that temperatures of 23°F for short periods of time do not necessarily destroy older seedlings, at least during the latter part of the growing season. More detailed information as to the occurrence of minima may be found in Appendix 2.

Daytime humidities as determined by wetbulb and drybulb thermometers were frequently below seven per cent. A comprehensive study of the humidity was not attempted.

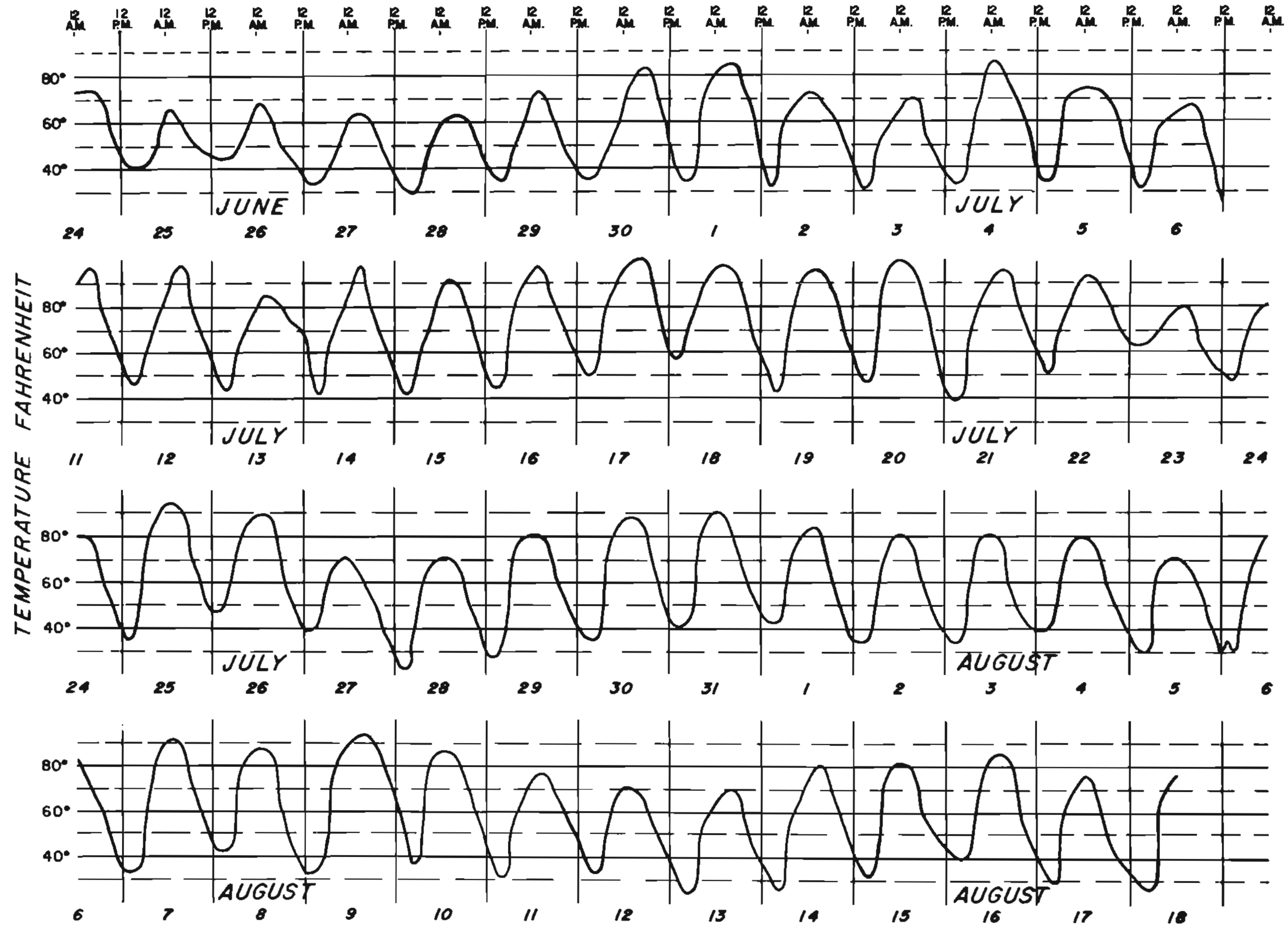


Figure 59. Air temperatures as recorded in Lost Forest during summer of 1959.

A number of samples made throughout the summer of 1959 and 1960 indicated a relative humidity during the day of from seven per cent during clear weather to twenty-five to thirty per cent during overcast periods. In fact thirty-four per cent humidity was measured during a light thunder shower.

No direct measurements of wind velocities were made but daytime winds of sufficient force to move sand were observed frequently during the summer. Winds were particularly strong in March 1960 when a dense cloud of fine sand was observed over the dune fields. Winds were sufficiently strong and persistent during the month of June to be a serious factor in desiccation of pine seedlings.

Direct measurements of precipitation were limited to the summer months. A storm yielding .62 inches of rain occurred in August, 1959 and another provided 1.02-1.12 inches in late July, 1960. On November 9, 1958 there was 2.25 inches of snow on the ground. There was no difference in snow depth between the interior of the Lost Forest and the surrounding non-forested area.

The Tree Ring Record

The greatest uniformity and the closest relationship between growth rate and precipitation among the samples was found in the Lost Forest tree ring data. This was partially due to the fact that fourteen individuals were sampled there whereas only five trees were sampled at the Fremont weather station and five at The Poplars station. The precipitation measurements obtained from The Poplars station showed the poorest agreement with tree ring growth. This is to be expected since with only five individual stems present most of the criteria used in selecting sample trees (see Methods) were not applicable. In fact, two of the individuals at The Poplars were growing on the same root system; the others were growing on widely differing sites. The individual showing the nearest to normal appearance is shown in Figure 63.

Figure 60, which shows the growth rates of five individual trees at Fremont, serves to illustrate that all trees do not respond exactly the same to changes in precipitation. Individual variation is especially common on severe sites and slight differences in microsites may produce differential responses among individual trees. This is particularly true when comparing annual fluctuations (7, 58, 106). Two individuals failed to show the same growth response to higher levels of precipitation even as late as 1955. The response of these two individuals is very similar to that of the mean for the five trees at The Poplars which is also a very severe site (Figure 61).

However the general agreement among individual trees for both annual growth fluctuations and long term trends

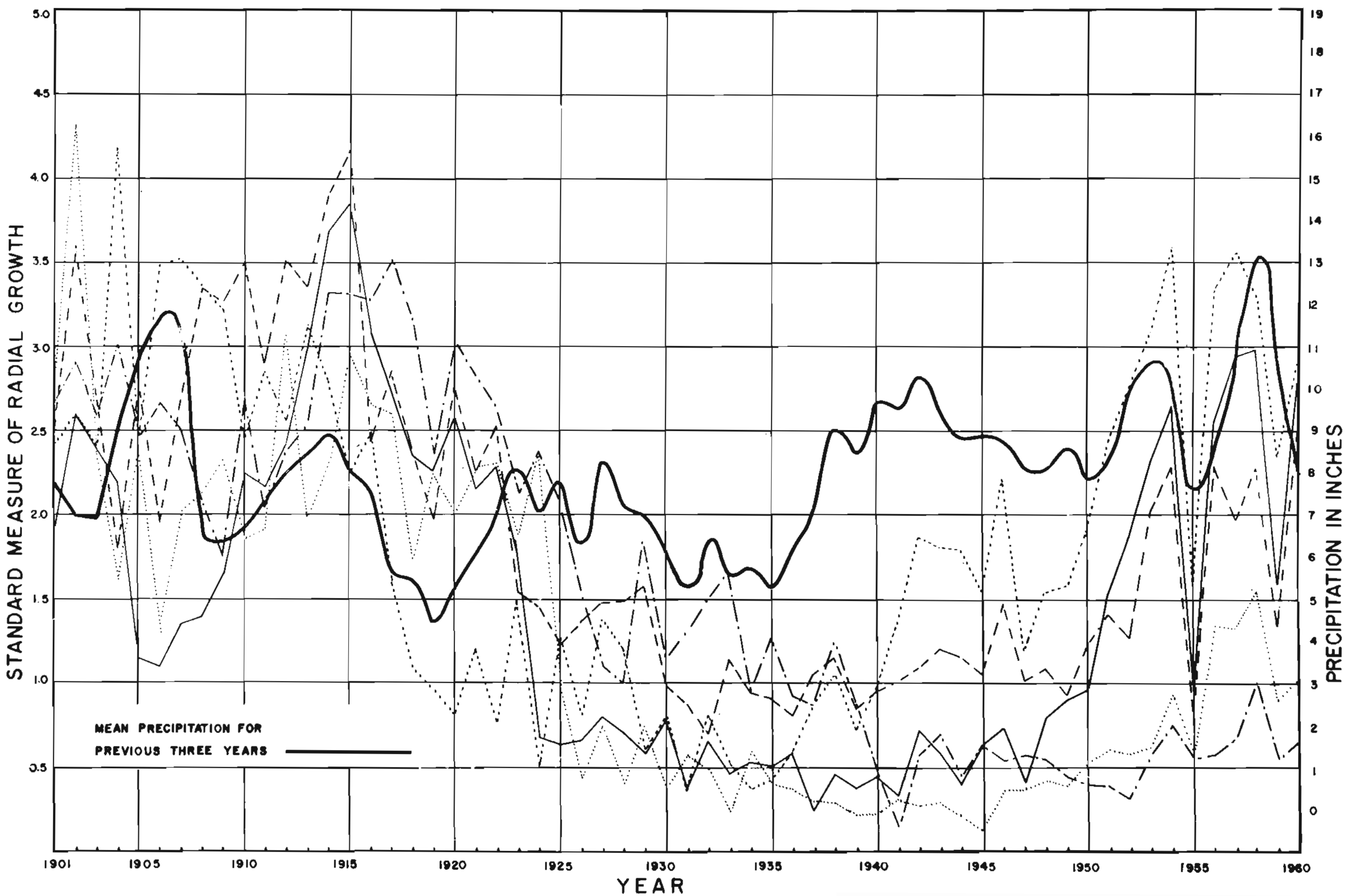


Figure 60. Growth patterns of five trees at Fremont weather station with estimated three-year mean precipitation for Cliff superimposed.

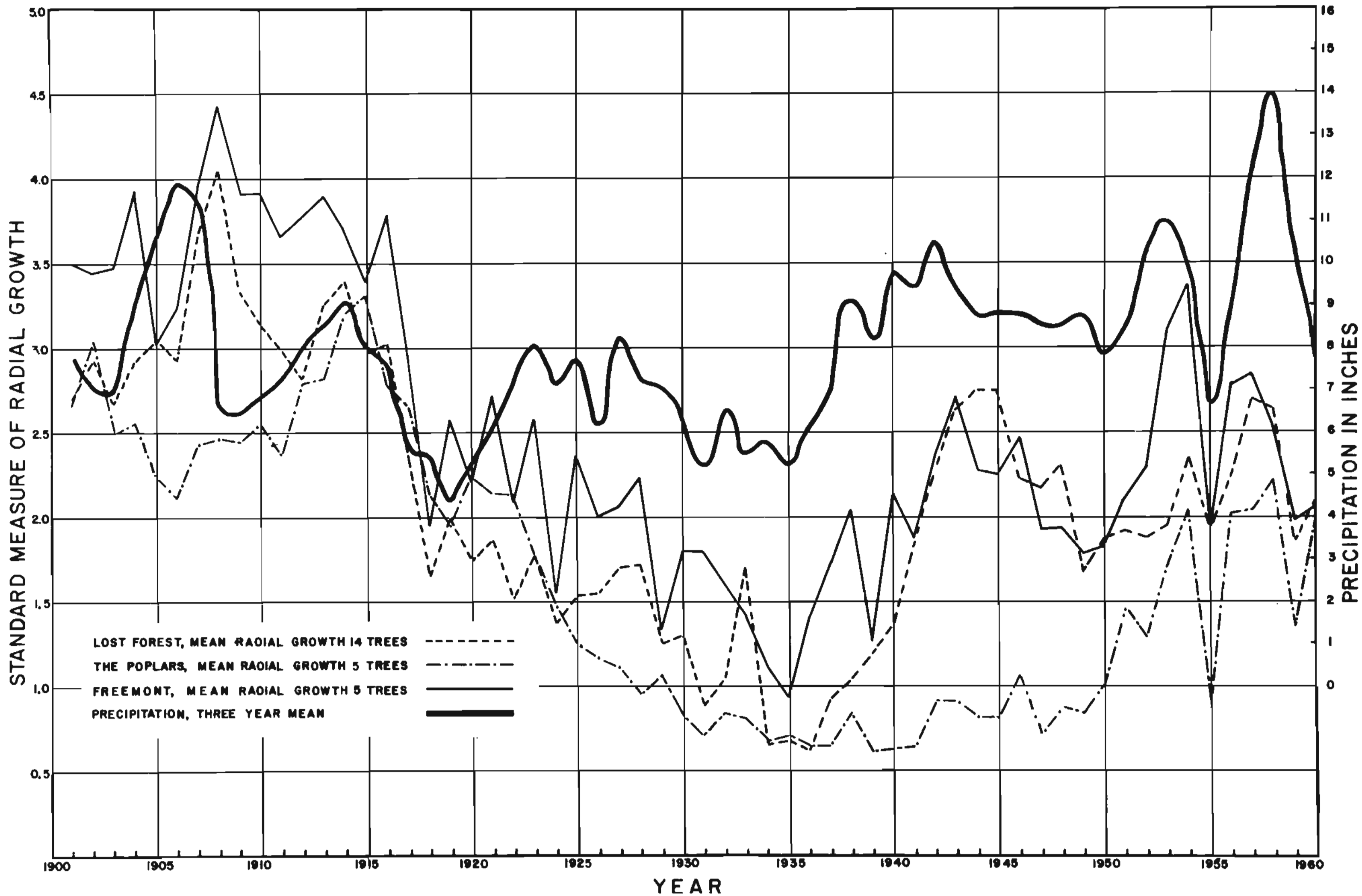


Figure 61. Comparison of radial growth rates for Lost Forest, The Poplars and Fremont. Three-year mean precipitation for Cliff superimposed.

and the general agreement with the three-year mean precipitation suggest that the mean radial growth responses of the five trees should provide a reliable reflection of precipitation trends at the Fremont weather station. That this is the case is illustrated in Figure 61.

The mean radial growth rates of the Lost Forest and The Poplars trees as expressed in units of standard measure are also shown in Figure 61. The curve representing the mean of three years' precipitation has been superimposed upon the figure. This mean is based upon the precipitation of the current October-September year and the two previous years. The agreement of this mean with annual growth fluctuations is readily apparent.

Agreement for the long-term trends is very good between mean growth rates of Lost Forest and Fremont trees. The mean growth rate of the Lost Forest and Fremont trees also agree well with mean precipitation. This is additional evidence supporting the reliability of the assumption that Fremont precipitation records reflect similar climatic trends in the Lost Forest.

It is interesting that there is a noticeable lack of agreement of The Poplars radial growth data with the long-term precipitation trends (Figure 61). This departure is most apparent following periods of severe drought and may reflect a lack of ability to recover induced by the extremely severe soil moisture conditions under which these trees are growing. It was noted that cone production was extremely rare under all of The Poplars trees while trees from the other localities were abundant cone producers. Other indications of low vigor were evident as well (Figure 63).

Regardless of the specific mechanism responsible for the poor recovery, it appears probable that the poor agreement of the Poplar trees is related to a deterioration of vigor and to a subsequent inability for a rapid recovery when more adequate precipitation does occur. This indicates that although trees growing in xeric situations are excellent indicators of past climatical trends the extremely severe sites may be undesirable when choosing samples for such work. This may be the reason that Antevs found such a lack of agreement among the samples which he obtained near Lakeview (9).

Keen has expressed his growth rates in terms of departure from the mean but the tree ring growth data from the Lost Forest, Fremont, and The Poplars can be compared although the latter are expressed in another measure. When such a comparison is made for annual fluctuations during the period which the author's study is concurrent with Keen's, excellent agreement is found with both the Fremont and the Lost Forest data (Figure 62). A general

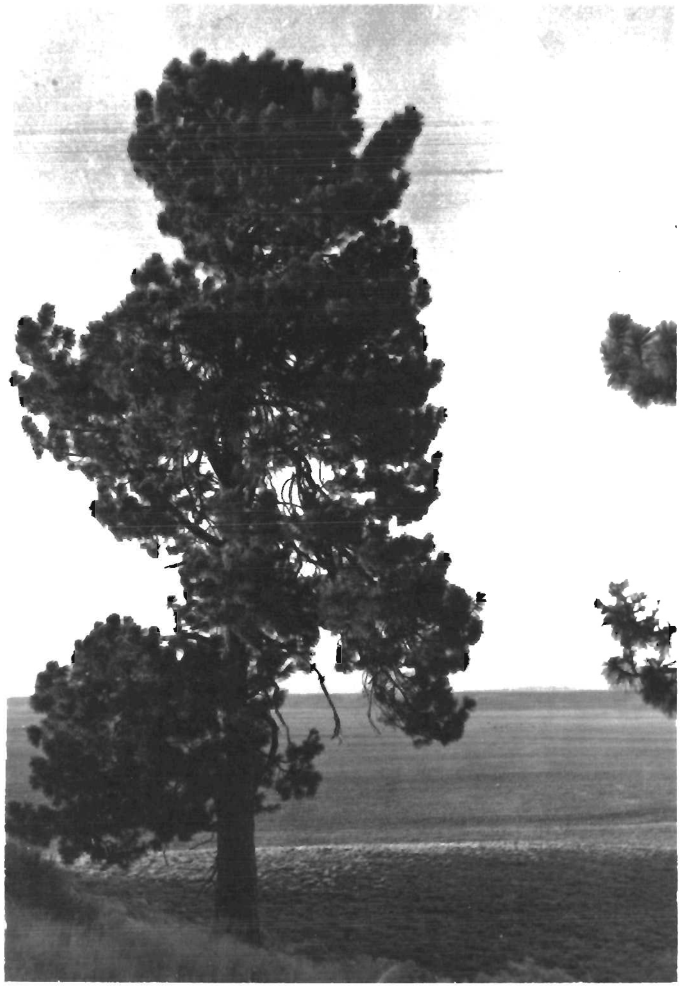
Figure 62. Comparison of Lost Forest tree growth with last 36 years of Keen's long term records.

agreement with the annual fluctuations of The Poplars is noted but the long term trends failed to coincide, probably because of the extreme severity of the growing site of the five specimens analyzed at The Poplars.

Considering the agreement among the tree ring data and agreement of the latter with recorded precipitation, lake levels and stream flow, it can be assumed that the tree ring record characterizes the changes in the climate for the Lost Forest as well as the rest of the Great Basin for the past six-hundred years. Keen states that the years 1900-1919 are normal for the period which his study covered. The period 1900-1919 also includes the period during which the United States Weather Bureau's station, Cliff was maintained. We can say, therefore, that the 9.62 inches of the mean precipitation recorded in Cliff from 1908-1916 approximates the normal for the past 600 years.

Isolated Ponderosa Pines

Twenty isolated pines were investigated. These were located from five to as much as twenty miles into the "sagebrush desert" away from the ponderosa pine forests. Most of them were not reproducing but indicate that ponderosa pines can survive for long periods of time where the climatic conditions are too severe for maintenance as a forest. Two isolated individuals are shown in Figure 63.



Lone Pines near Brothers

Lone pine near The Poplars

Figure 63. Isolated ponderosa pine trees.

Germination Characteristics of Pine Seeds

Standard Germination Test - Germination of seeds from the Lost Forest with seeds from three other sources at the normal temperature regimes used for testing ponderosa pine seeds in the Oregon State Farm Crop Seed Laboratory indicated a definite superiority in the germinative energy of the Lost Forest seeds.

At the end of the fourth day 89.4 per cent of the Lost Forest seeds had germinated. The five lots of one-hundred seeds each showed 95.0, 94.0, 88.0, 80.0 and 90.0 per cent respectively. While the next best germination occurred in the "wet Site" lot with a mean of 63.0 per cent, the other two seed lots showed 51.0 per cent and 50.2 per cent each. Germination among the individual replicates of the other sources were also very uniform. This left little doubt that the Lost Forest seeds were capable of more rapid germination at the temperatures (20° and 30°C) employed in the germinating oven.

Experimental Germination The results of an experiment designed to compare germinative energy of Lost Forest seeds with seeds from other sources under conditions more nearly approximating those found in the general area of the Lost Forest also indicated superiority of Lost Forest seeds.

Figure 64 and Table 23 show this superiority very clearly.

No unsound seeds were found consequently the percentages are based on the total number of seeds. The last entry for each treatment was the date of germination of the last seed. The untreated-seed test was terminated at twenty-eight days or seven days after the last seed had germinated. Unidentified fungus or fungi became very active after approximately twelve days in the germinator. It is probable that the lower temperatures are responsible for this. Fungi are probably responsible for some of the irregularity of the germination curves in Figure 64.

In no instance does the final germination percentage of any of the other sources exceed that of the Lost Forest, nor does the accumulated germination percentage of other sources at any point in time exceed that of the Lost Forest seeds.

Germination at 5^{o} - 15^{o}C of seeds which had been pretreated by stratification showed that the Lost Forest and the other two dry-site sources were all superior to the wet-site source in speed of germination. Where the only pretreatment applied to the seeds consisted of soaking for twenty-four hours before germination, the wet-site and the Lost Forest seeds were distinctly superior. When seeds were placed dry in a petri dish without pretreatment, the Lost Forest and one of the dry sites displayed superiority.

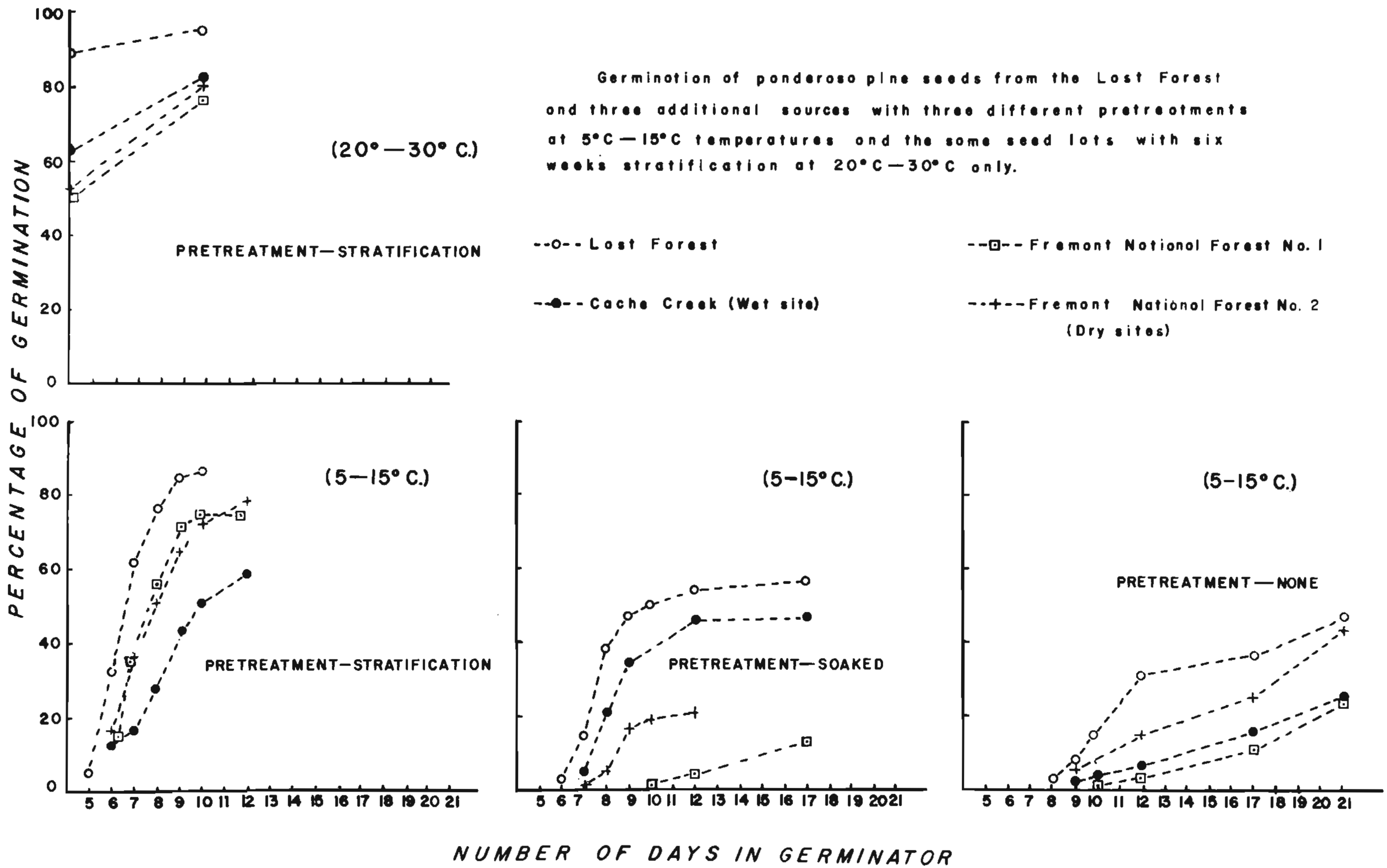


Figure 64. Germination behavior of seed lots.

Table 25

PERCENTAGE OF SEEDS GERMINATED BY DAYS IN GERMINATING OVEN

Time in oven	Lost Forest % of Total Seeds			Cache Creek % of Total Seeds			Fremont #4 % of Total Seeds			Fremont #3 % of Total Seeds		
	Strat.	Soak	Dry	Strat.	Soak	Dry	Strat.	Soak	Dry	Strat.	Soak	Dry
5	4.8											
6	33.6	3.2		12.0			17.6			15.2		
7	62.4	15.2		18.4	4.8		36.0	0.8		37.6		
8	76.8	38.4	3.2	28.8	20.8		50.4	4.8		56.0		
9	85.6	47.2	8.0	44.0	35.2	2.4	64.8	16.8	3.2	72.0		
10	86.4	50.4	15.7	50.4		4.0	72.8	19.2	10.4	73.6	1.6	1.6
12		54.4	30.4	59.2	36.0	6.4	79.2	20.8	14.4	74.4	4.0	3.2
17		56.6	36.8		36.8	16.0			24.8		12.8	11.2
21			46.4			25.6			43.2			24.0

The wet site and the remaining dry site seed lots were not significantly different from one another.

Discussion as to the significance of superior germinative ability or germinative energy can be only speculative. The results definitely indicate a physiological superiority of the seeds as expressed by germinative energy. This superiority could be due to conditions existing during the years when the seeds were collected, or it could be the result of physiological characteristics of the seeds produced by the peculiar environment of the Lost Forest. Some differences could be accounted for by difference in seed handling such as maturity when collected, but the seeds of the Lost Forest site and the "wet site" were collected by the author and treated identically from the time the cones were gathered. The only difference, other than the source, was the fact that the wet site cones were taken from squirrel caches while cones were hand picked from the Lost Forest trees. Cutting and storage of cones by squirrels could have a deleterious effect on germinative energy although Lavender and Engstrom (108) found no evidence of such effect in their work with Douglas fir seeds.

There are two broad a priori reasons why this superior germinative energy may be a selective factor. First, there is a general advantage to the individual which produces seed of superior germinative ability, and second an explanation can be given to show why superior germinative energy can be a positive survival factor under conditions existing in the Lost Forest. The explanation consists of three basic elements: (1) an adequate moisture supply existing throughout most of the year from six inches to one foot or more below the sand surface. (2) the moisture present in the upper layers of sand to which seedling roots can penetrate only during very limited periods of time. Usually this only amounts to a few days after a rain. (3) temperatures sufficiently high to provide enough heat for germination exist during the time when moisture is adequate at the most for only a few days during each year. Therefore, the ability to break dormancy and to germinate rapidly is obviously a distinct advantage since circumstances suitable for germination and survival occur but rarely.

In summary, ability of seeds to germinate quickly and thus penetrate the loose soil with the greatest possible speed gives them a definite survival advantage. Since the Lost Forest has been associated with sands for many thousands of years and since it has probably been isolated for most of its existence either by lakes or by sagebrush desert, it is quite possible that this characteristic has become fixed in the population.

Drought Resistance Study

The one-hundred and twenty Lost Forest seedlings survived a mean of 28.1 days after the soil had reached the wilting point as determined phytometrically. Seedlings from one source in the Fremont National Forest survived a mean of 29.7 days after the wilting point had been reached. One lot from a mixed Douglas fir--white fir--ponderosa pine site survived a mean of 29.3 days. The remaining site from the Fremont National Forest survived a mean of 28.8 days. The differences in survival time after the soil moisture had reached the wilting point were not statistically significant. An analysis of variance for the Lost Forest and the best Fremont site also failed to show a significant difference at the 5% confidence level.

Considerable variation in the length of survival was manifest within each pot and among the pots in which the seedlings were planted. The large variance was probably due to the failure to recognize the point at which death of the seedlings occurred as well as to individual plant variation. Although it cannot be said from the results of this experiment that the Lost Forest seedlings are either more drought resistant or less drought resistant than the other sources tested, it does give a good indication that the ability of seedlings to extract moisture from the soil at high tensions is not alone responsible for maintenance of the present stand of pines in the Lost Forest.

The following data show the mean root, the mean top-weights, and the root-top ratios for each source. The differences were not significant.

Table 26

DROUGHT STUDY, SEEDLING WEIGHTS IN GRAMS

Lost Forest		Cache Creek		Fremont #3		Fremont #4	
Root	Top	Root	Top	Root	Top	Root	Top
.198	.156	.193	.159	.208	.166	.183	.142
Ratio 1.27		1.21		1.25		1.20	

These results, when considered with the results of the seed germination experiments described on the preceding pages, point out the danger of over-simplification of genetic adaptation. This is particularly true with respect to securing seeds from a known "difficult" site and expecting them to grow in some other spot also adjudged to be "difficult." Since ponderosa pine as a species has already become adapted to xeric conditions, genetic development of a specific mechanism for drought avoidance is just as logical as genetic changes which permit internal physiological adaptation to still lower moisture conditions.

Pollen Identification

Pine as well as other pollens were found in the sediments at all intervals examined from 29.0 inches to 40.0 inches. No pollen was found in one sample collected at 40.5 inches. None were detected in the samples from 21.0 to 28.0 inches. No samples were taken from materials above 21.0 inches. This established with a reasonable certainty that ponderosa pine, chenopods, grass, sagebrush and possibly juniper were present nearby about 6,400 years ago at the time of eruption of Mt. Mazama. It is unlikely that pollen from pine as distant as those of today would provide as high a proportion of the pollen types found in the sediments, since there was nearly as many pine pollens present as all the others together. Although pines are normally over-represented in the pollen spectra it appears probable that most of these pollen were from a local source.