AGE CLASSES OF WESTERN WHITE PINE PLANTING STOCK IN RELATION TO ASPECT OF PLANTING SITE IN NORTHERN IDAHO [1]

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INTRODUCTION

In the northern Rocky Mountain region there are vast areas of forest land denuded by fire, which will remain virtually unproductive for generations to come unless planted by hand with nursery-grown trees. After the first sweep of fire through the original stands of western white pine timber (*Pinus monticola*) on these lands, the forest in most instances started to come back naturally, but before recovery was complete fire came again and this time swept away all the small new trees and all sources of seed for future growth. Forest planting is the only practical means of making such land productive.

Because of the vast amount of forest planting to be done in this region, it is desirable that research point out the means by which it can be undertaken at smallest cost and with the best possible results in thrifty young trees. This paper is an account of a few experiments to that end, other studies with a bearing on survival of plantations being still under way.[2]

Two very important factors in forest planting are the aspect [3] or exposure of slopes used for planting and the class of stock employed, for these are factors which both singly and in combination have a definite effect on survival of the trees. In the experiments reported herein five classes of stock representing three different ages of trees were tested on each of four slopes. The exposure of the slopes was determined in each instance by averaging the compass readings on the plots of each series. The slope classed as northeast had no deviation from this direction and the northwest, east, and west did not vary greatly, the first being 14° north of due northwest and the last two 8° north of east and 2° south of west, respectively.

The topography was such that the four aspects studied could be found close together, each with a gradient of 25° to 30° and at practically the same elevation, 3,350 to 3,700 feet. It is essential in work of this kind to arrange test plots so as to minimize irregularities in uncontrolled influences, such as differences in the competing vegetation, variation in the direction of slope, and changes in the quality of soil within plots and between plots. The soil, for instance, is often deeper and more favorable for plant life near the base of a slope than higher up. In these experiments the plots on each slope ran parallel to each other up and down the slope, each containing 600 trees of a certain age class set in 8 rows. Because of the uniformity of the

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[1] Received for publication Apr. 1, 1926; issued October, 1926.
[2] The experiments on which this report is largely based were started by E. C. Rogers near Wallace, Idaho.
[3] "Aspect," as used by foresters, denotes the direction toward which a slope faces.

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sites as a whole and the narrowness of the plots used, there is every reason for confidence in the results obtained.

The slit method of planting was used. This method is rapid and requires but one man for the entire operation, the soil being worked with a short-handled mattock and the seedlings planted with the free hand.

The crew for the experimental plantings consisted of a foreman, eight planters, and a packer. Each planter set out one row of trees in each plot, so that the method of planting might be considered uniform. To make later observations and records easier, each plant was marked with a serial number on a white-tipped stake.

The planting was done in the spring of 1915 with age classes of nursery stock designated as 2–2, 1–2, 2–1, 2–0, and 1–1.[4] At the end of the dry period in the fall of 1915, 1916, and 1917, all plants were examined, the surviving plants were counted, and the current stem-height growth of 200 plants in each plot was measured to the nearest tenth of an inch. The measured plants were chosen from all parts of the plot, upper as well as lower ends, the selection of 25 plants from each row insuring an equal representation of the work of each planter. As nearly as possible, the same plants were measured each year. Changes in the list of trees measured the first year were made only where necessary in order to confine the observations on growth to normal, uninjured plants. This was done because mechanical injury bears no obvious relation to the age class of the trees or to the exposure of the planting site.

SURVIVAL BY AGE CLASSES

A study of the percentage of planted trees surviving through three seasons, as given in Table 1, makes apparent certain relationships.

TABLE 1.—*Survival percentages of western white pine planting stock by age classes, aspects, and seasons* [a]

Age class	Northwest			Northeast			East			West			Average		
	1915	1916	1917	1915	1916	1917	1915	1916	1917	1915	1916	1917	1915	1916	1917
2–2	100.0	99.4	99.1	98.7	98.6	97.6	99.2	98.3	98.2	97.3	93.2	87.4	98.8	97.4	95.6
1–2	99.5	98.8	98.8	99.8	98.7	99.0	99.4	98.8	98.4	95.9	92.2	80.7	98.7	97.1	94.2
2–1	98.4	96.7	95.8	99.0	97.6	96.7	98.4	96.6	95.9	95.0	87.9	77.4	97.7	94.7	91.4
2–0	97.5	96.3	94.6	98.4	96.0	91.7	99.3	98.6	97.5	91.0	80.5	69.4	96.5	92.8	88.3
1–1	97.6	95.0	93.5	96.1	90.1	88.0	95.1	90.8	88.1	83.8	75.4	63.1	93.2	87.8	83.2
Average	98.6	97.2	96.4	98.4	96.2	94.6	98.3	96.6	95.6	92.6	85.8	75.6	97.0	93.9	90.5

[a] Trees planted in May, 1915, on the Placer Creek area near Wallace, Idaho.

It may be seen from the average survival for all aspects that 2–2 stock was most successful, with 1–2, 2–1, 2–0, and 1–1 following in descending order. This order held for the favorable northwest aspect, and even more clearly for the west aspect, where survival in general was lower. On the slopes facing northeast and east the 2–2

[4] As readers familiar with nursery practice will know, this terminology indicates the number of years spent by the plant in the seed bed and in the transplant bed. For example, the 2–2 stock remained two years in the seed bed and two years in the transplant bed, and was 4 years old at the time of field planting. Similarly, 1–2 stock and 2–1 stock were both 3 years old, but the former was transplanted at 1 year of age the latter at 2 years. The 2–0 stock was seedlings 2 years old used in the field without previous transplant ing.

stock yielded first place to the 1–2 stock, but only by small margins. The 1–1 stock was poorest on all aspects.

This similarity of the relative survival of age classes for different aspects gives added meaning to the figures for average survival as an indicator of quality of stock. The intrinsic qualities that enable one class of stock to survive better than another have not been definitely determined. Differences in survival, however, are thought to arise not only from variation in size and vigor as a result of difference in age, but also from variation in anatomical proportion resulting from different cultural treatment in the nursery. Thus 1–2 and 2–1 stock or 2–0 and 1–1 stock, although the same age, differ anatomically because of the different times at which they were pruned and transplanted in the nursery. The survival of 3-year-old trees was intermediate between the 2-year-old and 4-year-old trees, suggesting a general tendency toward higher survival with increased age. This tendency is not proved, however, because in this study the influence of age can not be separated from that of class of stock.

Aspect of planting site is as important a factor in survival as is class of stock, for reforestation of any area can be successful only when growing conditions there meet the requirements of the trees planted. Severity of site, as indicated by differences in survival, also emphasized the differences attributable to quality of stock. The west slope sites were clearly the most severe. The other, more moderate sites, were about equally favorable except that mortality was slightly less on the northwest slope than on the other two.

Assuming that all readily avoidable causes of death were eliminated from the tests, the above comparison on the basis of numbers of trees surviving gives a conception of relative values of classes of stock and aspects of planting site. Such an assumption, however, would not be justified in the absence of observations on the causes of mortality. For this reason all dead trees were dug out and inspected at the annual fall examination.

For most of the trees no reason for death other than drought could be detected, but occasional evidence of other causes was found. Some roots had been pruned too short, some trees had bark stripped from their roots, and others had scraped stems. These three causes can be kept at a minimum by careful handling of trees and the culling out of injured individuals. Shallow planting, whether resulting from roots cut too short or from trees set with their roots in poor positions, caused death because the surface layers of soil dried out most rapidly. Deep planting may have resulted in poor aeration for roots and may have buried part of the tops. Plants set under large fallen logs had a poor chance to live. Even after heavy September rains it was noticed that the soil in such places was dust-dry and often used by grouse for wallows. Still more fatal was the planting in what seemed to be fairly deep soil on the root mass of wind-thrown snags.

The most frequent cause of death listed other than drought was sliding soil on steep slopes. This is not to be confused with the rapid and much more destructive mass movement of soil, logs, and other débris caused by one of the snow slides common in the region, but is rather a creeping of soil, small rocks, and other surface litter from above the trees downward, usually caused by rain and melting snow. The sliding soil has a tendency to fill up the slight depression formed by planting and to bury the trees. Death of trees resulting from covering by sliding soil naturally fell heaviest on the youngest and shortest-stemmed trees, the 1–1 stock.

These younger trees seemed also to have been more subject to stem injury from tamping. The older trees were probably bruised as often, but were better able to withstand the injury. Similarly, by far the largest number of dead trees showing evidence of either mechanical injury or poor planting were on the west-facing slope. Such unfavorable conditions were probably as frequent on other aspects, but there greater moisture enabled the trees to live in spite of adverse conditions.

Less than 1 per cent of the trees planted, or 10 per cent of those which died, were affected by the above-mentioned unfavorable conditions, leaving 90 per cent of the deaths attributable only to drought. As has been indicated, the older plants usually survived better than the younger and the transplants better than the seedlings.

The conclusion that transplants are hardier than seedlings is corroborated by the results of small tests of age classes at other points. In one of these tests at Priest River, Idaho, in the spring of 1915 where 2–0 and 1–2 western white pine stock were planted on a flat and on a northeast slope, the transplanted stock (1–2) yielded higher survival in both situations. In another test near Haugan, Mont., in the fall of 1922, parallel trials of 3–0 and 1–2 white pine stock on a northwest slope yielded higher survival again for the transplanted (1–2) stock. Also a plantation on a northeast slope in the fall of 1924 resulted in higher survival for 1–2 transplants than for 3–0 seedlings. In this plantation 2–0 trees were inferior to both of the other classes of stock.

Success in planting in the region as a whole is very largely dependent upon adequate rainfall, especially during the first year or two after planting, and this was shown in the experiments made in the present study. The nearest weather station is at Wallace, Idaho, about 3 miles away and several hundred feet lower in elevation. The Weather Bureau records there indicated more than the average amount of rainfall in July and August for 1915 and 1916, the first two years after planting. Had this planting been done in the spring of 1917 or at any time during the next four years the results might have been quite different, for these were years of severe summer drought. Experiments in which the outcome is judged mainly by relative survival are likely to fail in such dry years, unless placed on the very best sites, because of universally high mortality. In like manner it has been observed that such experiments in moist years are often not very instructive for the opposite reason—mortality is so universally low that clear distinctions can not be made, except perhaps on the driest sites. Unfortunately, so far as the forests are concerned, drought can neither be controlled nor its occurrence predicted. Knowledge of drought hardiness must be accumulated year by year in the course of various observations on forest planting material.

HEIGHT GROWTH

Figure 1 shows the average elongation of stems or height growth of terminal shoots during the period of study.

It may be deduced from these measurements that the older the plant the greater is the height growth of stem. In general, the growth of the 3-year-old trees (2–1 and 1–2 stock) was intermediate between the younger (1–1 and 2–0) and the older (2–2) trees each year. This relationship is especially noticeable in the cumulative effect of three years' growth. That the older plants grew faster than the younger is shown not only by a comparison of growth during any one year, but also by the accelerated growth of any one class of stock during the three years. Acceleration of height growth over a period of years is a matter of common observation on somewhat older seedlings.

It appears from Figure 1 that on all aspects the height growth of 2–0 stock in any given season was less than that of 1–2 stock. However, considering the fact that the transplanted stock was 1 year older than the seedlings, might it not be fairer to contrast the growth of 1–2 stock the first and second seasons after planting with that of 2–0 stock during the second and third seasons? An objection may be made that the seedlings had more time than the transplants to

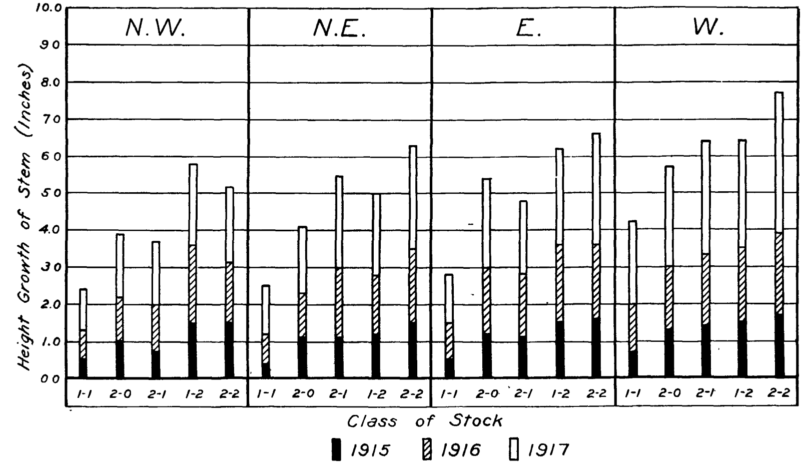

FIG. 1.—Height growth of stems of western white pine planted in the spring of 1915 on the Placer Creek area, Wallace, Idaho

recover from the shock of planting, but this objection would hardly apply to both the second and third years. Also, as stem growth occurs during the spring and early summer, it should not have been greatly influenced in this case by summer drought, especially as the months in question were above normal in amount of precipitation.

If this standard of comparison be accepted, and the growth data be charted as in Figure 2, it is evident that the 2–0 stock is growing at rates slightly faster on an average than those of the 1–2 stock. Also, by the same standard 1–2 stock is growing relatively faster than 2–2 on all aspects, making the slightly higher survival of the latter seem of less consequence. The significance of this comparison will be more apparent when relative planting costs are discussed.

Aspect also had a pronounced effect on growth, and the same trends are shown during each season and by each class of stock. The fastest stem growth took place on the west slope, then on the east, northeast, and northwest slopes in decreasing order. The average growth of the planted stock during the 3-year period following planting was nearly 2 inches greater on the west slope than on the northwest, whereas the east and northeast slopes led the northwest by an inch and a half inch, respectively. Thus it may be seen that the poorest survival was accompanied by the most rapid growth, and vice versa.

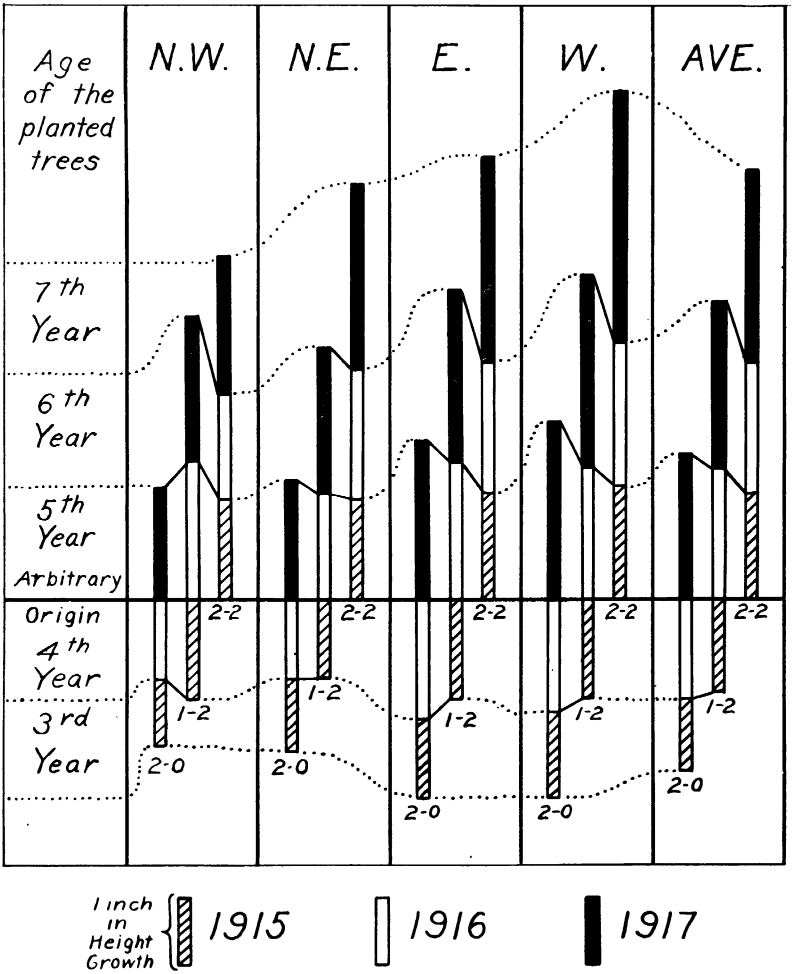

FIG. 2.—Comparison of growth of trees of same age. Stem height growth of different classes of stock during the first three years after planting

A somewhat obvious explanation of this opposite action on survival and on growth proves fallacious on analysis. Because considerable variation in development exists between individual plants of any class of stock, it seems at first glance reasonable to suppose that on drier sites only the superior plants survive, and consequently raise the growth averages for these sites above those taken on moist sites, where natural selection is less severe. In other words, it might be reasoned that, when all survivors are considered, the quality of plants left after natural selection would be higher on the drier than on the moister sites, and that the difference might well be sufficient to account for the greater growth on drier sites.

This supposition will not "hold water," however, when a very simple test is applied. Inasmuch as survival of the different classes of stock on the moist northwest slope was fairly uniform and a wide divergence in the survival of these classes appeared on the dry west slope, it should follow that the stock on the west slope that survived least well, namely, the 2–0 and 1–1 lots, would show the greatest relative advance in height growth over that on the northwest aspect, for with them selection was most severe. However, when the decrease in survival for each class on the west slope below that on the northwest slope is expressed in percentages and compared directly with the percentage increase in growth on the west over the northwest, no consistent relation obtains. This is shown clearly in Table 2. Furthermore, the rather slight differences in survival on the northwest, northeast, and east slopes are in contrast to striking differences in growth. The hypothesis that natural selection following planting determines the growth rates on these sites does not seem tenable.

TABLE 2.—*Comparison of growth and mortality relations on northwest and west aspects three years after planting*

Age classes	Decrease in survival percentage on west aspect below that on northwest aspect	Per cent increase in growth on west aspect over that on northwest aspect
2–2	11.7	48.1
1–2	18.1	27.6
2–1	18.4	73.0
2–0	25.2	41.0
1–1	30.4	75.0

In seeking a truer explanation, a little speculation may be justified. In the complex interaction of environmental influences it may well be that light has a dominant rôle in the determination of the rate of growth on these slopes. The northwest slope receives but little more than diffuse light, whereas the west slope is exposed to direct sunlight in summer during the greater part of the day. Although little or nothing is known as yet of the optimum light intensity for synthesis of plant food—for assimilation, for cell division, and stem elongation of western white pine during its early development—it is possible to estimate from the figures for mortality from drought that transpiration, as well as evaporation from the soil, was greatest on the west aspect and least on the northwest. If, as is sometimes held, faster transpiration is accompanied by faster absorption of nutrient salts, sunlight may have been a controlling influence in the growth differences observed.

COST

Survival and growth have been considered in an effort to judge the relative merits of different age classes of planting stock and different aspects for planting sites. The cost per thousand of established trees is a better criterion where it can readily be determined. Cost is a factor that can never be disregarded in practice.

In comparing planting stock on the basis of survival costs it must be remembered that only relative differences for single years are comparable, because the cost of production and planting of tree stock fluctuates greatly from year to year with the price of labor and supplies. The same relative differences in cost should be fairly constant from year to year, however. The nursery costs shown in Table 3 are based on nursery practice and labor conditions existing in the spring of 1918 and include all expenses from seed collection to loading tree shipments on the train. The field cost is the same for all age classes and is taken from the cost of planting 1–2 white pine on the St. Joe National Forest in the spring of 1917. It includes shipping charges for nearly the same distance as for the stock used on the Wallace area. An obvious imperfection in this method of figuring lies in the fact that the smaller-sized trees can be both shipped and planted somewhat more cheaply than the larger. By neglecting these things a slight burden will be placed on the 2–0 and 1–1 stock and a corresponding advantage given to the 2–2 stock. The cost of survival may be computed by the following formula:

$$\text{Cost per 1,000 survivors} = 100 \times \frac{\text{total cost of planting 1,000 trees}}{\text{percentage of survival}}$$

Substitution in this formula of figures given in Tables 1 and 3 gives the data for Table 4.

TABLE 3.—*Costs of planting per 1,000 trees*

Age class	Nursery	Field	Total
2–2	$3.64	$9.99	$13.63
1–2	3.28	9.99	13.27
2–1	3.06	9.99	13.05
2–0	1.67	9.99	11.66
1–1	2.70	9.99	12.69

The data in Table 4 indicate clearly that for an equal investment in planting work more living trees were obtained with 2–0 stock than with any other age class tested when planting was done on favorable aspects such as the northwest, northeast, and east, and this advantage would have been accentuated had it been possible to consider in the figures the somewhat cheaper shipping and planting charges for this class of stock. On the severe west aspect the oldest stock, the 2–2, appears to have been less expensive, although when allowance is made for its having been perhaps unduly favored in the cost figures, the margin between the 2–2 and the 1–2 classes of stock may be considerably reduced. In general, 2–0 was least expensive, 1–1 most expensive, and the three older transplant classes were intermediate and a great deal alike. The universally high cost on the west aspect is due, of course, to the high mortality on that exposure.

TABLE 4.—*Cost per thousand trees surviving three years after planting on different aspects and with different age classes*

Aspect	Age classes					Average
	2-2	1-2	2-1	2-0	1-1	
Northwest	$13.75	$13.43	$13.62	$12.33	$13.57	$13.34
Northeast	13.97	13.40	13.49	12.71	14.42	13.60
East	13.88	13.49	13.61	11.96	14.40	13.47
West	15.59	16.44	16.86	16.80	20.11	17.16
Average	14.30	14.19	14.39	13.45	15.62	

SUMMARY

In general the survival of planted western white pine trees places 2–2 transplanted stock at the top, with 1–2, 2–1, 2–0, and 1–1 following in descending order. Height growth also conforms to this order. The cost of survival definitely favors 2–0 seedlings on moderate sites, and 2–2 or 1–2 only on the more severe sites.

Aspect of planting site is as important as the class of stock. Of the four exposures tested the lowest survival, accompanied by the fastest growth, occurred on the west exposure. The east, northeast, and northwest aspects showed considerably higher survival in the order given.