SURVIVAL IN FOREST PLANTATIONS IN THE NORTHERN ROCKY MOUNTAIN REGION[1]

By C. S. SCHOPMEYER

Northern Rocky Mountain Forest and Range Experiment Station

Although forest planting has been carried on for more than a quarter of a century in the Northern Rocky Mountain Region, the ultimate in planting practice has not yet been attained. Information on several phases of planting work has been obtained by studying all available plantation records. Results of the study are presented together with a brief description of the planting practice used in the region and a discussion of factors affecting mortality with reference to methods of increasing survival.

TREES have been planted every year since 1910 in the national forests of Region One of the U. S. Forest Service which includes Montana, northern Idaho, and northeastern Washington. Although the fundamentals of planting practice in this region have been worked out, a few points have not yet been definitely settled. Is spring or fall the better season for planting? Is any particular age class of stock[2] superior to others for planting? In general, what percentage of the planted trees have survived? Plantation survival records kept by the Section of Planting provide a source of abundant data out of which information on these questions may be obtained. At the end of the 1937 season 1,150 plantations had been established on an aggregate area of 93,878 acres, of which 49 percent were planted with ponderosa pine (*Pinus ponderosa*), 27 percent with western white pine (*P. monticola*), 4 percent with Engelmann spruce (*Picea engelmanni*), and 20 percent with other conifers and mixtures of two or more species. A statistical study was made of the survival records on these plantations to obtain information on the previously mentioned questions. The results of the study are presented in this paper.

Nursery and Planting Practice

Before proceeding to an appraisal of the plantation survival records, a brief consideration of nursery and field planting practice followed in the region may be helpful. A detailed description of nursery practices in this region was given by Olson (*6*).

All planting stock of native species is grown at the Savenac Nursery, Haugan, Mont. Only economically important species ecologically adaptable to nursery and field planting conditions are propagated. In the nursery, seedlings are watered regularly throughout the summer and are drought-hardened in the fall by gradually decreasing the frequency of watering. At the time of transplanting, roots of seedlings are usually pruned to a length of about 5 inches to induce the development of a short, bushy root system. When stock is lifted for shipment, it is pruned to a length of 8 inches. The absence of a long taproot enables a planter to set the root system in the ground without doubling it up. The short bushy root system makes the seedling better adapted for the absorption of the limited amount of available moisture in the surface layers of the soil, and thus compensates, to some extent, for the absence of a long taproot.

Planting technique and spacing have been subjects of much discussion in recent years. At present seedlings are planted using the method described by Wahlenberg (*7*). Seedlings are placed in holes, about 8 inches deep and 2 inches square, made with a short-handled mattock. Prior to 1935 seedlings were spaced 8 feet by 8 feet giving a stocking of 680 seedlings per acre. Because of the heavy mortality of seedlings after planting, spacing was changed in 1935 to 7 feet by 7 feet or 890 trees per acre to increase stocking on the planted areas.[3] The shade afforded by stumps and logs on the ground was recognized as a definite aid to survival of seedlings early in the history of planting. In practice, crews are instructed to place seedlings

[1]Prepared with the cooperation of the Division of Timber Management, Section of Planting, Region One, U. S. Forest Service.

[2]Age class of planting stock is customarily designated by two figures, e.g., 2-1, of which the first indicates the number of years in a seedbed and the second the numbers of years in a transplant bed. The nurseryman designates stock which has not been in transplant beds as *seedlings* to distinguish them from *transplants.* In this paper the term *seedling* is used in the broad sense and includes *transplants.*

[3]In 1938, a stocking of 890 trees per acre on the poorer sites and 800 trees per acre on the better sites was started.

on the north sides of stumps and logs, where possible, to take advantage of this protection.

Prior to about 1933 planting was done by local residents and transient laborers many of whom were hired year after year. With this type of labor many well-trained planters were developed. The facility of these planters, however, was more apparent in speed rather than perfection in the planting of individual seedlings. Since the advent of the New Deal agencies in 1933, practically all planting has been done with C. C. C. and E. R. A. labor.

Description and Appraisal of Survival Data

Since planting at present is confined principally to the portion of the region lying west of the Continental Divide, it is desirable to limit the study to plantations within this area. Approximately 3 percent of the total planted area is in the portion of Montana which lies east of the divide. Since most of the plantations there were failures, planting was discontinued in 1918 and the Boulder Nursery on the Helena National Forest, in which planting stock for this area was grown, was abandoned. These eastern Montana plantations are not included in this study.

Survival in field plantations is based on staked row counts. The standard procedure of the Section of Planting is to stake a row of seedlings extending through each plantation in a manner intended to include all site conditions within the plantation and a sample of the work of each member of the planting crew. Stakes are set immediately after the planting operation. The number of seedlings in a staked row is determined by the size of the plantation. For plantations of less than 300 acres the size of the sample is shown in Table 1.

For plantations larger than 300 acres, 100 trees are added for each additional 100 acres, or fraction thereof.

Considering the wide variations in soils and topography that often exist, especially within the larger plantations, these staked row samples are probably too small to be truly representative of all site conditions on their respective plantations. Neither do the samples represent any site condition in particular except by accident. This characteristic of the staked row sampling procedure greatly limits the value of the data therefrom for scientific analysis.

An examination of the staked row on each plantation should be made at the end of the first, third, and tenth growing season after planting according to the existing schedule. In practice, however, this schedule has not always been carried out.[4] Approximately three-fourths of the plantations over 10 years old have been examined three times, but on many of these the three examinations were not made according to the proposed schedule. Many plantations which were examined the first year were not examined the third year, and vice versa. Some plantations were examined after the third year but not after the tenth year.

Table 1.—Size of Staked Row Samples for the Determination of Plantation Survival

Area of plantation	Size of sample: Number of trees	Size of sample: Percentage of total number of planted trees (based on 680 trees per acre)
(Acres)		
1-25	200	2.4
25-50	300	1.2
50-100	400	0.8
100-200	500	0.5
200-300	600	0.4

An even more serious complication is that tenth-year survival has seldom been based on the original staked row sample. The stakes usually disintegrate or are covered up before 10 years have elapsed. Tenth-year examinations have been mainly an ocular estimate of the number of planted trees per acre present at the time of the examination.[5] At this stage, however, it is sometimes difficult to distinguish between planted trees and natural reproduction when both are of the same species. Hence, the results of tenth-year examinations probably do not accurately represent survival of the planted seedlings on a considerable number of plantations.

The plantation survival data are presented for two purposes. The first is to get a general measure of the efficiency of the planting program as a whole; that is, the percentage of the total number of planted seedlings which have survived. The second purpose is to determine, for each species, the effect of season of planting and age class of stock on survival. To accomplish the first purpose, the survival percentage of each plantation is weighted by its area in acres. For the second purpose the survival percentage of each plantation is given unit weight regardless of

[4]Since 1936, practically all plantations have been examined according to the schedule.

[5]Starting in 1939, all tenth-year examinations will be made by means of the quadrat method of sampling.

area. Weighting by acres is not a satisfactory means of bringing out the effect of season of planting and age class of stock on survival because, with such weighting, survival is unduly influenced by size of plantations. Large plantations are not necessarily more representative of particular conditions than small plantations. Hence, a weighted survival percentage gives undue emphasis to localities where much planting has been done.

To make use of all available data, survival percentages for each class of stock of each species and the two seasons of planting have been grouped according to the number of years after planting. The first examination includes first-year survival. The second examination includes survival percentages determined between the second and the sixth years, inclusive, but mostly in the third year. The third examination includes any survival percentages determined after the sixth year, but mostly in the tenth year. When the third examination showed a higher percentage than the second examination it was assumed to be the same as the second examination.

Analysis of Data

A summary of all available plantation survival percentages for the area included in this study is given in Table 2. This table shows the mean survival percentages of spring- and fall-planted stock of all species, together with average deviations of individual plantations from these means.

A general measure of the efficiency of planting in this region is the mean of all tenth-year survival percentages. As shown in Table 2, this mean, weighted by the acreage of each plantation, is only 42 percent. To determine the influence of season of planting and age class of stock on this low survival figure, analyses were made on the data summarized in Table 2.

The mean survival percentages by plantations for western white pine and ponderosa pine in Table 2 are presented graphically in Figure 1. These two species were selected because they are the only ones for which sufficient data are available to make reasonably valid comparisons. Although the accuracy of the curves in Figure 1 beyond the third year is not great because of the previously mentioned limitations in the data, the curves do show general trends. They indicate that spring-planted stock has a higher survival percentage than fall-planted stock except in the case of ponderosa pine after the seventh year. This exception may be accounted for in the inaccuracy of the tenth-year survival counts. The same inaccuracy may account for the continued downward trend of survival in the spring-planted stock of ponderosa pine while the other curves tend to level off after the fifth year. The most striking point brought out by these curves is that approximately 45 percent of the planted seedlings die during the first year and that mortality is in most cases negligible after the fifth year.

The greater part of the mortality in plantations of western white pine and ponderosa pine occurs during the first year; accordingly, more detailed analyses of the differences in survival between spring- and fall-planted stock are limited to first-year survival data. Table 3 shows that the mean first-year survival percentages of all spring-planted plantations of western white pine and ponderosa pine are 7 and 10 percent higher, respectively, than those of all fall-planted plantations. The results of a t test[6] of individual plantation differences show, in Table 3, that these differences are statistically significant. With the exception of western red cedar, which has not been planted in the spring season, the mean first-year survival percentages of spring- and fall-planted stock of all native species are presented graphically in Figure 2 using data from Table 2. In this figure the superiority of spring planting is shown in the case of each species. These comparisons, together with the statistical tests on the means of all plantations of the two major species, western white pine and ponderosa pine, show that in general spring planting has resulted in higher first-year survival than fall planting among the native species of this region.

The data on which Table 2 is based were analyzed to determine the effect on survival of age class of planting stock. In Figure 3 the mean first-year survival percentages of all classes of spring- and fall-planted stock of western white pine and ponderosa pine are presented. The average deviations of these means were found to be quite large indicating considerable variation in survival of individual plantations planted with the same age class of stock.

Considering these wide variations within age classes of stock the question arises: Are survival differences between age classes of stock significant? To answer this question an analysis of variance was made on both first- and third-year data for western white pine and ponderosa pine,

[6]A statistical device for determining significance. For explanation consult any general textbook on statistics.

TABLE 2.—SURVIVAL IN FOREST PLANTATIONS IN THE NORTHERN ROCKY MOUNTAIN REGION

Species	Season of planting	Time of examination (number of years after planting)																	
		1						2-6; mostly 3						7 or more; mostly 10					
		Plantations examined	Mean survival by plantations	Average deviation from mean	Total area of plantations examined	Mean survival (weighted by acres)	Average deviation from mean (weighted by acres)	Plantations examined	Mean survival by plantations	Average deviation from mean	Total area of plantations examined	Mean survival (weighted by acres)	Average deviation from mean (weighted by acres)	Plantations examined	Mean survival by plantations	Average deviation from mean	Total area of plantations examined	Mean survival (weighted by acres)	Average deviation from mean (weighted by acres)
		Number	Percent	Percent	Acres	Percent	Percent	Number	Percent	Percent	Acres	Percent	Percent	Number	Percent	Percent	Acres	Percent	Percent
Native Species																			
Larix occidentalis (western larch)	Spring	2	47	42	117	6	2	1	35	--	2	35	--	--	--	--	--	--	--
	Fall	2	28	0	104	28	0	3	39	11	63	27	7	1	16	--	52	16	--
Picea engelmannii (Engelmann spruce)	Spring	18	65	22	654	64	22	15	55	19	534	53	21	7	40	21	295	28	13
	Fall	26	54	21	1,595	53	17	25	41	16	1,641	41	12	10	38	14	687	44	11
Pinus monticola (western white pine)	Spring	73	64	15	6,350	59	14	53	52	14	3,834	49	14	27	50	18	2,278	46	15
	Fall	73	57	19	12,020	59	18	79	49	16	13,767	52	14	45	46	15	8,591	50	13
Pinus ponderosa (ponderosa pine)	Spring	186	58	18	20,124	58	17	118	47	18	12,437	49	17	53	36	15	8,559	34	13
	Fall	64	48	21	7,659	51	18	62	41	16	7,724	40	13	20	39	20	2,080	34	18
Pseudotsuga taxifolia (Douglas fir)	Spring	5	65	16	341	68	9	5	38	18	341	44	14	3	51	11	309	51	6
	Fall	7	58	26	179	57	25	9	44	19	178	45	18	4	36	9	87	54	2
Thuja plicata (western red cedar)	Fall	2	47	19	16	52	18	1	31	--	10	31	--	1	20	--	10	20	--
Mixed species	Spring	47	64	16	6,488	70	14	44	55	16	5,837	60	23	10	47	12	2,099	56	9
	Fall	37	46	13	6,669	46	14	39	38	11	6,456	38	11	11	35	14	2,597	38	11
All native species	Spring	331	61		34,074	61		236	50		22,985	52		100	42		13,540	40	
	Fall	211	52		28,242	53		218	43		29,839	45		92	41		14,104	46	
Non-Native Species																			
Larix leptolepsis (Japanese larch)	Spring	1	96	--	10	96	--	1	73	--	10	73	--	1	60	--	10	60	--
Picea excelsa (Norway spruce)	Spring	2	81	15	22	81	15	1	43	--	11	43	--	1	53	--	11	53	--
	Fall	1	13	--	26	13	--	1	3	--	26	3	--	--	--	--	--	--	--
Picea glauca (white spruce)	Spring	1	69	--	45	69	--	1	51	--	45	51	--	--	—	--	--	--	--
Pinus jeffreyi (Jeffrey pine	Spring	1	46	--	2	46	--	1	46	--	2	46	--	1	46	--	2	46	--
Pinus resinosa (Norway pine)	Spring	1	41	--	10	41	--	1	22	--	10	22	--	--	--	--	--	--	--
	Fall	1	52	--	24	52	--	2	37	15	30	46	10	1	30	--	24	30	--
Pinus strobus (northern white pine)	Spring	9	50	26	1,379	47	10	10	44	25	1,498	43	14	5	39	3	1,238	39	3
	Fall	6	30	16	508	29	13	8	18	8	784	19	7	6	16	6	629	14	8
Pinus sylvestris (Scotch pine)	Spring	1	6	--	2	6	--	--	--	—	--	--	--	1	1	--	2	1	--
Sequoia washingtoniana (big tree)	Spring	1	55	--	13	55	--	1	43	--	13	43	--	2	34	4	29	35	4
All non-native species	Spring	17	54		1,483	48		16	45		1,589	43		11	38		1,292	39	
	Fall	8	31		558	29		11	80		840	19		7	18		653	15	
All species, native and non-native	Spring and Fall	567	58		64,357	57		481	46		55,253	47		210	40		29,589	42	

the only species for which sufficient data were available to obtain a fairly reliable estimate of error. Only plantations having both first- and third-year data were used in these analyses. The results of the analyses on first-year data are presented in Table 4. In all cases the calculated *F* values, which are a measure of significance, fall below the 5 percent level of significance (approximately 2 standard deviations). The analyses of third-year survival data gave similar results. These tests show that differences in survival between age classes of stock are not significant. Hence, if any one age class survives better than the others, it cannot be determined from the available data.

Spring and fall survival percentages of western white pine and ponderosa pine by calendar years for the period from 1911 to 1936 show considerable variation in survival from year to year in both species. A careful attempt was made to correlate these varying percentages with climatic factors but no significant results were obtained. Reasons for the lack of correlation are, first, the small amount of data for any given year, and, second, local variations in climatic factors over the region together with the fact that weather stations are not near enough to the plantations to give sufficiently localized data.

Discussion of Results

There are controllable factors which, qualitatively at least, are known to have or are strongly suspected of having effects on survival. Some of these factors act universally; others pertain only to this region. In either event they probably do not act singly to cause mortality, but as interactions of all possible combinations of factors. Quantitative data on the effects of these factors are very meager. Hence, any attempt to explain the generally low survival on plantations can be little more than an enumeration of these factors. Such an enumeration, however, may have value as a basis for further research.

There is considerable evidence, some of which is reviewed by Baldwin and Shirley (*1, 2*) to show that adaptation of a parent tree to its particular site may be passed on to the seed. In this mountainous region, with its great variety of site conditions, such adaptations should be considered when making shipments of planting stock from the nursery. At present shipments of planting stock are consigned, if possible, to the forest in which the seed used to produce the planting stock was collected. It is believed, however, that a much better adaptation of planting stock to site could be obtained by planting the stock at the same altitude and on the same exposure as that from which the seed was obtained. Without such a procedure, lack of adaptation to site may occur, with a resultant contribution to the mortality of planted trees. Considerable study must

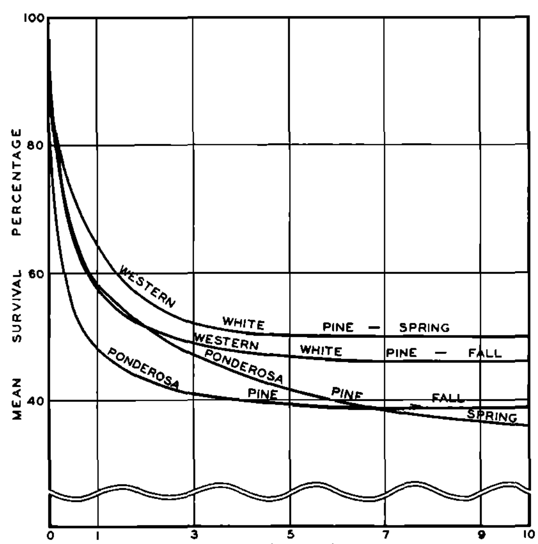

Fig. 1.—Survival trends of spring- and fall-planted stock of western white pine and ponderosa pine.

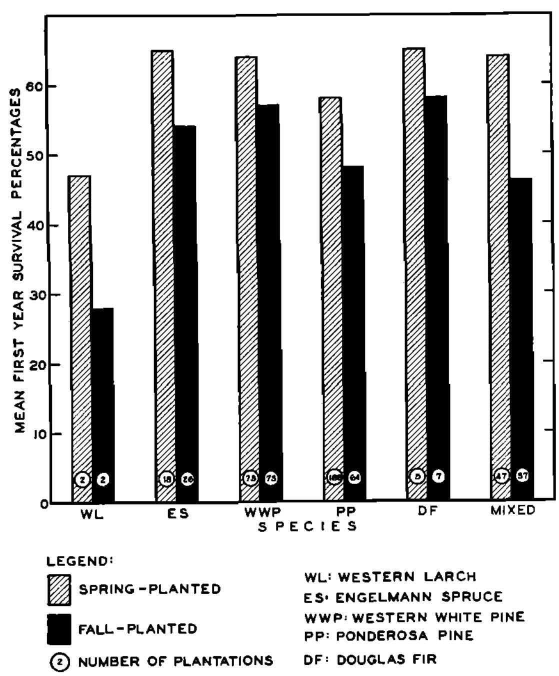

Fig. 2.—Mean first-year survival percentages of spring- and fall-planted stock by species.

TABLE 3.—SIGNIFICANCE OF DIFFERENCES IN FIRST-YEAR SURVIVAL BETWEEN SPRING- AND FALL-PLANTED STOCK OF WESTERN WHITE PINE AND PONDEROSA PINE

Item	Western white pine Spring	Western white pine Fall	Ponderosa pine Spring	Ponderosa pine Fall
Number of plantations	73	73	186	64
Mean survival (percent)	64	57	58	48
Standard error of mean (percent)	1.7	2.6	1.6	3.1
Difference between means (percent)	7		10	
Standard error of difference (percent)	3.1		3.4	
$t = \frac{\text{Difference between means}}{\text{Standard error of difference}}$ [1]	2.2		2.9	

[1]Values of t greater than 2.0 are considered significant.

TABLE 4.—ANALYSIS OF VARIANCE OF CLASS OF STOCK IN SPRING- AND FALL-PLANTED WESTERN WHITE PINE AND PONDEROSA PINE BASED ON FIRST-YEAR SURVIVAL PERCENTAGES

Species	Season of planting	Source of variation	Degrees of freedom	Sum of squares	Mean square	F (calculated)	F (5 percent point)
Western white pine	Spring	Class of stock	5	236	47	0.15	4.46
		Remainder	41	13,109	320		
		Total	46	13,345			
	Fall	Class of stock	4	905	226	0.72	3.70
		Remainder	48	15,075	314		
		Total	52	15,980			
Ponderosa pine	Spring	Class of stock	5	2,430	486	0.86	2.33
		Remainder	76	42,890	564		
		Total	81	45,320			
	Fall	Class of stock	4	2,409	602	1.35	2.85
		Remainder	44	19,647	447		
		Total	48	22,056			

be made, however, to determine the economic and practical limitations of obtaining an increase in survival by better adaptation of seedlings to site.

One of the major causes of mortality among planted seedlings is the summer drought which occurs rather consistently during July and August each year in this region. In addition to these summer droughts, the occurrence of dry periods immediately after planting are not uncommon. Such droughts, occurring before the roots of newly planted trees recover their normal absorbing capacity frequently cause considerable loss. Although drought itself cannot be controlled, mortality caused by drought can be controlled to some extent by increasing the drought resistance of planting stock. A considerable reduction in drought mortality might be attained by improving the drought hardening procedure used at present in the nursery.

Carefulness in planting is known to be a factor affecting survival. In any recently planted area there may be found among the dead trees some with roots doubled up, others with part of the stem placed below the level of the soil surface, and still others in unpacked soil. Often, good planting spots in the shade of logs or stumps are not used. Results of a study on carefulness of planting by Cushman and Weidman (*3*) show that poor planting accounted for about 11 percent of plantation losses during the season of 1936.

From the time stock is lifted from the nursery beds until it is planted, it must be handled carefully to enable it to survive after planting. Sufficient care has not always been used in handling stock during this interval. Roots have been dried out or broken when stock was lifted from the nursery beds. Delays during transit have resulted in the drying or molding of roots. Dormancy of stock has been broken before it has been planted. Such occurrences are not conducive to good survival. On an experimental scale, extra care in handling stock, involving the use of refrigeration during storage and shipment, combined with careful planting has resulted in 20 percent greater survival than that obtained by the usual routine methods.

It is generally believed that vigorous, healthy-looking seedlings have a better chance of surviving after being planted in the field than less vigorous seedlings. General vigor is a rather arbitrary criterion of good planting stock but it may be determined on the basis of such factors as total size, root-top ratio, form of roots and crown, stem thickness, and color of foliage. The inclusion of seedlings of low vigor among those planted probably accounts for some of the mortality.

Although the results of this study show that spring is the better season for planting, conclusive data are not yet available showing the time within the spring season best suited for planting. If planting is done too late in the spring, root development may not keep up with the decreasing level of available soil moisture as the summer drought progresses. Preliminary observations indicate that survival of stock planted during the first two weeks of the six-week spring planting season is decidedly better than that planted during the last four weeks. It follows that some of the mortality may be attributed to late spring planting.

Studies on mycorrhizae indicate that seedlings of some species of pines may not survive on infertile sites without mycorrhizal roots to aid in the absorption of mineral nutrients and water. Hatch (*5*) has found that when abundant soil moisture and mineral nutrients are available, mycorrhizal roots do not generally develop. At the Savenac Nursery development of mycorrhizal roots is sometimes observed on seedlings. However, such development is somewhat erratic. It does not occur in all beds every year. It is probable, although no data are available to prove the point, that a considerable amount of the planting stock shipped from the Savenac Nursery does not have mycorrhizal roots. Such stock, when planted on sites which are comparatively low in soil nutrients and sterile with respect to mycorrhizae, may die because of its inability to absorb sufficient nutrients and water.

The fact that fall-planted stock has not survived as well as spring-planted stock is contrary to the results of Wahlenberg (*7*) who found in his experiments that season of planting had slight effect on survival. The difference observed in this study may be attributed in part to the fact that fall weather is not, in general, as favorable for planting as spring weather.

Freezing air temperatures, which are encountered more frequently during fall planting than during spring planting, may injure seedlings before they are placed in the ground. Further, fall rains following the summer drought have not always coincided with fall planting schedules. Frequently fall rainfall is not sufficient to make fa-

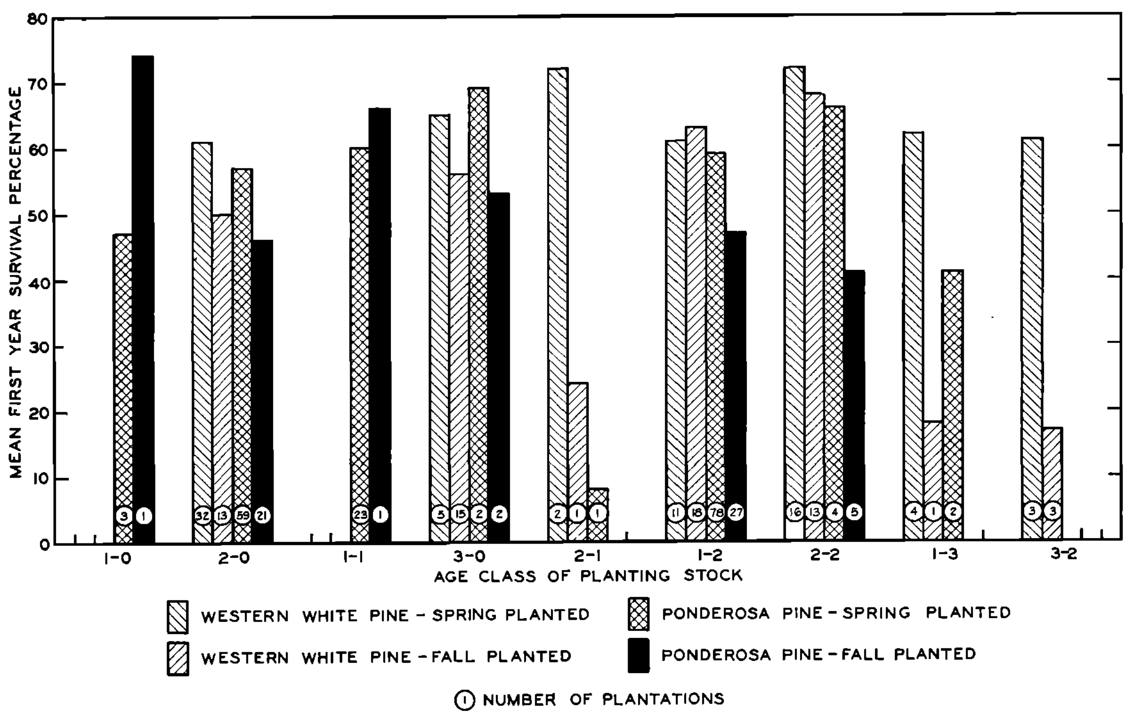

Fig. 3.—Mean first-year survival percentages of the various age classes of stock used in spring- and fall-planting of western white pine and ponderosa pine.

vorable planting conditions. A deficiency of available soil moisture at the time of fall planting may injure or kill a seedling by desiccation either directly by diffusion of water from moist roots to drier soil or indirectly by inhibition of the frost hardening processes with resultant frost injury. In the spring, however, soil moisture is always abundant for a short time as a result of melting snow, and is usually supplemented by spring rainfall. Spring planting must be done early to take advantage of these favorable conditions.

Before the days of the C.C.C., unfavorable fall weather probably affected survival to a greater extent than it does now. At that time planting crews worked out from temporary camps near the planting sites. Rather than bear the expense of maintaining camps while waiting for favorable planting weather, the tendency then was to go ahead with the planting regardless of the weather. This tendency is probably responsible for a considerable part of the losses on fall plantations. Now with C.C.C. camps established within working distances of almost all planting sites, the men can work on other projects in the fall until soil moisture conditions are favorable for planting. When that time arrives, planting stock is shipped to the site and the job is started. If no favorable planting weather occurs in the fall on a particular planting site, the project is postponed until the following spring.

Wahlenberg (*7*), in a comparison of age classes of stock on four different aspects, found that the older age classes of both western white pine and ponderosa pine survived better than the younger age classes and that transplanted stock was superior to seedling stock. These results are apparently contradictory to the results of the analyses presented in this paper which show no significant differences between age classes of stock. However, the contradiction is more apparent than real. In this study the nature of the data did not permit a separation of the effects of all of the ecological, genetic, and administrative factors in the analyses. It is probable that the net effect on survival of all of these factors and their interactions varied from plantation to plantation. This variation is too large to permit the detection of significant differences in survival between ages classes of stock. However, this result does not refute the possibility that such differences may exist.

Studies now being made by the Section of Planting of the effect on survival of age class of stock, time of planting, carefulness of planting and handling, and general vigor of planting stock, have already thrown some light on planting problems. These studies have shown that greater care in handling and planting as well as earlier spring planting can materially increase survival as compared to that obtained by routine methods. However, with an average survival percentage of only 42 percent for all plantations 10 years after planting, there is still much room for improvement. It is obvious that more intensive research is needed to obtain a thorough understanding of all factors involved and to work out a better planting practice.

Planting Costs

Planting costs, although not a part of this study, are an important corollary. For administrative records, costs are computed on an acreage basis considering the number of trees put into the ground. For the five-year period from 1932 to 1937 the average total cost per acre was $11.77 (*4*). With an average stocking of 700 trees per acre at the time of planting during this period, the cost per 1,000 trees is $16.77 (*4*). If planting costs are based on tangible results, that is, the number of established trees, the cost is increased considerably. With an average survival of only 42 percent in all plantations over 10 years old, the cost per 1,000 established trees is $39.93.

The problem of reducing planting costs is a difficult one. With the methods used during the period covered by this study, any desired degree of stocking may be obtained by planting 2.4 times the desired number of established trees per acre to allow for the 58 percent average expected mortality. A better method of obtaining the desired stocking is the planting of fewer trees having a greater survival percentage. Survival may be increased by improvements in planting practice, but if the additional cost of improvements raised the present cost per 1,000 established trees, an increase in survival would not be economically desirable. To determine whether or not a proposed improvement is economical, it is necessary to know the limit of the additional expense which may be incurred without raising the cost per 1,000 established trees. Suppose, for example, that improvements could be made in planting practice with a resultant increase in survival of 10 percent. If the cost per 1,000 established trees remains at $39.93, the cost of attaining this increase in survival will be $3.99 per 1,000 trees. Hence, improvements in planting practice can be made without raising the existing cost per 1,000 established trees, provided that the cost of the improvements does not exceed $3.99 per 1,000 trees for each 10 percent increase in survival.

Summary

During the period 1910-1937, a total of 1,150 plantations were established on an aggregate area of 93,878 acres in western Montana, northern Idaho, and northeastern Washington.

The means of all recorded first-year survival percentages of spring-planted western white pine and ponderosa pine trees are 7 and 10 percent higher, respectively, than those of fall-planted trees of the same species.

An analysis of all available first- and third-year survival data on plantations of various age classes of planting stock showed that there are no significant differences in survival between age classes of stock of either western white pine or ponderosa pine.

The mean tenth-year survival percentage of 210 plantations distributed over the region on an aggregate area of 29,589 acres is 42 percent.

Literature Cited

1. Baldwin, H. I. 1936. A forest seed program for the United States. Jour. Forestry 34: 766-770.
2. Baldwin, H. I. and H. L. Shirley. 1936. Forest seed control. Jour. Forestry 34: 653-663.
3. Cushman, W. H. and R. H. Weidman. 1937. Survival increased by carefulness in planting. Applied Forestry Note No. 81. Northern Rocky Mountain Forest and Range Exp. Sta.
4. DeJarnette, G. M. 1937. Annual planting report. Region One, Forest Service, U. S. Dept. Agric.
5. Hatch, A. B. 1937. The physical basis of mycotrophy in Pinus. The Black Rock Forest Bull. 6.
6. Olson, D. S. 1930. Growing trees for forest planting in Montana and Idaho. U. S. Dept. Agric. Circ. 120.
7. Wahlenberg, W. G. 1928. Experiments with classes of stock suitable for forest planting in the northern Rocky Mountains. Jour. Agric. Research 36: 977-1000.

THE WATER REQUIREMENT OF ROCKY MOUNTAIN CONIFERS

By JACOB ROESER, Jr.

Rocky Mountain Forest and Range Experiment Station[1]

Water requirement studies for Rocky Mountain conifers under laboratory conditions have been in progress for many years in Colorado. This paper presents the last of a series of studies and deals with water use of seedlings grown in containers with ample water. The results permit ranking coniferous species in order of the amount and efficiency of water under the conditions of the experiment.

In order to supplement earlier studies by Bates[2,3] on the general subject of water requirements of Rocky Mountain conifers, an experiment was started in 1925 to determine the relative water use of naturally developed stands of coniferous seedlings. This experiment was conducted at the Fremont Forest Experiment Station which is maintained by the Forest Service on the slopes of Pike's Peak in central Colorado. Ten years' records are available, the last field work being completed in 1936. From these data five native conifers are rated on the basis of their requirements for water from moist soils.

Methods

Seedlings were grown in twelve galvanized iron water tight containers each 24 inches deep and 16 inches in diameter. The containers were divided into two groups of six cans each' fine loam being used in one group and Permian red sand in the other. The species tested in each soil type were ponderosa pine (*Pinus ponderosa*), lodgepole pine (*P. contorta*), limber pine (*P. flexilis*), pinon pine (*P. edulis*), Douglas fir (*Pseudotsuga taxifolia*), and Engelmann spruce (*Picea engelmannii*). Seeds of ponderosa pine,

---

[1]The Rocky Mountain Forest and Range Experiment Station succeeded the Fremont Forest Experiment Station where this study was conducted.

[2]Bates, C. G. Physiological requirements of Rocky Mountain trees. Jour. Agric. Research 24:97-164. 1923.

[3]———. The mass production of dry weight by trees, as affected by age and soil conditions. Paper presented at annual meeting of Botanical Society of America, December 1925.