Enhancement of Seedling Establishment on the Klamath Tree Farm

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Final Report

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and

Oregon State University

Acknowledgment

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Enhancement of Seedling Establishment on the Klamath Tree Farm

This is the final report concerning Seedling Establishment on Klamath Tree Farm; a cooperative study between Oregon State University and the Weyerhaeuser Company (FRL Project 910-20). The project was begun by Weyerhaeuser in the spring of 1973 and became a cooperative study in October, 1974. The objectives of the study were:

1) To compare the survival and growth of lodgepole and ponderosa pine in three major vegetation zones on the Klamath Tree Farm.

2) To relate differences in survival and growth to seedling performance potential, soils, vegetation, site index and selected environmental variables.

3) To recommend a stratification system of the tree farm capable of improving reforestation success. This system will be based on the analysis outlined in 2 above such that the relative difficulty of reforestation can be included in management considerations.

For further details of the cooperative agreement see the attached copy.

The original design and subsequent cooperative agreement were based on a series of assumptions not previously recorded which will be discussed later in this report.

1) Everything possible would be done to insure maximum regeneration success. (i.e. High quality vigorous seedlings lifted in early spring would be planted on a properly prepared site as early in spring as practical.)

2) Average survival would be 50% using the above proceedure.

3) Subsequent growth would be consistent with that observed in other plantations on the tree farm. (i.e. Approximately 10 years to reach breast height.)

4) Early fertilization, the year after planting, would accelerate establishment and early growth of the seedlings.

5) Any changes in the seedling environment caused by site preparation would not substantially change the prior environment that is reflected by different vegetation types.

The remainder of this report is divided into the following sections: an Environmental Analysis, Seedling Survival Summary, Seedling Growth Summary, Plant Moisture Stress Differences, Seedling Performance Potential Summary, Discussion and Recommendations.

Environmental Analysis

Temperature

Air temperature 1 foot above the soil surface at each of the six sites was collected using a 30 day Partlow recording thermograph. A summary of the available maximum and minimum mortality temperatures for 1973, 1974 and 1975 is presented in Figure 1. The six sites were ranked using the maximum temperatures in June (mid-growing season) for the years 1973, 1974 and 1975. Although site differences are not great, a ranking from warmest to coolest based on the month of June when growth is probably most active follows:

1) Pokegma (POK)* (Warmest)
2) Porter Butte (PB)*
3) Camp 4 (C-4)*
4) Mitchell (MIT)*
5) Yamsay Snowbrush (YS)*
6) Yamsay Bitterbrush (YB)* (Coolest)

Soil temperature data for the 8" depth support a conclusion that Westside sites are approximately 10° F warmer and have a longer growing season

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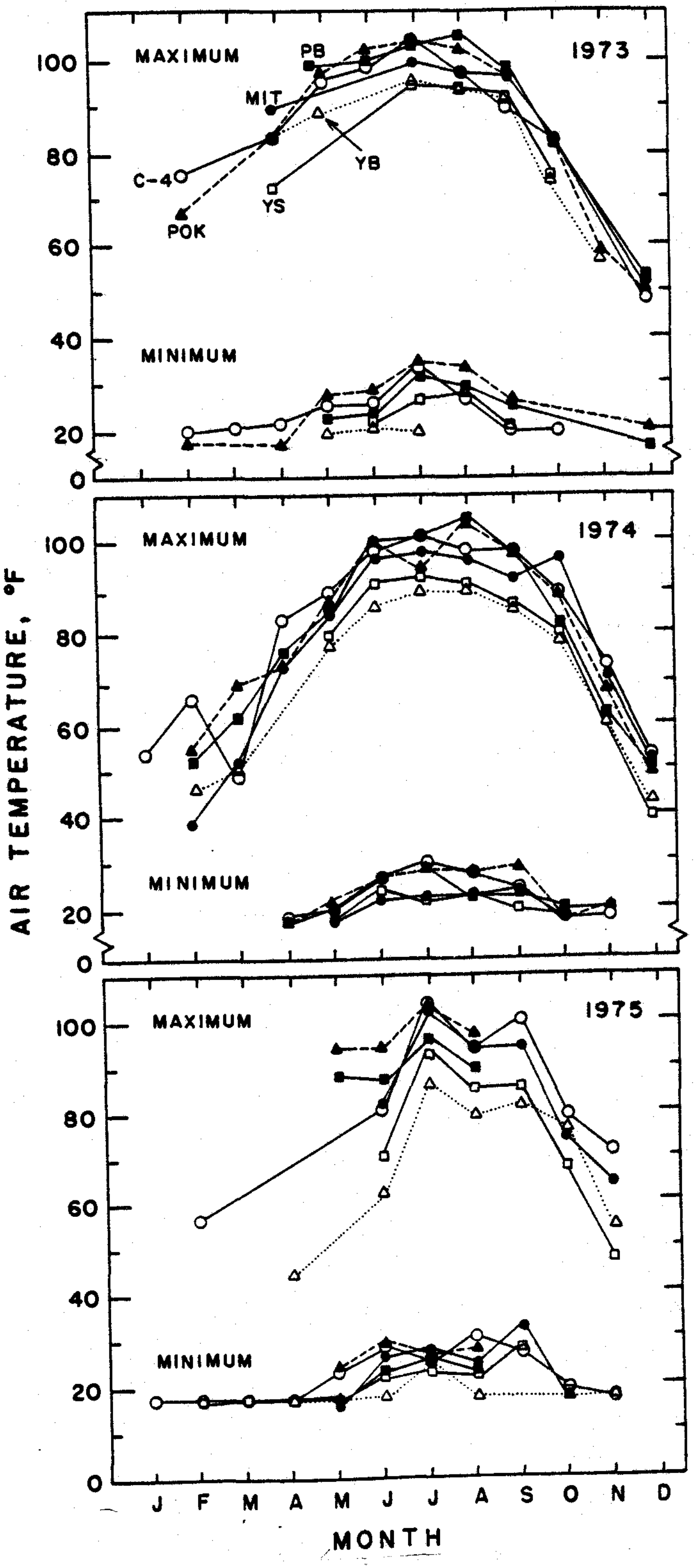
*These abbreviations will be used throughout this report to designate the six experimental sites.

Figure 1. A summary of monthly maximum and minimum air temperatures at 12 inches above the soil surface for 1973, 1974 and 1975.



(Figure 2). Frosts on all sites during the growing season are common. With the exception of Pokegma and Camp 4 in 1973 and Mitchell in September 1975 and sites had at least one frost in every month. Yamsay Bitterbrush is the coolest site with minimum temperatures of 25° F or lower in every month for all three years. Year-to-year differences between sites based on maximum and minimum temperatures are relatively small. Frequency and severity of frost are the two most significant indicators of site temperature differences (Table 1) and must be taken into account when planning any new plantations. There was insufficient soil temperature data for any meaningful comparisons.

Precipitation and Soil Moisture

Precipitation at each of the six locations was collected and recorded during 1973, 1974 and 1975. A summary of monthly precipitation is presented in Figure 3. The typical pattern is complete recharge of the soil profile during the period between December and April followed by a drought during the May to November growing season period. Seedlings must sustain themselves during this drought from either water stored in the soil or scattered precipitation from occasional erratic isolated storms which occur during the period. This stored water combined with any inputs during the growing season (Figure 4) make up the supply that the vegetation and seedlings have to draw on. The only soil moisture data available is for the surface six inches. The moisture in this level does not directly influence seedling performance. One important estimate of the moisture supply is to calculate the water capacity of the surface two feet (Table 2). Some integrated moisture supply measurement such as plant moisture stress (PMS) is more important in evaluating impact on seedling. Seedling PMS will be discussed later in this report.

Figure 2. Soil temperatures at 6" below the surface for the six experimental locations.

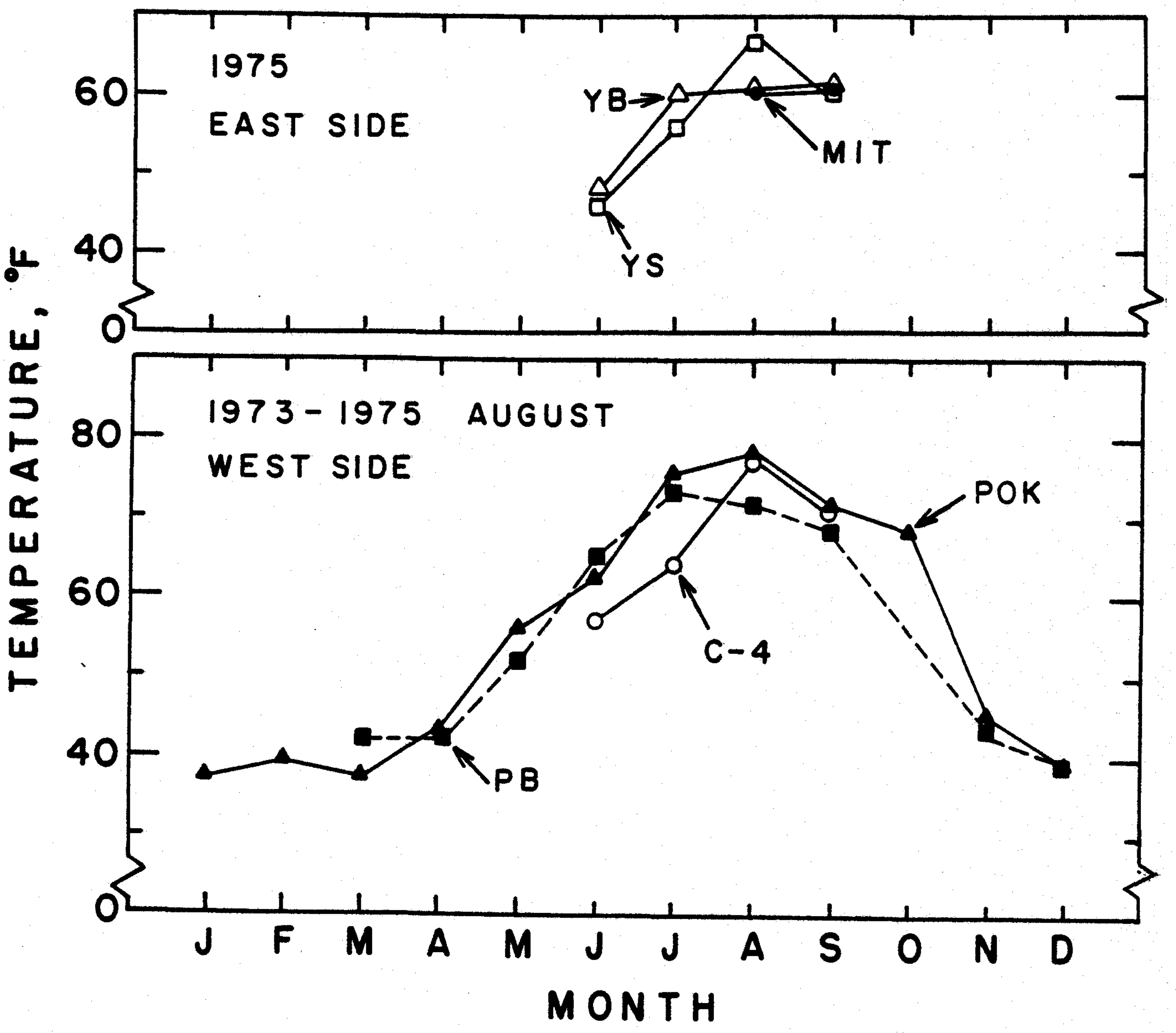


Table 1. Percent of night-time temperatures below 32° F for six sites during 1973-1975.

LOCATION	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Year, 1973							
Camp 4	67 (10)[1]	19	6	0	0	-	58 (16)
Pokegama	69 (31)	26	3	0	3	3	-
Porter Butte	-	39 (3)	13	0	0	17	-
Mitchell	65 (26)	-	30 (10)	10	12	20 (3)	90 (42)
Y-Snowbrush	-	-	-	10	21 (3)	28 (10)	75 (43)
Y-Bitterbrush	83 (59)	45 (26)	-	29 (3)	61 (23)	62 (24)	84 (61)
Year, 1974							
Pokegama	73 (23)	45 (10)	10	3	6	10	-
Porter Butte	73 (37)	53 (29)	10	3	26 (3)	35 (6)	-
Year, 1975							
Camp 4	-	-	45	10	16	7	45 (23)
Pokegama	25	3	5	3	-	-	-
Porter Butte	54 (13)	50 (3)	4	31 (4)	-	-	-
Mitchell	-	-	42	6	13	0	58 (16)
Y-Snowbrush	-	-	82 (27)	10 (3)	16 (10)	23	81 (29)
Y-Bitterbrush	-	-	95 (76)	39 (10)	87 (45)	100 (77)	94 (84)

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[1] Number in parenthesis is % of nights below 25° F.

Figure 3. Recorded monthly precipitation at four of the experimental sites and the Klamath Falls airport which is shown for comparison purposes.

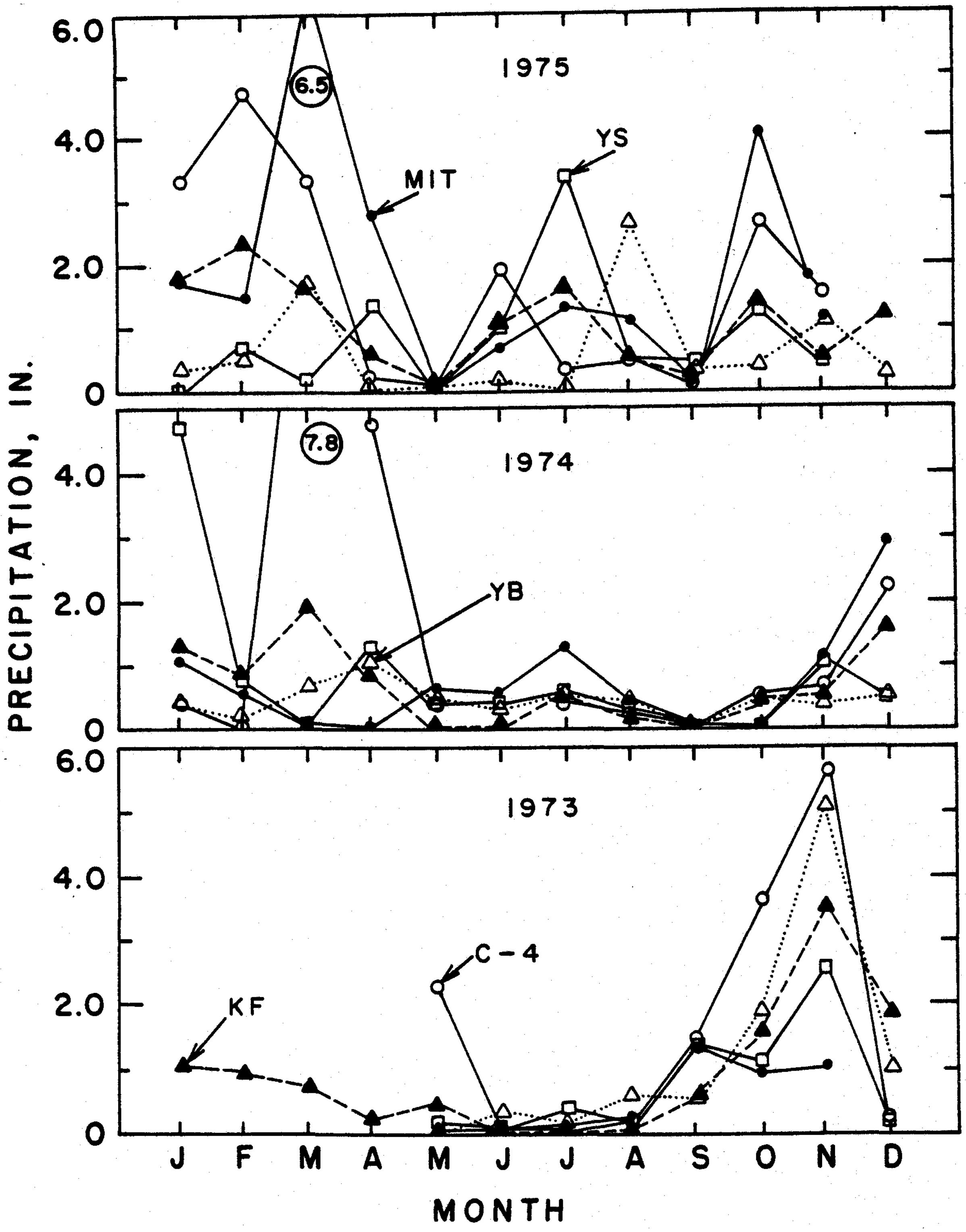

Figure 4. Precipitation falling during the growing season for four sites.

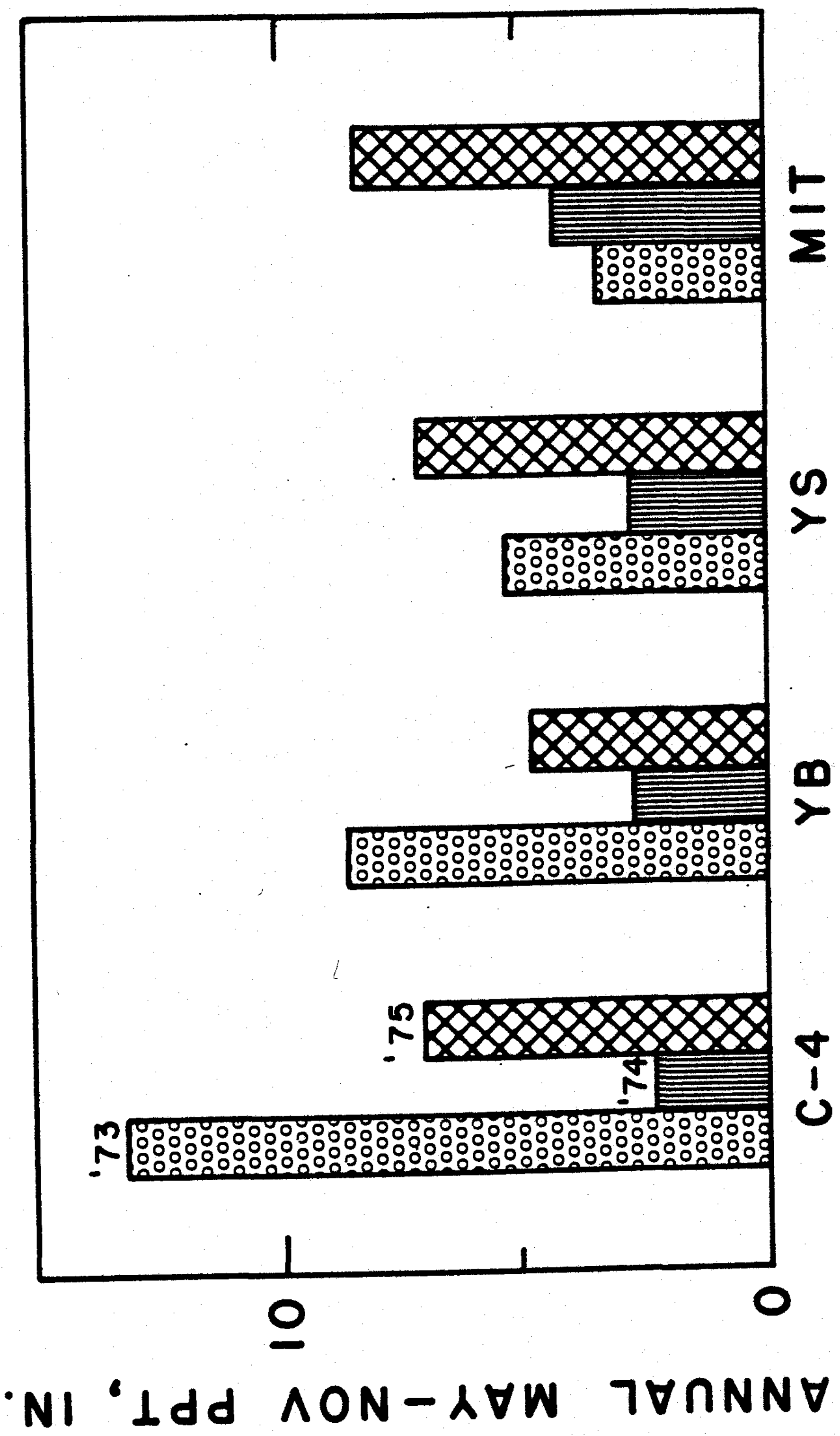

Table 2. Estimated Available Water in First 24" of Soil at Six Locations in Inches.

Location	Inches of Water At Field Capacity	Inches of Water At Wilting Point	Inches of Water Available for Plants*
Camp 4	7.28	3.68	3.60
Pokegama	7.28	3.68	3.60
Porter Butte	8.40	4.52	3.88
Mitchell	6.38	4.10	2.28
Y-Bitterbrush	4.35	2.19	2.17
Y-Snowbrush	5.12	2.68	2.44

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*(a) Estimate assumes 0% rock content in top 24" soil profile.

(b) Estimated using Buckman & Bradly, 1960, The Nature & Properties of Soils, p. 176.

(c) Soil textures were obtained from soil survey plot cards.

Vegetation

The two most important factors affecting establishment of ponderosa pine and lodgepole seedlings on the Klamath Tree Farm are temperature and moisture. Vegetation through its water use has more impact on the water balance of the seedling than perhaps any other factor during the early establishment period. The site preparation carried out on all sites was excellent in that it provided complete vegetation control at the time of planting. During the two years after planting a gradual reinvasion took place on all plots. This invasion is recorded in Figure 5 for the ponderosa pine and lodgepole areas. These figures show the fastest reinvasion on Mitchell and Porter Butte sites. The predominant vegetation of the reinvasion was sedge, grass, on the eastern plots in contrast to the western plots where reinvading vegetation was composed primarily of forbs and shrubs. Herbicide control of this vegetation will be necessary in order to maintain the favorable moisture regime which the seedlings have experienced up until now.

Seedling Survival Summary

The survival of ponderosa and lodgepole pine through the fall of 1975 is shown in Figure 6. These graphs are for the control plots. There was very little difference between fertilized and control with the exception of Porter Butte fertilized lodgepole pine which was apparently located on a slightly different site. This conclusion is based on both the vegetation and seedling response for that plot. Initial survival at the end of the first growing season ranged from a high of 97% to a low of 74%. The majority of the mortality took place during the first growing season with the exception of lodgepole pine on the Porter Butte site where losses continued from 81% down to 60% by the fall of 1975. Note that survival even under the poorest situation was substantially above the 50% level estimated when the study plan was

Figure 5. Changes in vegetative cover during 1974 and 1975 for all experimental sites.

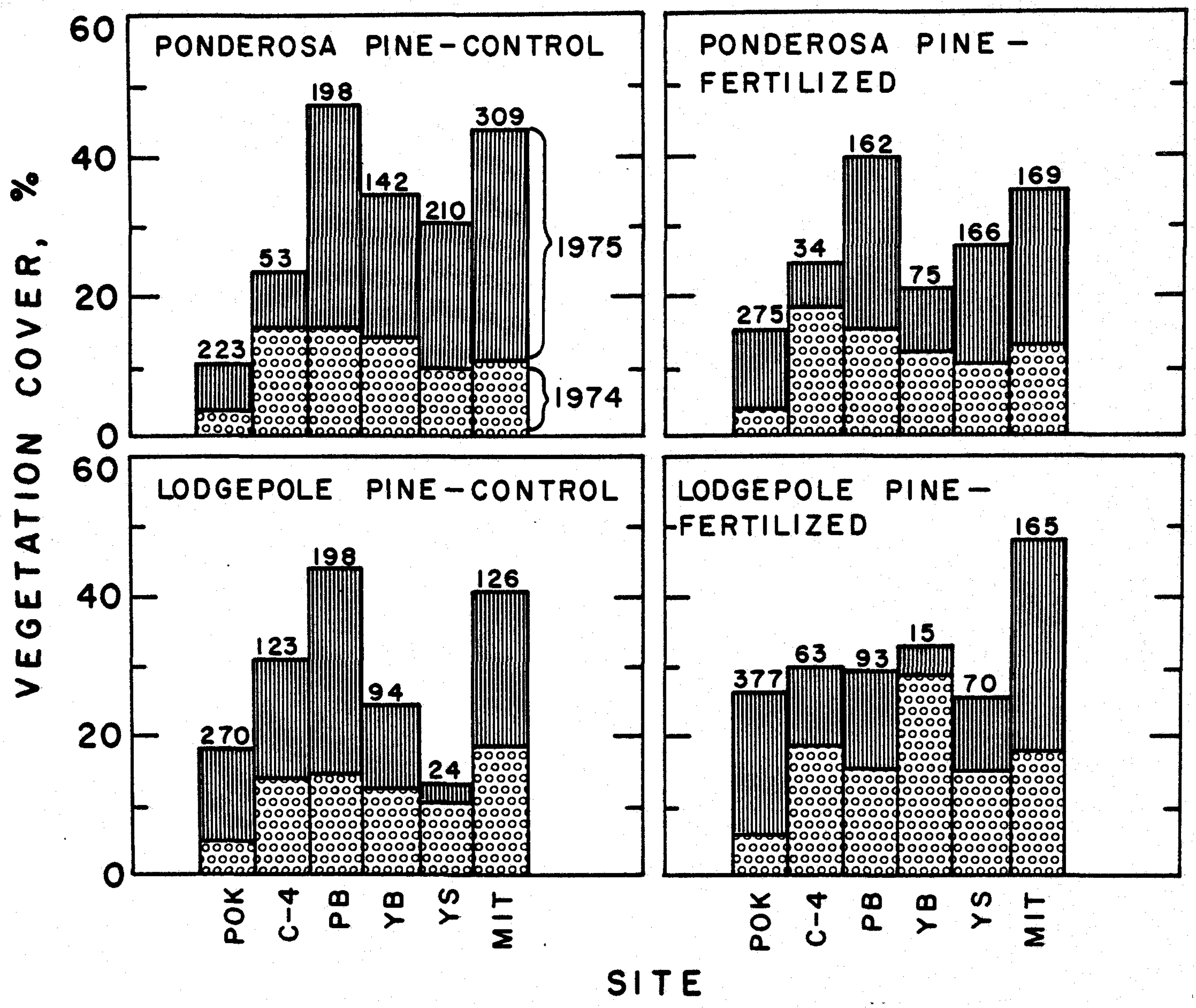
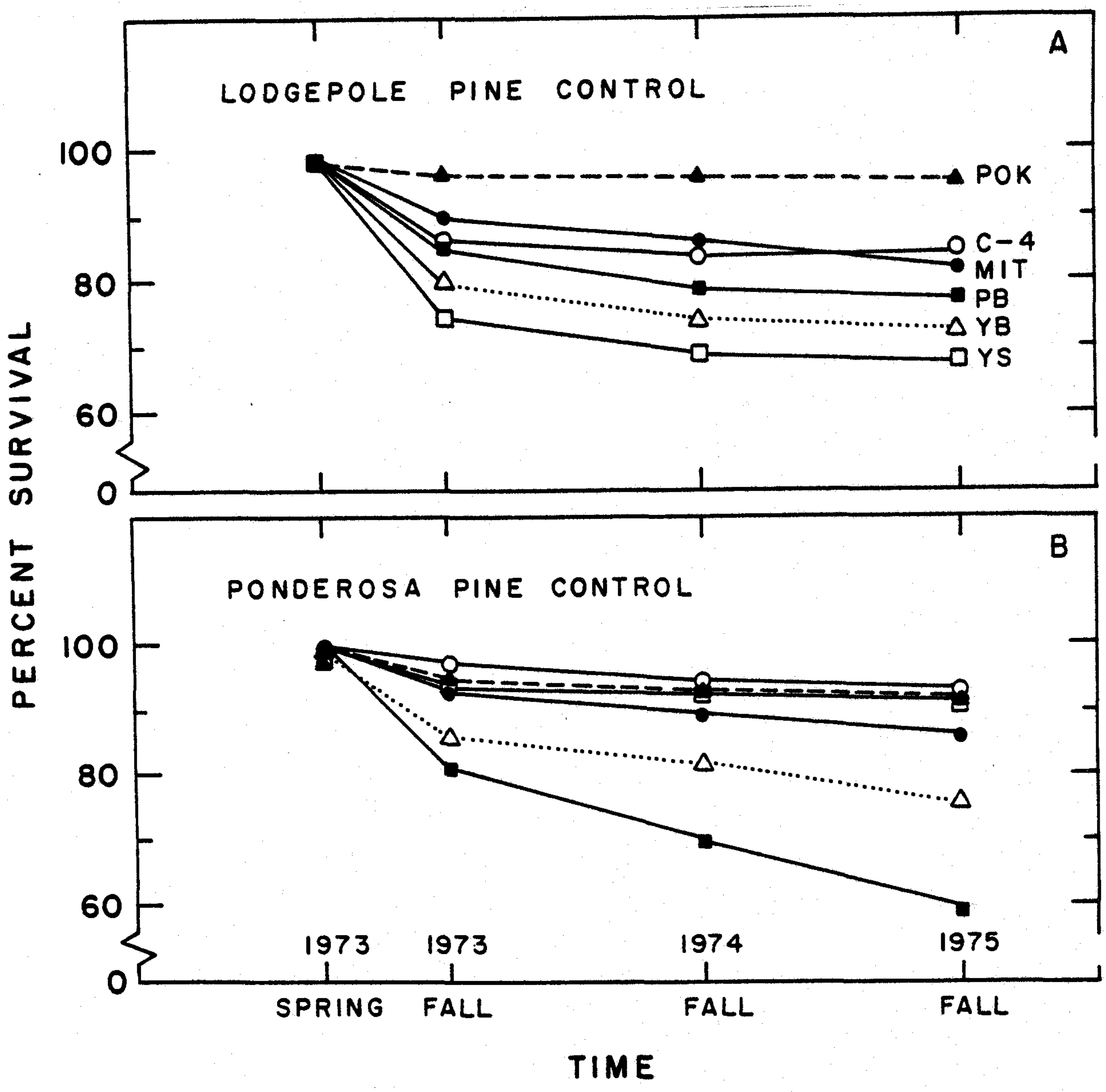


Figure 6. Survival of lodgepole and ponderosa pine control plots. Fertilized plots showed similar trends.



written. Based on the data collected there is no significant difference between lodgepole and ponderosa pine survival.

Seedling Growth Summary

In this study two different measures of growth were used to characterize the initial seedling performance, average height growth and shoot dry weight changes. A summary of the height growth is presented in Figure 7. Note the difference in height growth on two contrasting sites (C-4 and YS). At Camp 4 there is probably no significant difference between the treatments with the possible exception of the fertilized ponderosa pine showing a slower growth rate at the end of Fall, 1975. On the Yamsey Snowbrush site, in contrast, the treatments and species interaction are such that unfertilized lodgepole pine and fertilized ponderosa pine made significantly higher growth than fertilized ponderosa pine and unfertilized lodgepole showing a species fertilizer interaction for that location. The year-by-year height increment of the two species with the fertilizer and control plots averaged together are shown in Figure 8. These data show the improved juvenile height growth of lodgepole pine compared to ponderosa pine with a particular advantage on the Mitchell site and Yamsey Snowbrush sites. They also show a tapering off of height growth at Camp 4 and a decline in height increment at Porter Butte. Both of these probably caused by competing vegetation reducing the moisture supply available to the seedlings.

Figure 9 shows an analysis of shoot dry weight after the first growing season for three different planting years. The planting stock size increases between 1973 and 1976 show up rather dramatically here. Also note that the dry weight increments for larger seedlings are substantially greater than for smaller sized seedlings. The increases in biomass of the seedling during the

Figure 7. Average height growth for three of the six experimental plots.

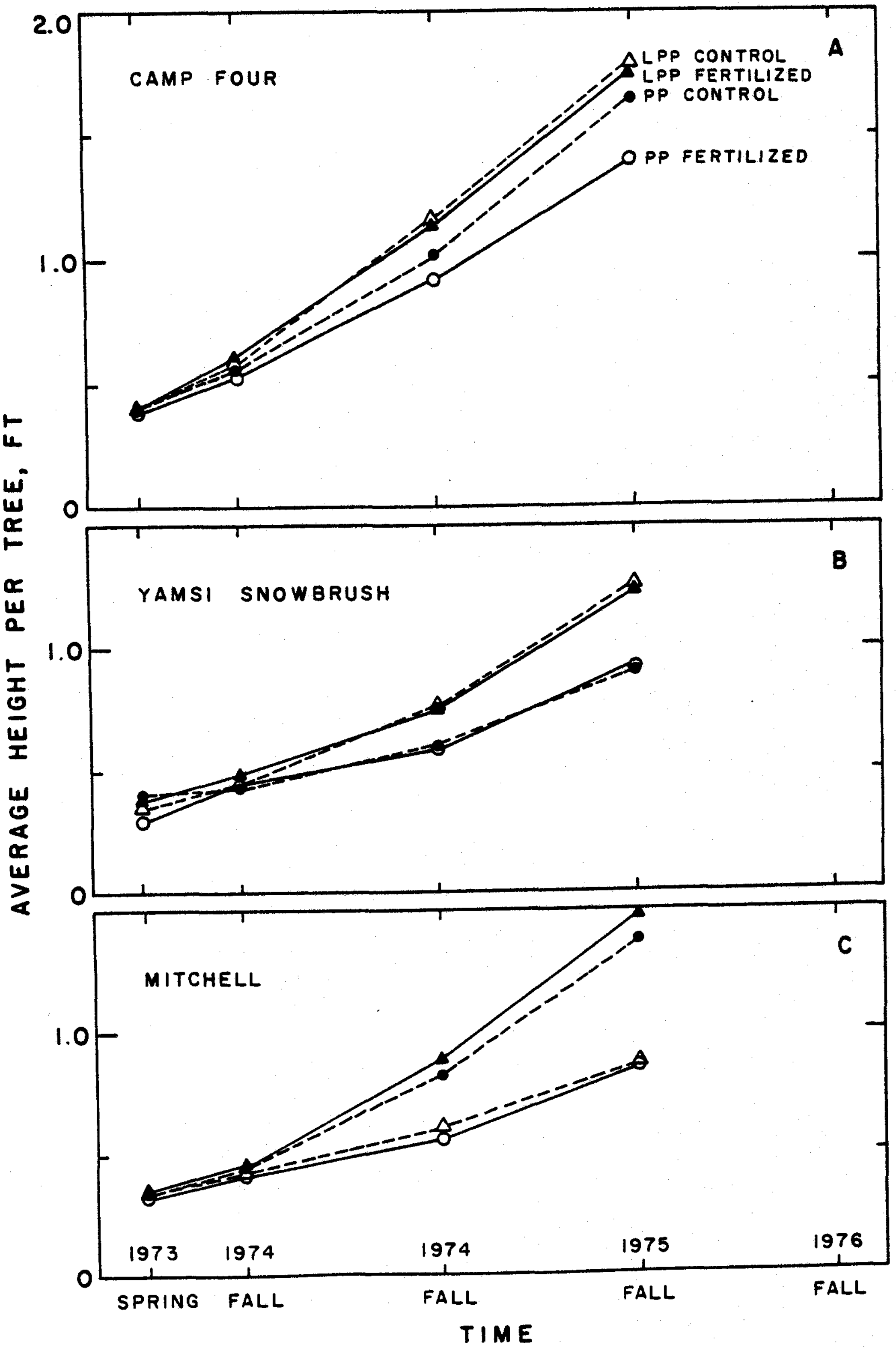


Figure 8. Average height increment of lodgepole and ponderosa pine for each site. Fertilized and control plots have been averaged together.

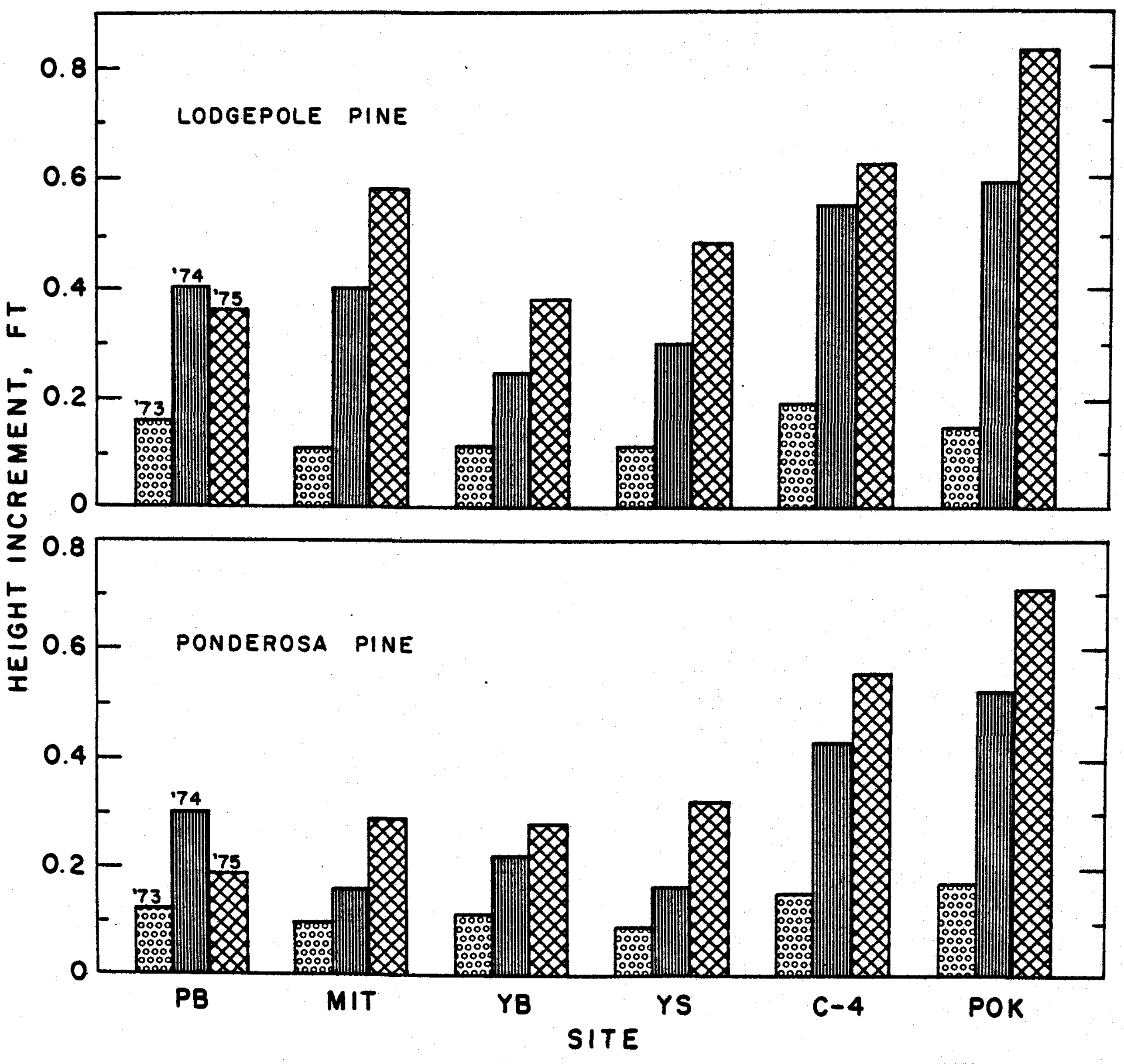
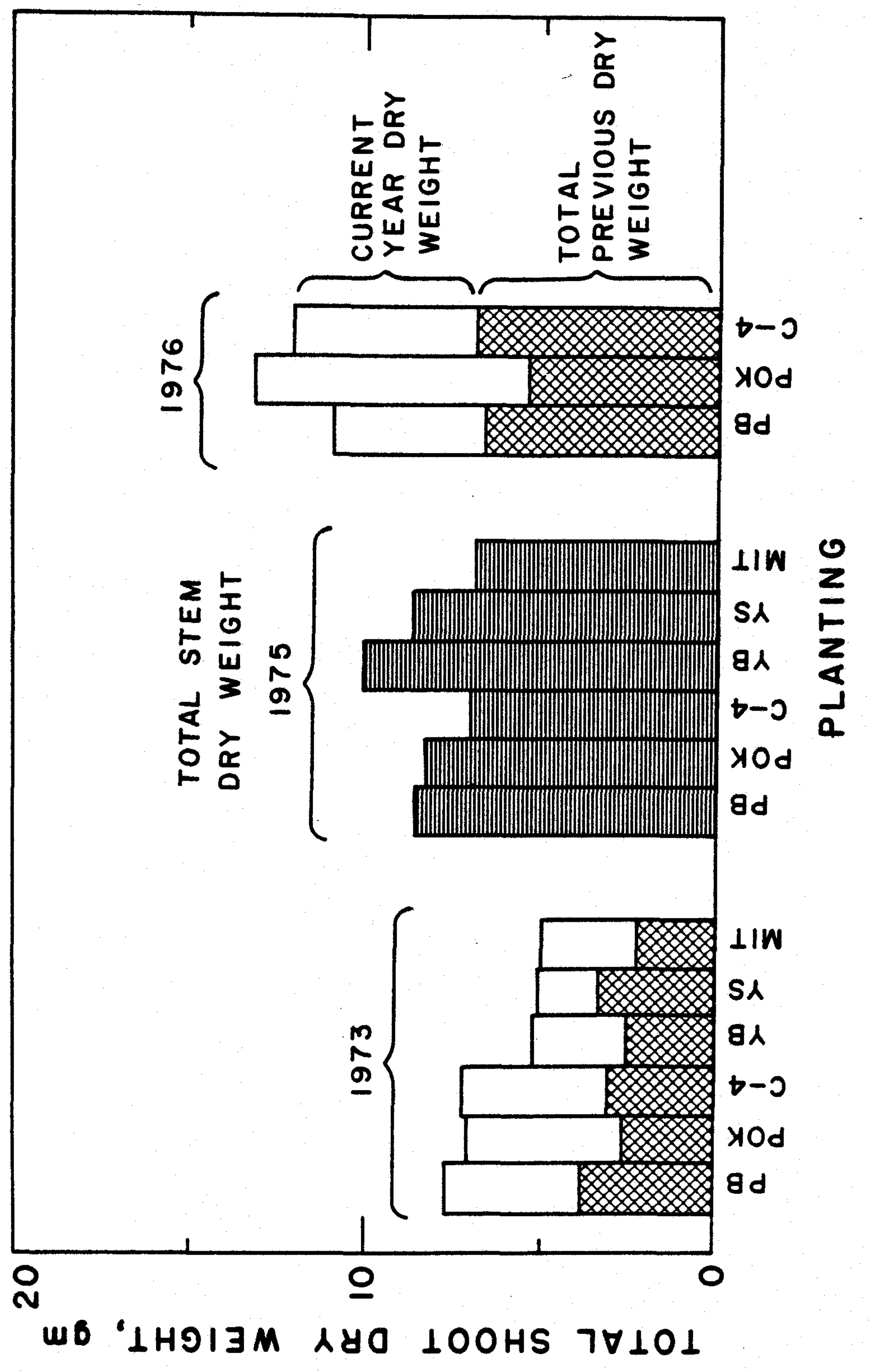


Figure 9. Dry weight of seedlings after the first growing season for seedlings planted in 1973, 1975, and 1976. Shoot growth for 1973 and 1975 is shown.



year immediately after planting is probably the best measure of seedling vigor and an estimate of subsequent plantation performance. Because a seedling which grows rapidly during the first year is off to a vigorous start which should carry it for several years into the new rotation in contrast to one which has suffered a transplant shock and may require many years to recover, if recovery is at all possible.

Plant Moisture Stress Differences

The moisture relationships during the year of establishment are one of the important factors which limit seedling survival and growth. PMS data in sufficient detail to describe site differences with the seedling response to site difference are difficult to collect, however. A summary of available data are presented in Table 3a and 3b. In the current study the data which was collected showed no significant drought occurred on any of the sites during the establishment period. Moisture stress levels during the 1973 and 1974 planting seasons did not exceed 10 atmospheres on any site and the 1975 summer was characterized by below normal temperatures and above average precipitation. Again PMS levels did not reach a critical level on any of the sites. Consequently, it must be concluded that a combination of weather and excellent site preparation prevented seedlings from encountering significant moisture stress during the establishment period. The remaining difference in seedling response on the sites is probably caused by differences in the temperature regime at each site. Particularly the frequency of low temperatures and frosts.

Table 3a. Summary of plant moisture stress by site for 1973, 1975, and 1976.

LOCATION	SEEDLING TYPE	1973 (MID AUG.) MAX	1973 (MID AUG.) MIN	JUNE 10 MAX	1975 (MID SEPT.) MIN	1976 (1st WEEK AUG.) MIN
CAMP 4	PLUGS	14.8	4.9	12.0		
	BARE ROOT	15.4	5.2	13.8	7.0	8.0
POKEGMA	BARE ROOT				6.5	6.0
PORTER BUTTE	BARE ROOT				8.0	7.0
MITCHELL	PLUGS	15.8	4.6	12.5		
	BARE ROOT	15.2	5.1	14.2	8.0	
YAMSAY SNOWBRUSH	PLUGS	14.4	4.4	13.2		
	BARE ROOT	14.6	5.4	17.4	9.0	
YAMSAY BITTERBRUSH	PLUGS	15.0	4.2	13.0		
	BARE ROOT	15.0	5.5	15.6	9.5	

Table 3b. Seasonal changes in early morning PMS at each site during the 1975 growing season.

	JUNE	JULY	AUGUST	SEPTEMBER
POKEGMA	4.5	5.0	7.5	6.5
CAMP 4	4.0	4.5	5.5	7.0
PORTER BUTTE	4.5	-	5.5	8.0
MITCHELL	7.5	4.0	4.5	8.0
YAMSAY BITTERBRUSH	5.0	5.0	5.5	9.5
YAMSAY SNOWBRUSH	6.0	6.5	9.0	9.0

Seedling Performance Potential Summary

1975/76 Laboratory and Field Results

Two previous summaries concerning this set of experiments were reported in February 1975 and January 1976. The purpose of these laboratory tests was to examine the possibility of using speed of bud burst and root growth capacity as an indicator of seedling field performance potential. Correlations with actual field performance are reported here based on data collected from the 1975/76 planting season.

The experimental design for the 1975/76 studies is outlined in Table 4. The laboratory experimental design was changed to include an acclimation period for the fall lifted stock. Two watering treatments were used, a non-stressed treatment where seedlings were watered to field capacity weekly, and a stress treatment where seedlings were watered to field capacity at the beginning of the growth chamber test and not watered thereafter. The late spring and early spring lifted treatments were also reversed in order of planting and testing in the growth chamber in an attempt to make the experimental conditions similar to those encountered in the field. Thus, the late spring lifted stock had a shorter cold storage period and early spring lifted stock a longer cold storage treatment.

The laboratory speed of bud burst is given in Table 5. Note that the significant increase in time to bud burst occurred in the fall lifted and stressed treatments both in terms of the number of days to bud burst and the total number of seedlings to break bud at the end of the seventh week. In addition early spring lifted and stressed treatment had a significantly reduced number of trees that break bud. This is probably associated with the abnormally long 94 day cold storage treatment for stock lifted early in the spring.

Table 4. Experimental treatments for the 1975/76 laboratory and Klamath Falls field studies. Laboratory Study.

TREATMENT[1]	LIFTING DATE	COLD STORAGE (DAYS)	PLANTING DATE	ACCLIMATION PERIOD (DAYS)	STARTING DATE
FALL LIFTED	12 NOV	14	26 NOV	56	21 JAN
A. OVERWINTER STORAGE	12 NOV	132	23 MAR	7	30 MAR
B. EARLY SPRING LIFTED	30 MAR	94	2 JUL	7	9 JUL
C. LATE SPRING LIFTED	20 APR	22	12 MAY	7	19 MAY

Klamath Falls Field Study

TREATMENT	LIFTING DATE	COLD STORAGE (DAYS)	PLANTING DATE	LOCATION
A. OVERWINTER STORAGE	10 NOV	150	8 APR	Camp 4, Pokegma Porter Butte
EARLY SPRING LIFT EARLY PLANT	2 APR	6	8 APR	All Sites
B. EARLY SPRING LIFT LATE PLANT	30 MAR	63	1 JUN	Camp 4, Pokegma
C. LATE SPRING LIFT NO STORAGE	20 APR	3	23 APR	All Sites
LATE SPRING LIFT LATE PLANT	20 APR	42	1 JUN	All Sites

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[1] Additional Treatment - 1/2 seedlings were stressed to simulate field conditions.
Stressed--watered to field capacity at day 1 only.
Nonstressed--watered to field capacity at 1 week intervals.

Table 5. Laboratory determination of the speed of bud burst by treatment for the 1975/76 lifting season.

TREATMENT	DAYS TO BUD BURST[1]	TOTAL BUD BURST AT DAY 42 %
FALL LIFTED		
STRESSED	35	55
NONSTRESSED	27	98
OVERWINTER STORAGE		
STRESSED	26	80
NONSTRESSED	21	100
LATE-SPRING LIFTED		
STRESSED	19	90
NONSTRESSED	19	85
EARLY-SPRING LIFTED		
STRESSED	21	68
NONSTRESSED	19	78

[1] 50% OF SEEDLING POPULATION IN BUD CLASS 4.

The root growth capacity by treatment is listed in Table 6. These data show that root growth capacity within each treatment was highly variable and that early spring lifted seedlings had poor performance along with the stressed seedlings of both late spring lifting and overwintered storage. Note that even the seedlings with the poorest root growth compare favorably with those reported by Stone et al. and Jenkinson for ponderosa pine seedlings in California. The performance of the seedlings in terms of survival, height growth, and average dry weight increase during the experiment are given in Table 7. Notice that based on these data the overwinter storage treatment had the best overall performance. Also, there was a significantly high mortality in the early spring lifted and stored treatment. The rate of height growth shows that the fall lifted stock performs more slowly under stressed conditions than under non-stressed conditions (Figure 1a). In terms of height growth overwinter storage was best for both stressed and non-stressed treatments.

Table 8 shows the effect of an acclimation period on fall lifted stock. The 1974 fall lifting had a very short period of acclimation probably not sufficient to fulfill the seedlings chilling requirements. Consequently, in 1975, fall lifted seedlings were subjected to two months of an eight hour photoperiod and a constant 40° F to fulfill the chilling requirement. Note that there is a decrease in the number of days to bud burst, average height growth increased, and root growth capacity increased when the stock was acclimated for 60 days. The increased average root growth capacity is probably not significant due to the highly variable root growth of 2-0 ponderosa pine seedlings.

Table 6. Root growth capacity of seedlings lifted during the 1975/76 lifting season (10 seedlings for each treatment were measured).

	AVERAGE NUMBER OF NEW ROOTS BY SIZE CLASS				AVG. LENGTH OF NEW ROOTS (CM)
TREATMENT	5-40 MM	41-80 MM	81+ MM	TOTAL	
FALL					
STRESSED	130 ± 51*	20 ± 12	8 ± 5	158	416 ± 225
NONSTRESSED	126 ± 46	27 ± 11	12 ± 7	165	497 ± 180
OVERWINTER					
STRESSED	92 ± 40	12 ± 8	5 ± 3	109	275 ± 131
NONSTRESSED	157 ± 48	26 ± 14	9 ± 5	192	507 ± 199
LATE-SPRING					
STRESSED	115 ± 44	12 ± 5	5 ± 4	132	301 ± 125
NONSTRESSED	154 ± 90	19 ± 14	7 ± 6	180	442 ± 286
EARLY-SPRING					
STRESSED	85 ± 64	9 ± 8	4 ± 4	98	220 ± 189
NONSTRESSED	155 ± 146	10 ± 17	3 ± 5	168	278 ± 354

*ONE STANDARD DEVIATION FROM MEAN.

Table 7. Laboratory determination of survival, height growth and increase in dry weight for seedlings lifted during the 1975/76 season.

TREATMENT	SICK OR DEAD SEEDLINGS (%)	AVERAGE HEIGHT GROWTH[1] (mm)	AVERAGE WEIGHT OF NEW SHOOT GROWTH[2] AFTER: 30 DAYS (gm)	42 DAYS (gm)
FALL LIFTED				
STRESSED	2.5	13.3	0.35	0.38
NONSTRESSED	2.5	36.6	0.43	1.06
OVERWINTER STORAGE				
STRESSED	2.5	17.9	0.36	0.48
NONSTRESSED	0	37.6	0.92	1.50
LATE-SPRING LIFTED				
STRESSED	7.5	14.5	0.42	0.45
NONSTRESSED	15.0	19.0	0.71	1.11
EARLY-SPRING LIFTED				
STRESSED	30.0	11.1	0.41	0.45
NONSTRESSED	22.5	16.6	0.57	1.04

[1] Average of live seedlings only.

[2] Oven-dry weight.

Table 8. Acclimation period and its affect on speed of bud burst, height growth and root growth.

STOCK PERFORMANCE	DAYS OF ACCLIMATION[1] 14[2]	 56[3]
DAYS TO BUD BURST	42	35
AVG HT GROWTH AT 42 DAYS (mm)	22.0	36.6
AVG LENGTH NEW ROOT GROWTH AT 30 DAYS (cm)	426 ± 169	497 ± 180

[1] 8 hour photoperiod; constant 40° F
[2] Stock lifted 25 Nov 74; 7 days cold storage
[3] Stock lifted 12 Nov 75; 14 days cold storage

Table 9 shows the 1975 bud development for seedlings planted on the Klamath Tree Farm. The interval between 25% and 75% of the seedlings reaching stage 4 bud class was used to depict the impact that different lifting and storage treatments had on the seedlings. This time interval will allow the relative speed of bud burst to be estimated irrespective of the date of planting. The time interval between 25% and 75% of the seedlings reaching stage 4 is a measure of the rate at which seedlings are breaking bud rather than the time to bud break and is a more meaningful measurement particularly in field studies where comparisons between sites and planting date are made. Speed of bud burst data for the 1976 field planted seedlings is shown in Table 10.

Discussion

Both temperature and moisture conditions on the six sites studied vary considerably from year to year. The most important growth limiting factor when competing vegetation is controlled is the cold temperatures found on the east side sites compared to the west side sites. Figure 2 shows that soil temperatures on the 3 east side sites are substantially colder than the west side sites. It is obvious from examining Figure 4 that the May to November precipitation is erratic from one year to the next. It is also important to remember when examining precipitation in this period that a substantial amount of precipitation collected during this period comes in very small increments and adds little or no moisture to the rooting portion of the soil profile. Table 2 also emphasized that there are substantial differences in the amount of water held by soil at each site. These estimates, of course, do not reflect rock contents which are variable from one site to another, but due serve to demonstrate the importance of estimating water availability for a given site. Probably the most significant environmental factor which affects newly planted

Table 9. Number of Days Required for 25%, 50%, and 75% of Trees To Reach Bud Class 4 at Seven Locations For Seedlings Planted in 1975.

Location	Treatment	DOP	# Days 25%	50%	75%	Interval From 25% - 75%
Pokegama	Spring lift	5-6	34	41	44	10
Y-Snowbrush	Spring lift	6-2	35	41	45	10
Y-Bitterbrush	Spring lift	5-9	41	45	48	7
Porter Butte	Spring lift	5-8	41	46	54	13
Porter Butte	Fall lift	5-8	48	60	86	38
Camp 4	Spring lift	5-7	42	50	61	19
Camp 4	Fall lift	5-7	46	55	67	21
Mitchell	Spring lift	5-19	45	54	58	13
Bear Butte	Spring lift	5-14	48	55	60	12

Table 10. Number of Days Required for 25%, 50%, and 75% of Trees to Reach Bud Class 4 by Treatment and Location For Seedlings Planted in 1976.

Treatment	DOP	# Days 25%	50%	75%	Interval From 25% - 75%
<u>Pokegama</u>					
O. Winter	4-6	80	83	87	7
Early lift + early plant.	4-6	73	77	87	14
Late lift + mo storage	4-23	60	63	69	9
Early lift, late plant.	6-1	39	42	45	6
Late lift, late plant.	6-1	36	45	86	50
<u>Camp 4</u>					
O. Winter	4-6	84	86	92	8
Early lift	4-6	84	87	97	13
Late lift + mo storage	4-23	68	70	74	6
Early lift, late plant.	6-1	40	43	47	7
Late lift, late plant.	6-1	44	47	84	40
<u>Porter Butte</u>					
O. Winter	4-8	84	89	98	14
Early lift	4-8	84	89	98	14
Late lift	4-23	68	72	78	10
Late life, late plant.	6-1	42	55	86	44

seedlings is summarized in Table 1 where the night temperatures below 32° F for the six sites are analyzed for the years 1973, 1974 and 1975. This table shows that a very high percentage of the nights received frost during the active growing season. For example in June 1975, 76% of the nights were below 25° F. This is sufficient cold to drastically limit growth during the normal growing season. Each time a seedling is frozen below 32° it's growth is temporarily restricted the following day. With consecutive nights of frost there may be several days before the seedling will again be able to continue photosynthesizing and making active growth. Thus probably one of the more significant limitations for growth during the growing season is the number of frosts and nights of even colder, below 25° F weather. On these sites we should consider providing shelter for that seedling to minimize the impact of night radiation frosts that occur during the growing season. The leaving of a dead brush canopy for example would probably increase night temperature substantially.

Seedling Survival and Growth

Both ponderosa pine and lodgepole pine had acceptable levels of survival at the end of three growing seasons, survival ranging from a low of 60% to 98% for the control plots. With the exception of the Porter Butte ponderosa pine control plot, all seedlings had above 75%. These studies show that given; 1) adequate site preparation to control competing vegetation, 2) high quality seedlings, and 3) a quality planting job, survival will be acceptable on sites that occur on the Klamath Tree Farm. This is in contrast to some of the earlier plantation studies which were conducted where a combination of poor site preparation, lower quality seedlings and variable planting quality caused numerous instances of low survival rates.

Survival is, however, not an end in itself. Seedlings must make continued rapid growth if they are to occupy and control the site within a reasonably short period of time. Figures 7 and 8 demonstrate that there is a wide variation in the amount of growth taking place on the plantations tested. It shows that lodgepole pine has a substantial advantage in terms of juvenile growth particularly on east side sites. Also demonstrated in these figures is a species fertilizer interaction which can occur. Based on the results of this study, the fertilizer can be either beneficial or detrimental when applied after one growing season depending upon the interaction of the site conditions and the fertilizer application. Consequently it would appear that an expanded fertilizer trial will be required to allow its use consistently on an operational basis.

Field Survival Potential

As a result of the laboratory and field experiments concerning field survival potential, one can conclude that the speed of bud burst is probably a good indicator of seedling vigor. Additionally, some measure of the root growth capacity is beneficial to get a balanced picture of seedling performance. Based on the results of the field studies, either over-winter storage or early spring lifting and early planting are best for good seedling performance. Late lifting and late planting is definitely detrimental to seedling establishment.

Relationship of Growth and Survival to the Environment

Any attempt to relate survival and growth to environmental measurements collected in this study, or to the vegetation stratification which was used initially must be related to temperature differences of the sites. The original hypothesis was that moisture and temperature combined would be the cause for differences in survival and growth on the sites examined. Improvement in the combination of factors mentioned earlier, site preparation, seedling quality, and planting quality, however, removed most of the differences which might be present on the sites. The removal of all competing vegetation, essentially left the sites in a non-watered stressed condition. Consequently the temperature regime of these sites was probably the most important difference in terms of seedling growth. Survival differences between sites were minimal. The most pronounced temperature differences on these sites, is tabulated in Table 1. Night frosts during the growing season had considerable impact on seedling growth. The use of a stratification system based on vegetation, as originally postulated in this study, for predicting and solving reforestation problems is consequently minimal.

Recommendations

1. Any attempt to predict field survival potential of seedlings should include some measure of both shoot growth (i.e. speed of bud burst) and root growth capacity for those seedlings.

2. Over-winter storage of seedlings appears to be feasible without significant losses in terms of either survival or growth. Freezing storage, although not considered in this study would appear to have promise in light of the operational difficulties in storing stock at above freezing temperatures. During 4 years of research studies on over-winter storage, there has never been a significant loss in seedling performance caused by long term storage. This is in contrast to the erratic results obtained in the operational over-winter storage of seedlings. Care of the seedlings during the storage period in terms of both temperature and moisture relationships must be included to eliminate any loss in seedling performance potential.

3. This study and past studies regarding seedling performance have shown the importance of care of the seedling during the entire process between lifting and out-planting in the field. Consequently it is necessary to monitor and maintain seedling quality while seedlings are out of the ground.

4. Further study of the cold temperature problem on the Tree Farm (i.e. frosts during the growing season) should be conducted. Additionally possible methods to ameliorate these conditions should be examined. Where conditions are extreme, protection of seedlings during the first several years after planting with either dead material on the site or possibly some other protective device should be examined.

5. Further study of fertilization after the first growing season should be undertaken to better understand the site/fertilization interactions.