

## INFLUENCE OF SHADE AND OTHER FACTORS ON PLANTATIONS.

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The summer of 1912 was a hard one for reproduction, natural and artificial, in central Massachusetts. While not exceptionally hot, there was a very scanty rainfall from June to November, and consequently a noticeable lack of ground moisture. Bogs which are ordinarily impassable except when frozen could be crossed dry-foot, and many farmers had their first experience in hauling water for stock and household uses. Natural reproduction of white pine from the seed year of 1911 practically disappeared in the open. Under these conditions, heavy losses in plantations established in the spring of the year were to be expected. Their occurrence, however, gave an unusual opportunity to distinguish the factors which result in survival or failure.

The data here presented were obtained in October and November following the drouth, on about three acres of the 1912 plantations on the Harvard Forest, Petersham, Mass.; and on a plantation established at the same time, belonging to the Brooks estate, also in Petersham. Both plantations were set out carefully,—the one on the Harvard Forest by students, the other by Italians working under the immediate supervision of a trained forester; and in the latter case, no counts were made on areas planted during the first day or two. Partial but careful inspection of both plantations early in June showed almost no immediate failure, and a very high percentage of plants with well developed new growth. The ordinary "mattock-hole" method of planting was used exclusively on the areas inspected, the only difference between the plantations being that on possibly half of the Harvard work the earth was compacted around the roots of the trees by the use of a wooden mallet instead of by stamping. The effect of this variation in the planting method could not be distinguished in this inspection.

The sites of the two plantations gave opportunities for con-

trasting the behavior of white pine stock under a variety of local influences. The portion of the Harvard white pine plantation occupied a gentle southerly slope near the crest of a well rounded ridge. The elevation is about 1,200 feet. The soil is well drained sandy loam, very stony. The area is typical of New England's abandoned ridge pastures, gradually seeding in with gray birch, white pine, red maple, and occasionally a black or red oak, or a chestnut. There are occasional bushes of *Crataegus* and *Viburnum*, and a low cover of grass, moss, sweet fern, and blueberry, grouped in some places, intermingled in others. With uniformity of stock, planting method, and broad site conditions, this area gave opportunity for determining the influence of shade, root competition, and proximity of stones. Small areas planted with Scotch pine and with red oak furnished a limited comparison of species. The Brooks plantation, all white pine, is on soil similar in composition, but much less stony, on the lower slopes and the flats of a valley at about 800 feet elevation. The area was almost completely cleared of a good stand of timber in the fall of 1910, and the brush burned in 1911. This plantation, within itself, furnished data on the influence of overhead shade and root competition. Within itself, and especially when compared with the Harvard plantation, it offered some data on stock.

The benefit, and in the case of natural reproduction, the practical necessity of some shade for white pine seedlings has never been disputed, to the knowledge of the writers. The degree of the benefit of shade was undoubtedly exaggerated by the drouth of 1912, in the plantations studied; but the figures for this factor should be of interest as an indication of what may be expected in similar dry years. In the inspection of the plantations, shade from trees of all species was recorded, for the six hours in the middle of a summer day, in four classes, based on duration. (See table.) Most of the trees in the first class had no shade from high trees whatever, although the class includes trees which received shade from high trees for not over an hour each day. Shade from low bushes, such as sweet fern or blueberry, or from tufts of grass, was recorded in three grades,—absent, medium, and heavy. To show the influence of shade, the record of three year white pine transplants, not subject to the influence of root competition or of nearby stones, is given in Table I.

TABLE I.

*Shade Influence in a Plantation of Three-year White Pine Transplants.*

| <i>Low<br/>Shade..</i> | <i>High<br/>Shade.</i> | <i>Trees<br/>Alive.</i> | <i>Trees<br/>Dead.</i> | <i>Total<br/>Number<br/>of<br/>Trees.</i> | <i>Per<br/>cent.<br/>Alive.</i> |
|------------------------|------------------------|-------------------------|------------------------|-------------------------------------------|---------------------------------|
| None,                  | None,                  | 341                     | 262                    | 603                                       | 56.5                            |
| "                      | 1 to 3 hrs.,           | 209                     | 48                     | 257                                       | 81                              |
| "                      | 3 to 4½ hrs.,          | 179                     | 34                     | 213                                       | 84                              |
| "                      | Over 4½ hrs.           | 235                     | 18                     | 253                                       | 93                              |
| Medium,                | None,                  | 382                     | 88                     | 470                                       | 81                              |
| "                      | 1 to 3 hrs.,           | 178                     | 26                     | 204                                       | 87                              |
| "                      | 3 to 4½ hrs.,          | 83                      | 9                      | 92                                        | 90                              |
| "                      | Over 4½ hrs.,          | 46                      | 0                      | 46                                        | 100                             |
| Heavy,                 | None,                  | 48                      | 7                      | 55                                        | 87                              |
| "                      | 1 to 3 hrs.,           | 29                      | 2                      | 31                                        | 94                              |
| "                      | 3 to 4½ hrs.,          | 12                      | 1                      | 13                                        | 92                              |
| "                      | Over 4½ hrs.,          | 18                      | 4                      | 22                                        | 82                              |
|                        |                        | 1760                    | 499                    | 2259                                      |                                 |

These figures show plainly the benefit of some shade for white pine the first year after planting. In this dry year, 43 out of every 100 trees without any shade died, while even the moderate shelter furnished by low brush, such as sweet fern, cut this loss more than half. Or again, the trees without shade were only about one-fourth (26.9%) of the total number, but furnished over one-half (52.5%) of the losses. With *some* shade the percentage of survival does not fall below 81, and averages 85.5. With *no* shade, the percentage is 56.5.

The number of trees in the lower half of Table I are insufficient to justify conclusions as to the most favorable degree of shade, although the falling values at the bottom of the column "Per cent Alive" are at least suggestive. The table does indicate that, within limits, the greater the amount of shade, the better the chances for success; and, what is of especial interest if true, that a protection of low shrubbery is of substantially equal benefit to one of short open-grown trees which may later cause great

damage, directly or indirectly. In other words, pine seedlings planted in the shade of birches, black oaks, or other trees in New England pastures get little more benefit from the shade than those planted in patches of sweet fern; and the latter will be free from injurious shade or mechanical damage in years to come. This is, of course, without considering the often compensating factor of root competition of the extra expense of planting in brush.

The Brooks plantation furnished striking corroboration of the value of shade in seasons like that of 1912. On one slope, scattered trees or small groups of hickory (*Hicoria ovata*) poles, 30 to 50 feet in height, had been left. The slope was planted without attention to these hickories, so that it was possible to get counts on two series of plots, each series alike in site, exposure, absence of low shade, ground cover, stock (2-year seedlings), planting method, and time of planting; but differing in that the plots of one series were shaded by these hickories at least three hours daily, while the plots of the other series were unshaded and more numerous. On the shaded plots, 201 out of 291 trees (69%) were alive; on the unshaded plots, 181 out of 500 trees (36%) were alive. The shade of the hickories had been insufficient to cause a noticeable difference in the growth of the coarse, low grass that covered the ground, but was enough to keep alive two seedlings out of every three, while only about one out of every three lived in the open.

By his experiments in the sand hills at Halsey, Neb., Bates has shown the great importance of root competition as a source of failure in plantations where rainfall is scanty. It was not to be expected, even after an unusual drouth, that its importance would be as great in New England, where the soil is loamy and the annual precipitation averages about 40 inches. Also no tree in the Harvard plantation was without some root competition from the bushes or sod that covered the old pasture, which afforded no comparison like the ridges and bottoms of the Nebraska sand hills. In this inspection of the Petersham plantations, root competition was noted when it was obvious, from the position of the tree with relation to other vegetation, that the ground occupied by the roots would also have to supply moisture to other plants, as when a tree had been planted at one side of a hole in a thicket of sweet fern. The results for the Harvard plantation are given in Table II.

Table II.

*Influence of Root Competition in a Plantation of Three-Year White Pine Transplants.*

| <i>Low Shade.</i> | <i>High Shade.</i> | <i>With Root Competition.</i> |                     |                         | <i>No Root Competition.<br/>(From Table I.)</i> |                       |
|-------------------|--------------------|-------------------------------|---------------------|-------------------------|-------------------------------------------------|-----------------------|
|                   |                    | <i>Number Alive.</i>          | <i>Number Dead.</i> | <i>Per cent. Alive.</i> | <i>Per cent. Alive.</i>                         |                       |
| None,             | None,              | 49                            | 58                  | 46                      | 56.5                                            |                       |
|                   | 1 to 3 hrs.        | 11                            | 12                  | 48                      | 81                                              |                       |
|                   | 3 to 4½ hrs.       | 10                            | 8                   | 56                      | 84                                              |                       |
|                   | Over 4½ hrs.       | 25                            | 7                   | 78                      | 93                                              |                       |
| Medium,           | None,              | 124                           | 91                  | 57                      | 81                                              |                       |
|                   | 1 to 3 hrs.        | 36                            | 18                  | 67                      | 87                                              | Average<br>65%<br>100 |
|                   | 3 to 4½ hrs.       | 36                            | 6                   | 86                      | 90                                              |                       |
|                   | Over 4½ hrs.       | 18                            | 5                   | 78                      | 100                                             |                       |
| Heavy,            | None,              | 48                            | 23                  | 68                      | 87                                              | Average<br>85.5%      |
|                   | 1 to 3 hrs.        | 12                            | 2                   | 86                      | 94                                              |                       |
|                   | 3 to 4½ hrs.       | 9                             | 3                   | 75                      | 92                                              |                       |
|                   | Over 4½ hrs.       | 9                             | 7                   | 56                      | 82                                              |                       |
|                   |                    | 387                           | 242                 |                         |                                                 |                       |

This table indicates that root competition caused an increase in the loss of 10% for the unshaded trees and of 20% for the shaded. It also emphasizes the importance of the shade factor, since we have the same general trend toward higher percentages alive with increase in shade. Medium or heavy low shade with root competition appears to have been preferable to no shade and no root competition.

A portion of the Brooks plantation had so heavy a ground cover of pine and hemlock needles and twigs from the cut off stand that there was no vegetation of any sort on the area when the planting was done. There was no shade. Grass and mullein started during the summer on the mineral soil exposed by digging the mattock holes, and their roots were the only competitors of the planted seedlings. The loss was very heavy, due partly to the stock (3-0) used. Of 231 without root competition, only 53 (22.9%) were alive; and of 214 with root competition, only 36 (16.9%) were alive. The strong influence of this root competition from herbaceous plants is best expressed by saying that for every three trees which successfully withstood both drouth and competition, a fourth would be alive had the latter factor been absent.

In the inspection of the Harvard plantation, a separate record

was kept of those trees which had a stone as close as 6 to 8 inches from the stem, whether the stone had been placed there by the planter or not. Although the amount of data is not large, it is sufficient to indicate that an exposed stone close to a planted tree was a strong adverse influence in this dry season. The data on this factor are given in Table III.

Table III.

*Stone Influence in a Plantation of Three-Year White Pine Transplants.*

| Low<br>Shade. | High<br>Shade. | With Stones.     |                 |                     | No Stone.                       |                                  |                     |
|---------------|----------------|------------------|-----------------|---------------------|---------------------------------|----------------------------------|---------------------|
|               |                | Number<br>Alive. | Number<br>Dead. | Per cent.<br>Alive. | Table I.<br>Per cent.<br>Alive. | Table II.<br>Per cent.<br>Alive. |                     |
| None,         | None,          | 47               | 64              | 42                  | 56.5                            | 46                               |                     |
|               | 1 to 3 hrs.    | 26               | 14              | 65                  |                                 |                                  |                     |
|               | 3 to 4½ hrs.   | 19               | 5               | 79                  |                                 |                                  |                     |
|               | Over 4½ hrs.   | 7                | 4               | 64                  |                                 |                                  |                     |
| Medium,       | None,          | 41               | 9               | 82                  | Aver-<br>age<br>77%             | Aver-<br>age<br>85.5%            | Aver-<br>age<br>65% |
|               | 1 to 3 hrs.    | 13               | 2               | 87                  |                                 |                                  |                     |
|               | 3 to 4½ hrs.   | 3                | 9               | 100                 |                                 |                                  |                     |
|               | Over 4½ hrs.   | 0                | 0               |                     |                                 |                                  |                     |
| Heavy,        | None,          | 5                | 1               | 83                  |                                 |                                  |                     |
|               | 1 to 3 hrs.    | 2                | 0               | 100                 |                                 |                                  |                     |
|               | 3 to 4½ hrs.   | 2                | 0               | 100                 |                                 |                                  |                     |
|               | Over 4½ hrs.   | 2                | 0               | 100                 |                                 |                                  |                     |
|               |                | 167              | 99              |                     |                                 |                                  |                     |

In the open, the stones apparently caused the death of 14 trees out of every 100 which had them. The influence of the stones is much less marked, however, when some shade is present, and is less than the influence of root competition. Radiation from the sun-heated stones undoubtedly caused increased transpiration from the needles of the planted trees, and may have tended to dry out the soil underneath. Whatever the means, a stone was a greater danger to a tree than root competition in the absence of shade; but was distinctly less dangerous than root competition when shade was present, although still a danger.

A total of 29 trees were found which had contended with both root competition and the influence of nearby stones. Of these, 5 were without shade—2 alive and 3 dead; while of the 24 with some shade, 14 (58%) were alive. The numbers involved are too small to justify comment other than that the percentages of

survival are about what might be expected after considering Table II and Table III.

In the Harvard white pine plantation the stock used was three year transplants. In the Brooks plantation, two and three year seedlings were used. As has been explained, the site conditions were not exactly similar; but they were sufficiently so to indicate broadly the relative values of transplant and seedling stock. The figures for trees in the open, without root competition or stones, follow:

| <i>Place.</i>       | <i>Stock.</i><br>( <i>White Pine.</i> ) | <i>Number.</i> | <i>Per cent.</i><br><i>Alive.</i> |
|---------------------|-----------------------------------------|----------------|-----------------------------------|
| Harvard plantation, | 3 yr. transplants,                      | 603            | 56.5                              |
|                     | 2 yr. seedlings,                        | 300            | 32.7                              |
| Brooks plantation,  | 3 yr. seedlings,*                       | 231            | 22.9                              |
|                     | 3 yr. seedlings,†                       | 100            | 37.0                              |

\*On cut over land with heavy litter.

†On old sticking-ground, light sod.

It is possible to give only one other good comparison on this question of stock. If we take as the conditions some high shade, no low shade, no root competition, and no stones, we secure the following figures:

| <i>Place.</i>       | <i>Stock.</i>      | <i>Number.</i> | <i>Per cent.</i><br><i>Alive.</i> |
|---------------------|--------------------|----------------|-----------------------------------|
| Harvard plantation, | 3 yr. transplants, | 723            | 86                                |
| Brooks plantation,  | 2 yr. seedlings,   | 291            | 69                                |

With the weather conditions as they were in Petersham in 1912, the use of seedling stock resulted in the loss of about 20% more of the trees than where transplant stock was used. The small numbers involved and minor variations in planting sites make it unwise to draw any conclusions as to the relative values of two years seedlings and three year seedlings. Neither of them gave a high enough percentage of survival in the open to establish a desirable stand.

The small 1912 Scotch pine plantation on the Harvard Forest, and the still smaller red oak plantation were inspected as well as the white pine area. Both of these small plantations were in a remarkably good condition, considering the circumstances.

Although planting method and time were the same for all three species, the average percentage of survivals show distinct variations, which might be partially accounted for, however, by variations in planting site :

| <i>Species.</i> | <i>Stock.</i>      | <i>Number.<br/>Inspected.</i> | <i>Per cent.<br/>Alive.</i> |
|-----------------|--------------------|-------------------------------|-----------------------------|
| White pine,     | 3 yr. transplants, | 3183                          | 73.5                        |
| Scotch pine,    | 2 yr. transplants, | 656                           | 88.7                        |
| Red oak,        | 1 yr. seedlings,   | 99                            | 92.6                        |

The number of the red oaks is too limited to warrant details. It should be noted, however, that they occupy the lower portion of a gentle southerly slope, and a small flat along an intermittent stream which was dry in the summer of 1912. The site was distinctly better than those of the pine plantations. It may also be of interest that 6 of the 92 live trees were sprouts. The stems of the trees had died, but in each case two sprouts had appeared.

The results in the case of the Scotch pine are worthy of a more detailed statement, for whatever one may think of this exotic for commercial planting in a region where the industries demand the soft light wood of the white pine, it showed remarkable hardiness. The site is an abandoned field, level, or sloping very gently to the south. The only shade was from two or three small birches and pines, and from one or two larger trees on the western edge. The soil is similar to that in the white pine area, but some of the stones were taken out when the field was plowed 20 to 40 years ago. In general, the site appears but very little better than the white pine area, especially if drouth is to be feared. The planting method was the same. A comparison of the figures for the two species, excluding all shaded trees, follows :

| <i>Species.</i> | <i>No Stones or Root<br/>Competition.</i> |                 | <i>With Stone.</i> |                 | <i>With Root<br/>Competition.</i> |                 |
|-----------------|-------------------------------------------|-----------------|--------------------|-----------------|-----------------------------------|-----------------|
|                 | <i>Number.</i>                            | <i>% Alive.</i> | <i>Number.</i>     | <i>% Alive.</i> | <i>Number.</i>                    | <i>% Alive.</i> |
| White Pine,     | 603                                       | 56.5            | 111                | 42              | 107                               | 46              |
| Scotch Pine,    | 526                                       | 89              | 87                 | 89              | 24                                | 75              |

The single Scotch pine which had both a nearby stone and root competition, but no shade, was alive. Of 18 Scotch pines with

some shade (none with over  $4\frac{1}{2}$  hours) not one was dead, although three of them had stones within six inches of the stem. Even after discounting these figures for possible differences in site (and the white pine's extra year in the nursery should more than offset this), the drouth-resisting ability of the Scotch pine was striking.

It is hoped that the foregoing data, incomplete though they are in many ways, will furnish an indication of what may be expected from planting under adverse weather conditions and on similar sites. The application of the data to the details of such a planting operation is obvious. The facts in the cases of these plantations may also be of use in determining the causes, exclusive of careful work or the opposite, of some successes or failures.