THE WATER CONTENT OF FOREST PLANTING STOCK IN RELATION TO SURVIVAL AND GROWTH

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THE WATER CONTENT OF FOREST PLANTING STOCK IN RELATION TO SURVIVAL AND GROWTH

by
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THESIS

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CHAPTER I INTRODUCTION

Living plants normally contain a high percentage of water. The exact water content of the plant varies with the species, its physiological condition, and the external conditions affecting supply and loss of water by the plant. When the water content of plants becomes too low, drought injury or death result.

Very little is known, however, of the critical water content of plants, especially of forest trees. A knowledge of the minimum water content below which trees could not survive when placed under favorable growing conditions would be of great value in reforestation work. Forest planting stock is often subjected to considerable drying from the time it leaves the forest tree nursery until it is planted in the field. General appearance has been the criterion used to judge the condition of forest planting stock but it is very difficult to determine by this method the true condition of the planting stock. Trees which have no chance of survival undoubtedly are often planted in the field with consequent waste of effort.

In order to put forest planting on a sound scientific basis foresters should know the water content requirements of trees and have a simple, rapid method of making water content determinations.

It was the aim of the investigations here reported to

determine the water content requirements of 3-0 seedlings of red pine, (Pinus resinosa Ait.), eastern white pine (Pinus strobus L.) and Norway spruce, (Picea excelsa Link), three conifers widely used in forest plantings in Northeastern United States. Results are given also of a method adapted for making rapid water content determination of plant materials.

All of the work was done at Michigan State College, using in particular the facilities of the Bogue Forest Nursery, the cold storage room of the Horticulture Department, and the plant physiology laboratory of the Botany Department. Field tests were conducted during the growing season of 1938.

CHAPTER II REVIEW OF THE LITERATURE

A search of the literature directly related to this subject revealed that very little similar work has been done. In fact no cases were found where actual moisture content at time of planting had been correlated with survival. However, several workers have carried on closely related studies.

The cold storage of forest planting stock has received considerable attention in the last few years by the Forest Service in the Northern Rocky Mountain Region. In the annual planting report (7) of this region in 1937 it was reported that the length of time the trees were in cold storage, up to 40 days, was not an important factor in survival. Condition of stock at the time of storage, however, had important effects on survival. Stock which was stored after bud development had begun showed a marked decrease in survival. The low temperature of 30°to 45°F. did not stop the bud advancement and the buds were elongated up to one inch at the time of planting. Planting stock therefore, should be stored for prolonged periods only when in dormant condition. These experiments were made principally with western white pine (Pinus monticola D Don.), ponderosa pine (Pinus ponderosa Lawson) and Engelmann spruce (Picea engelmannii Engelmann).

Petheram (6) found in Colorado that 2-1 ponderosa pine and 2-0 Douglas fir (Pseudotsuga taxifolia LaMarck, Britton) could be stored in the field in cold running water (30° to 35°F.) for two weeks without any harmful effects and up to three weeks without serious mortality. During storage only the roots were submerged.

Foresters usually have considered that the exposure of seedling roots to sun and wind will cause the trees to die but not much has been done to determine just how much exposure each species can withstand. Ziegler (8) working with 2-0 white pine in Pennsylvania observed that exposures longer than one hour caused a loss of 66 to 98 per cent of the trees. Exposures were made on average sunny, moderately windy days.

In another series of experiments with 2-0 white pine Ziegler (9) found that a 10 to 40 minute exposure whether occurring in the fall, in the spring, or in the fall and again in the spring was not serious except on windy days with low relative humidity. A comparison of fall exposure with spring exposure failed to show consistent differences, although the spring exposure, in general, seemed to show the greater loss. He also observed that the ill effects of exposure were manifested not only through the total loss of plants, but that even though the trees survived, their vigor might be impaired. Trees exposed 40 minutes and less showed an average current growth of 2 3/4 inches, while those surviving the longer exposures showed less than half the growth, or about 1 1/4 inches.

Ziegler included some data of Sponsler which showed that at room temperature the roots of 3-0 white pine seedlings dried out five to six times as fast as the tops.

Haasis (4) in Connecticut exposed the roots of 3-0 red pine and white pine in the shade and in the sun and found that greater mortality resulted from the sun exposures. He also noted that red pine was more susceptible than white pine to injury from exposure.

In southern Australia Carter (3) found that seedlings of Pinus insignis could not stand exposures of more than 10 minutes without heavy losses. With 50 or more minutes of exposure all seedlings subsequently died.

Laing (5) in Scotland followed the water content of 2-0 and 2-2 Norway spruce (Picea excelsa Link), Sitka spruce (Picea sitchensis Bonyard, Curriere) and European larch (Larix decidua Mill) for over a period of two years. He found that the period of minimum water content was from July to December with the lowest points in September and October. From January to June the water content increased reaching the maximum in May and June. He noted also that the water content of planting stock was definitely influenced by rainfall and soil moisture from December to May but not from June to November. During the latter period moisture content of the trees continued to fall despite an increase in soil moisture. Rising temperatures in spring were accompanied by a rise in moisture content until June, after which time water content began to drop irrespective of changes in temperature. Late spring frosts caused sharp drops in

water content but the normal percentage was quickly regained. He further observed that with the exception of larch, seedlings have a higher minimum water content than transplants. His results indicated that the older the seedlings or transplant the more stable its water content; it being less dependent on external conditions.

Laing emphasized the importance of the minimum amount of water in the plant. He observed that the water content of the tops of Norway spruce and Sitka spruce transplants under natural conditions never dropped below 100 per cent of the dry weight, or the roots below 170-180 per cent. This minimum of 100 per cent for transplants appeared to him a criterion of their condition at the time of planting, and if their water content was below 100 per cent the plants would probably be wilted, perhaps permanently.

CHAPTER III METHODS OF PROCEDURE.

The seedlings used in this study were packed in thoroughly moistened sphagnum moss, wrapped in burlap lined with paper, and placed in cold storage on April 8, 1938. There were two lots of seedlings, Lot A which was watered frequently throughout the storage period and Lot B which was not watered after the initial packing. In the cold storage vault temperatures ranged from 35° to 40°F. and the relative humidity was kept very high at all times.

The following table gives the average root and top lengths for the species used:

Table I. Length of Roots and Tops of Seedlings

Species	Age	Length in Cm.	
		Top	Root
Red pine	3-0	18.3	29.2
White pine	3-0	13.6	27.5
Norway spruce	3-0	14.7	26.0

After receiving treatment the seedlings were packed in thoroughly moistened sphagnum moss and planted soon afterward. The trees were planted in a plot in the nursery, 10 trees to a row, with the trees three inches apart in the row and rows six inches apart. After planting, the seedlings were watered frequently but did not receive any further treatment.

All moisture content determinations were made on the seedling tops as preliminary tests indicated that the use of the tops would give reliable results. The tops were cut into small pieces about 1/4 of an inch long, placed in glass weighing bottles and weighed immediately to the nearest milligram to get the fresh or green weight. The tops then were dried to constant weight in an electric oven at 95°C. In most cases this took from four to seven days. Throughout this study all water contents were computed on the basis of fresh or green weight.

Survival counts and growth measurements were made on all trees in October, 1938.

Four treatments were designed to carry out the experimental work of this study. These were as follows:

TREATMENT I. The Effect of Cold Storage on the Water Content of Seedlings.

For this treatment, plantings were made every week from April 11, 1938 to June 6, 1938. Each planting consisted of 10 trees of each species from Lot A, the watered lot, and 10 trees of each species from Lot B, the lot not watered. At the time of each planting, two trees of each species from both lots A and B were taken for moisture content determinations. All the trees in Lot B were used in this treatment.

TREATMENT II. The Effect of Rapid Transpiration on the Water Content of Seedlings.

This treatment consisted of a series of five plantings made from April 22, 1938 to May 2, 1938. All trees used were taken from Lot A, the watered lot.

On the day of each planting 12 trees of each species were taken from storage and exposed to conditions in the laboratory favoring rapid transpiration. The seedlings were placed upright in a box with the roots packed in moist sphagnum moss. The sides of the box extended only slightly above the root collar so that the air was free to circulate through the seedling tops. An electric fan was placed about a foot away on a level with the tops and allowed to blow on them for four hours. At the end of this period, 10 trees of each species were planted and moisture content determinations made on two trees of each species.

TREATMENT III. The effect of Exposure of Roots and Tops on the Water Content of Seedlings.

A series of eight plantings from Lot A, the watered lot, made up this treatment.

On May 5, 1938, 96 trees of each species were taken from storage and exposed in the laboratory. The seedlings were spread out on paper covered laboratory tables in a single layer with the tops and roots exposed. At the beginning of the treatment and every two hours thereafter a planting of ten trees of each species was made. At the time of each planting moisture content determinations were made on two trees of each species.

<u>TREATMENT IV</u>. <u>The effect of Exposure of Roots on the Water Content of Seedlings</u>.

This treatment consisted of a series of eight plantings from Lot A, the watered lot.

On May 12, 1938, 96 trees of each species were taken from storage and exposed in the laboratory. The seedlings were spread out in a single layer on paper covered laboratory tables. The roots were exposed but the tops were covered with paper and burlap to reduce transpiration. An electric fan was placed so as to keep the air constantly in motion over the roots. At the beginning of the treatment and every two hours thereafter for 14 hours, 10 trees of each species were planted. At the time of each planting moisture content determinations were made on two trees of each species.

CHAPTER IV RESULTS

TREATMENT I. The Effect of cold Storage on the Water Content of Seedlings.

The water content of the seedlings in Lot A, watered, and Lot B, not watered, did not vary appreciably during the period April 11 to June 6. Figures 1,2,3,5,6 and 7 show this clearly. Also the results indicate no significant difference in water content variation between Lot A and Lot B. However, there were significant differences in water content shown between species. The water content of white pine and red pine varied between 60 and 65 per cent while for Norway spruce it varied between 55 and 60 per cent, a significantly lower range.

Survival of all trees planted from Lot A and Lot B was consistently high throughout the planting period. The data for survival are shown in Figures 1,2,3,5,6 and 7. There was no significant difference in survival shown between Lot A and B except in the case of white pine. The survival of white pine in Lot B was slightly higher than in Lot A. The differences, however, were small and probably due to errors of sampling. As there was little difference in water content between Lot A and Lot B, significant differences in survival would not be expected.

Throughout the planting period there was a slight decrease in height growth with lateness of planting. Figure 4 shows the data for height growth in Lot A and Figure 8

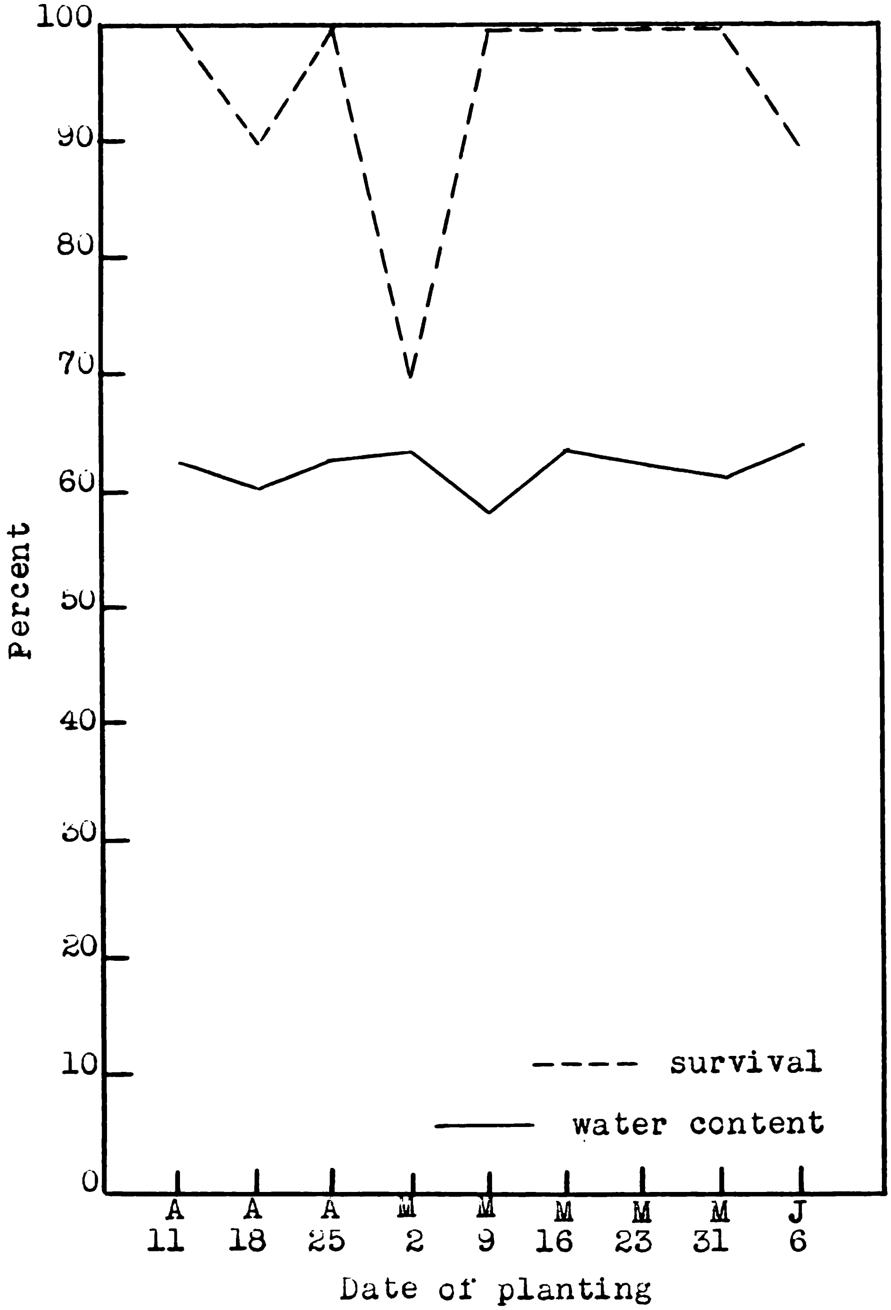

Fig. 1. Treatment I. Lot A. Water content and survival of white pine seedlings planted from cold storage April 11 to June 6.

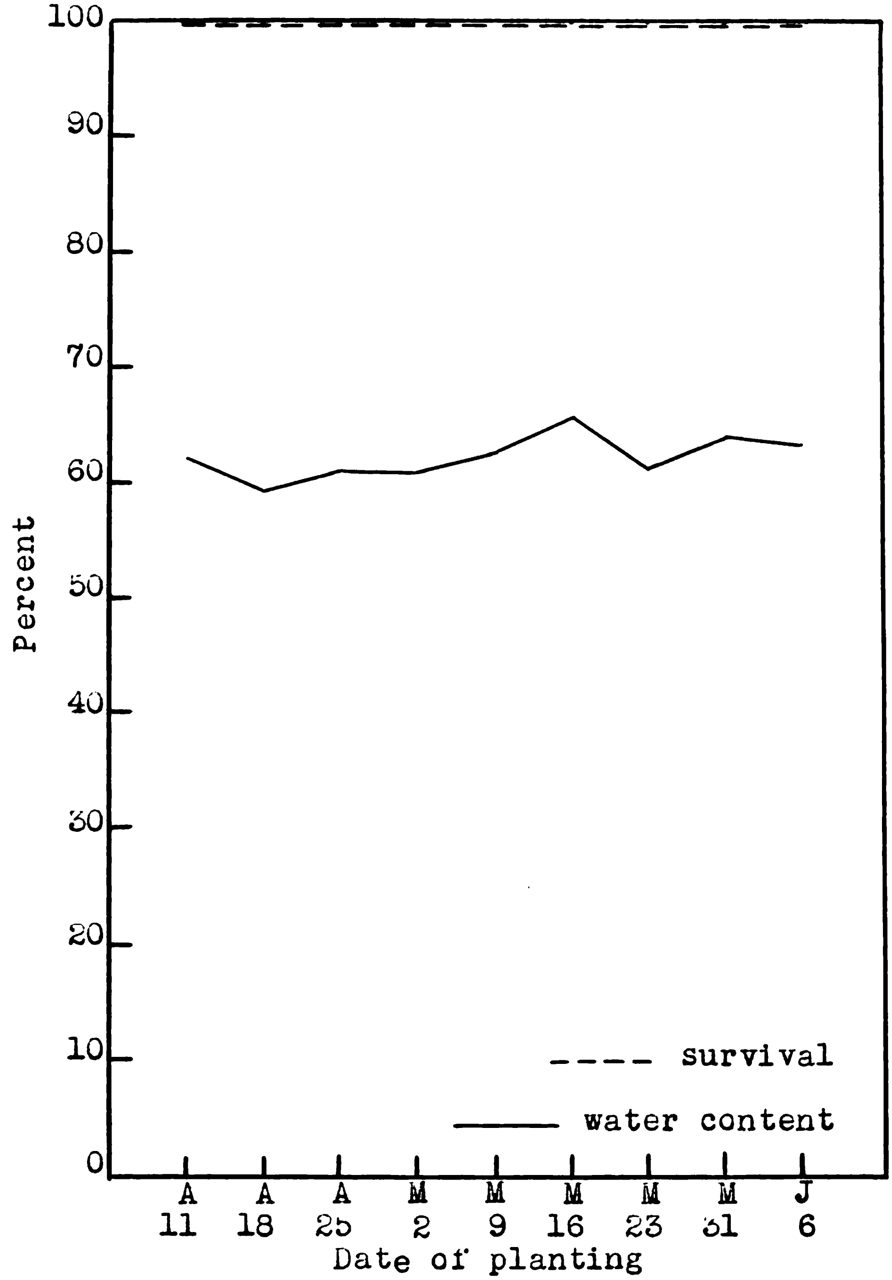

Fig. 2. Treatment I. Lot A. Water content and survival of red pine seedlings planted from cold storage April 11 to June 6.

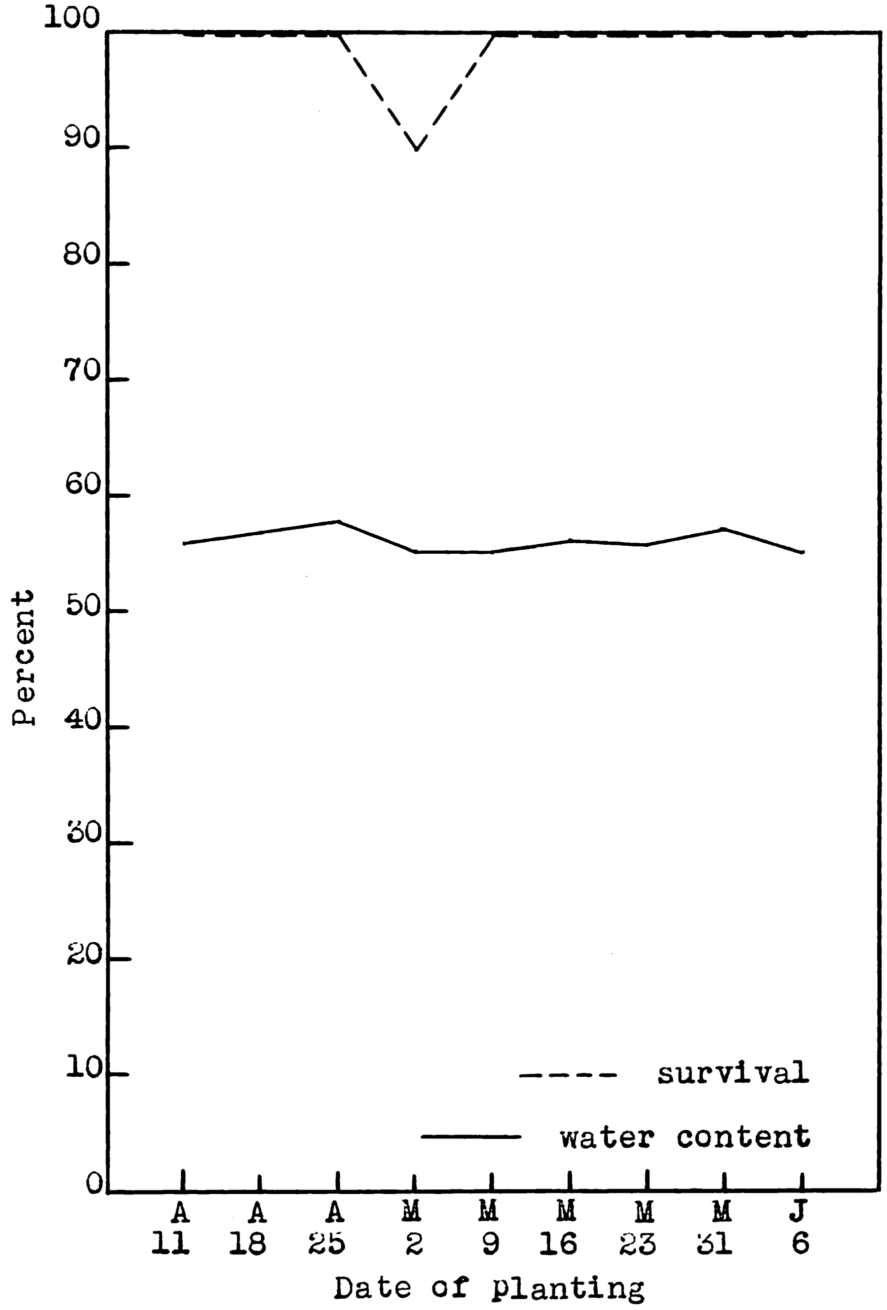

Fig. 3. Treatment I. Lot A. Water content and survival of Norway spruce seedlings planted from cold storage April 11 to June 6.

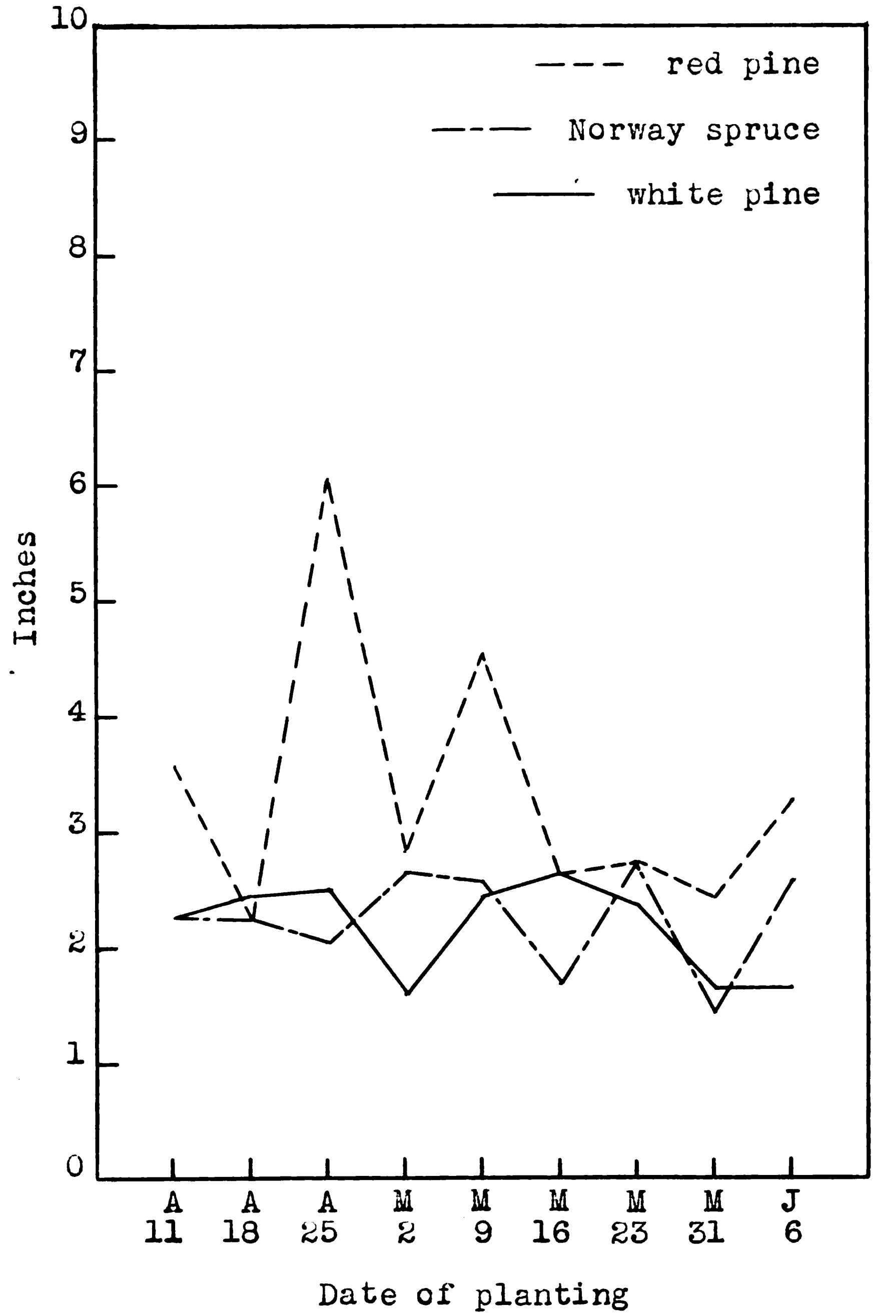

Fig. 4. Treatment I. Lot A. Height growth of red pine, white pine and Norway spruce seedlings planted from cold storage April 11 to June 6.

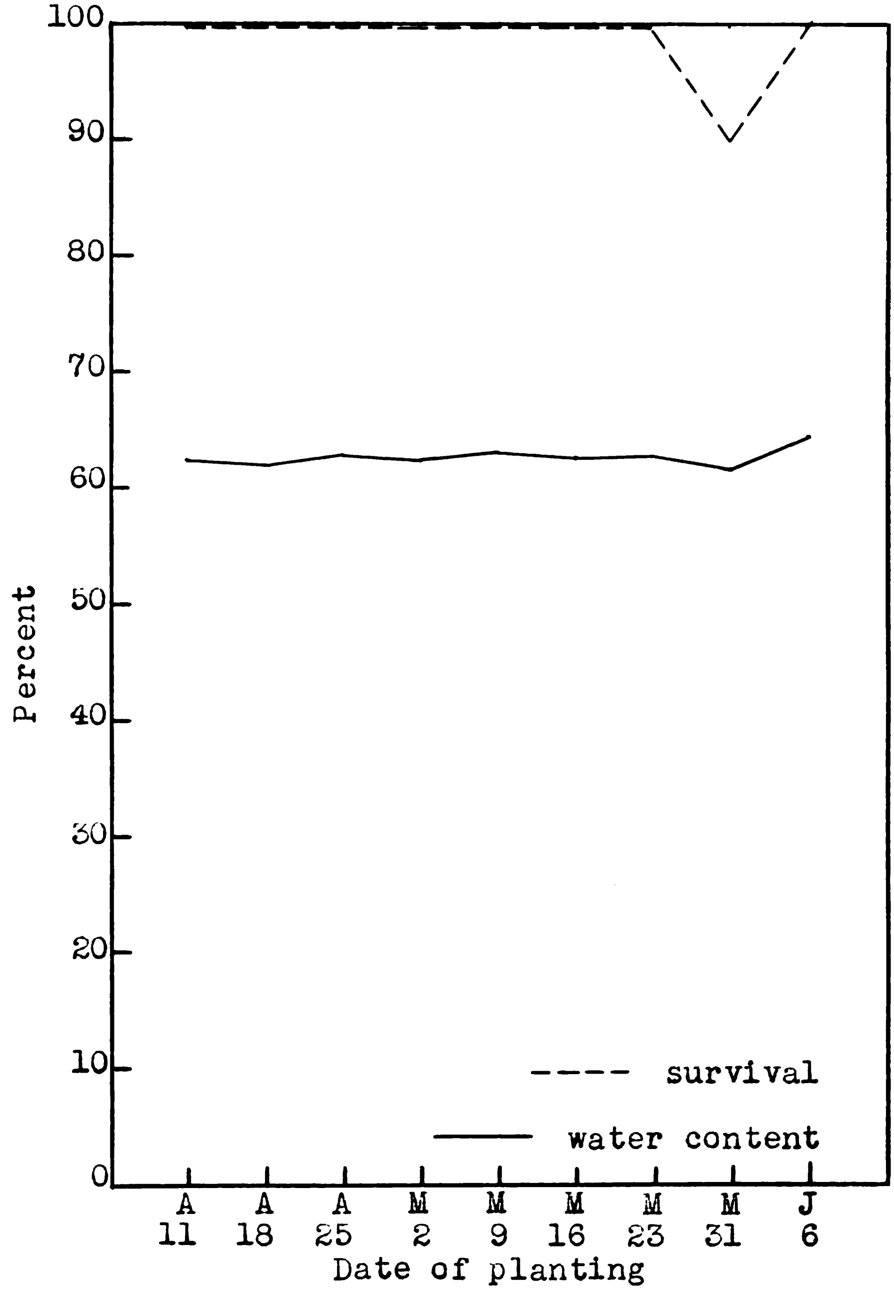

Fig. 5. Treatment I. Lot B. Water content and survival of white pine seedlings planted from cold storage April 11 to June 6.

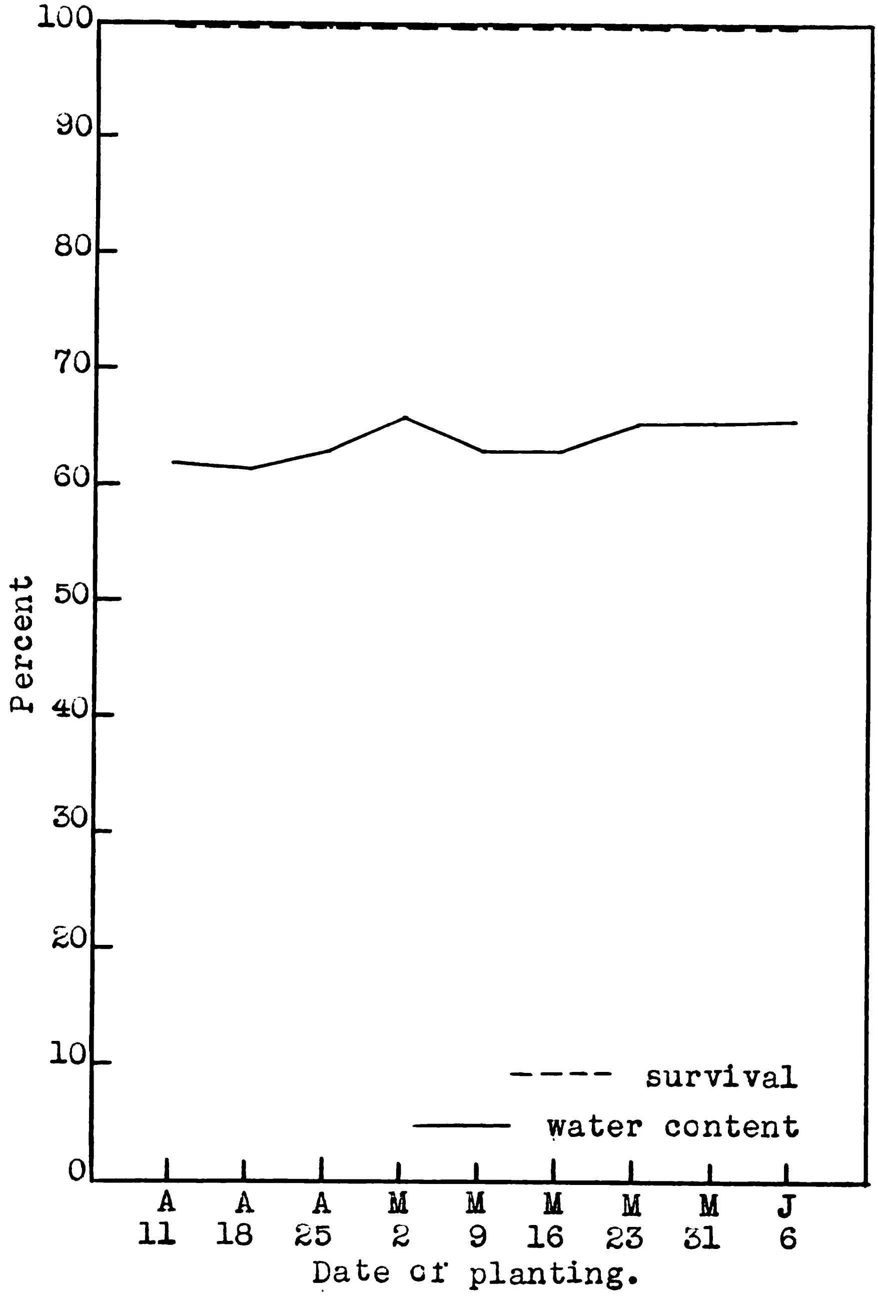

Fig. 6. Treatment I. Lot B. Water content and survival of red pine seedlings planted from cold storage April 11 to June 6.

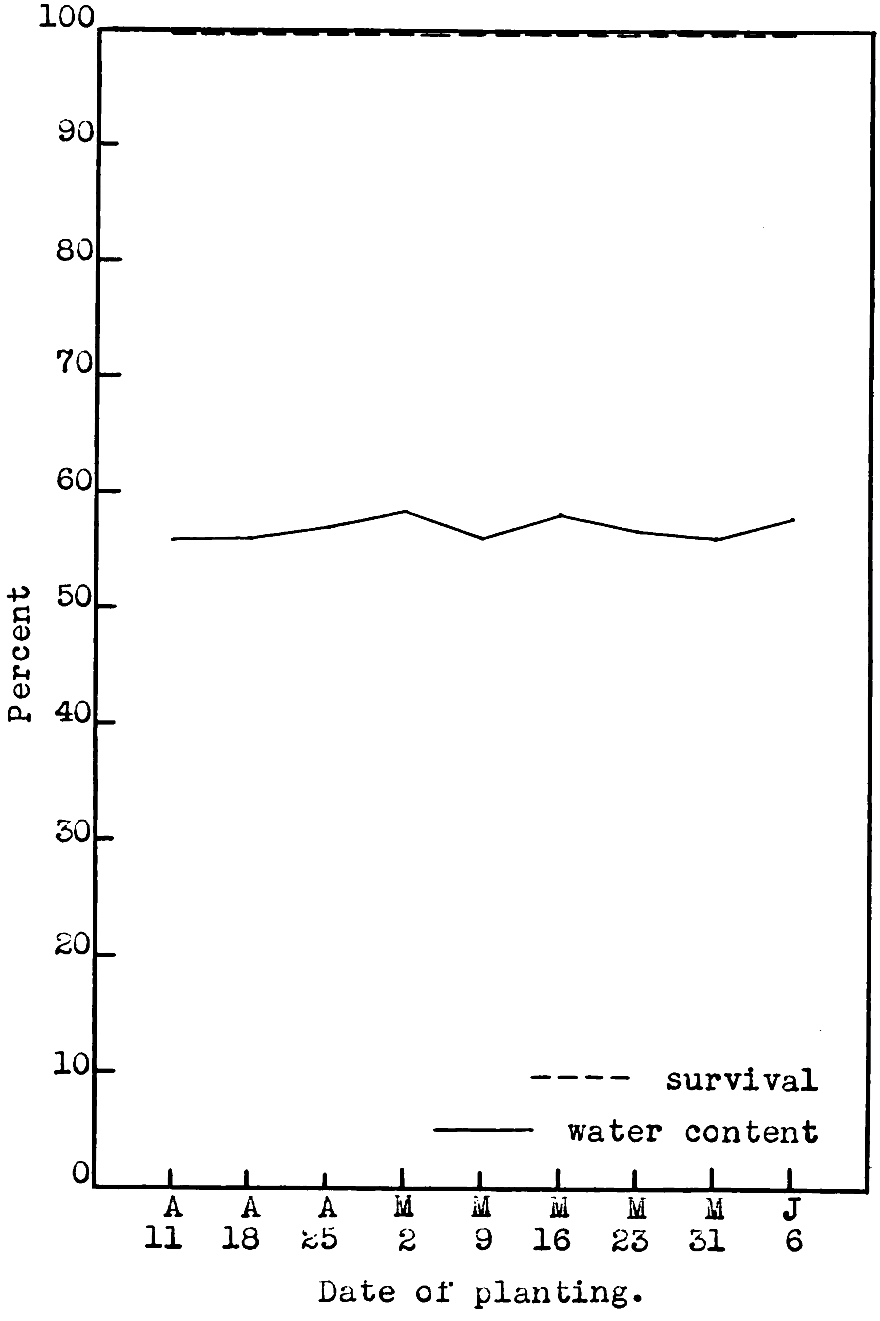

Fig. 7. Treatment I. Lot B. Water content and survival of Norway spruce seedlings planted from cold storage April 11 to June 6.

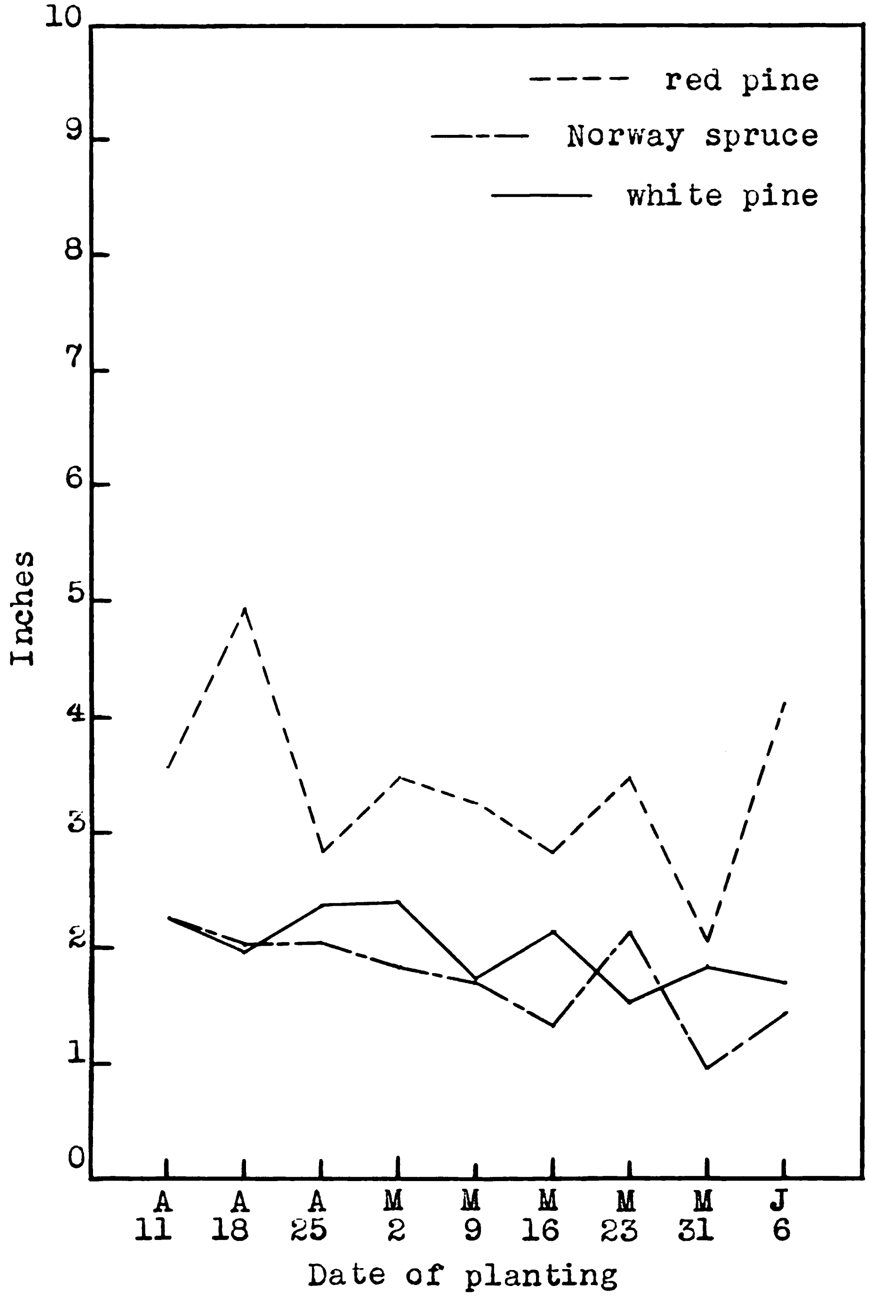

Fig.8. Treatment I. Lot B. Height growth of red pine, white pine and Norway spruce seedlings planted from cold storage April 11 to June 6.

for Lot B. Trees in Lot A made slightly better height growth than those in Lot B.

Height growth was extremely variable among the different species being most variable in red pine and least in white pine and Norway spruce. Red pine made the best growth while white pine and Norway spruce made significantly poorer growth. The height growth of white pine and Norway spruce was about the same.

There seemed to be a gradual change in the general appearance of the trees from the first plantings to the last. The trees in the later plantings in both Lots A and B had a yellow green color instead of the deep green color of the earlier plantings.

<u>TREATMENT II</u>. <u>The Effect of Rapid Transpiration on the Water Content of Seedlings</u>.

Results from rapid transpiration tests on five sets of seedlings show very little variation in water content. There was, however, a difference between species in the range of water content variation. In white pine and red pine the water content varied between 60 and 62 percent while in Norway spruce it varied between 50 and 55 percent. Water content results are shown in Figures 9, 10 and 11.

Survival was high for all sets tested. Figures 9, 10 and 11 give the survival percentages for each species in each test. All species gave practically complete survival.

Norway spruce and white pine made about the same height growth but showed a slight decrease in growth with

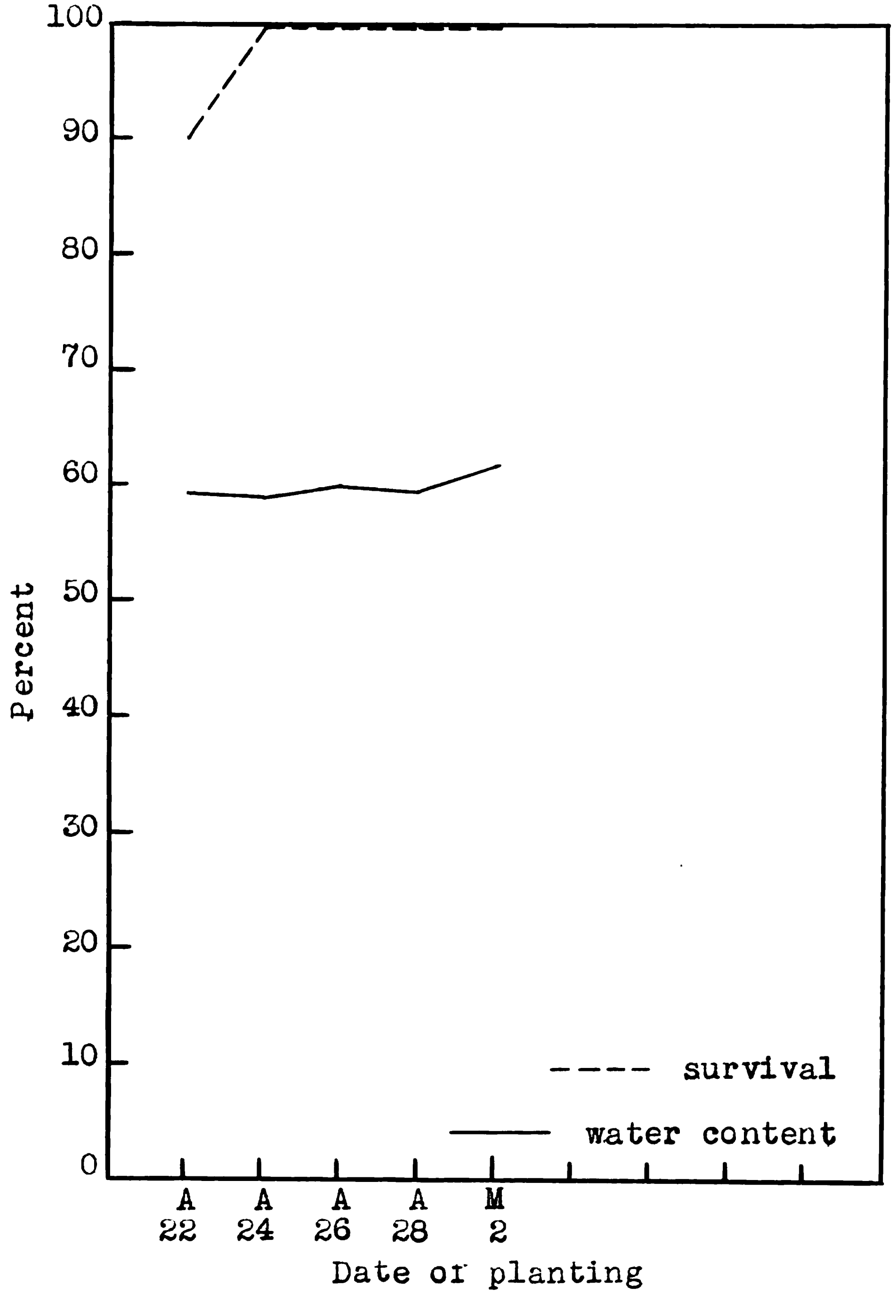

Fig. 9. Treatment II. Water content and survival of white pine seedlings after exposure of tops to rapid transpiration.

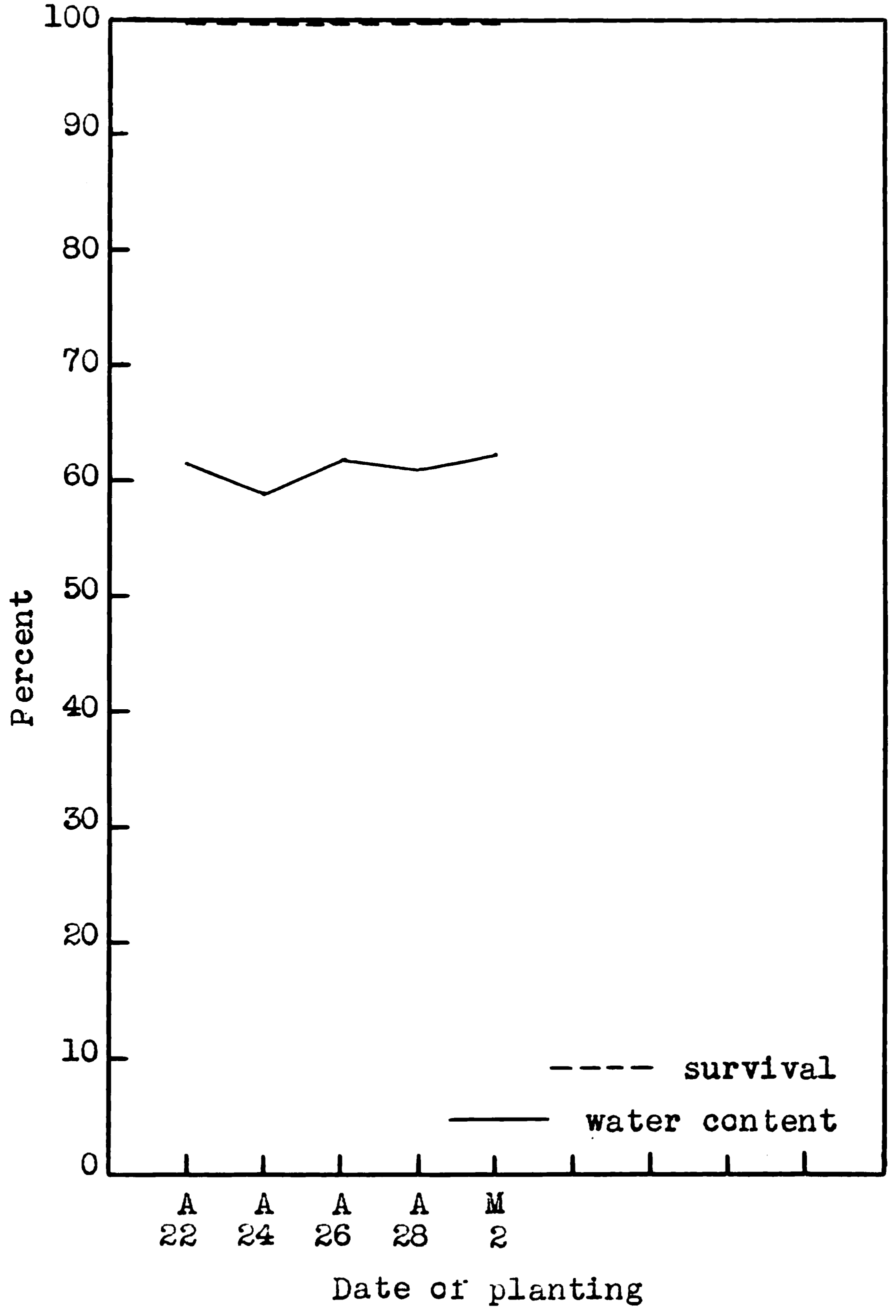

Fig. 10. Treatment II. Water content and survival of red pine seedlings after exposure of tops to rapid transpiration.

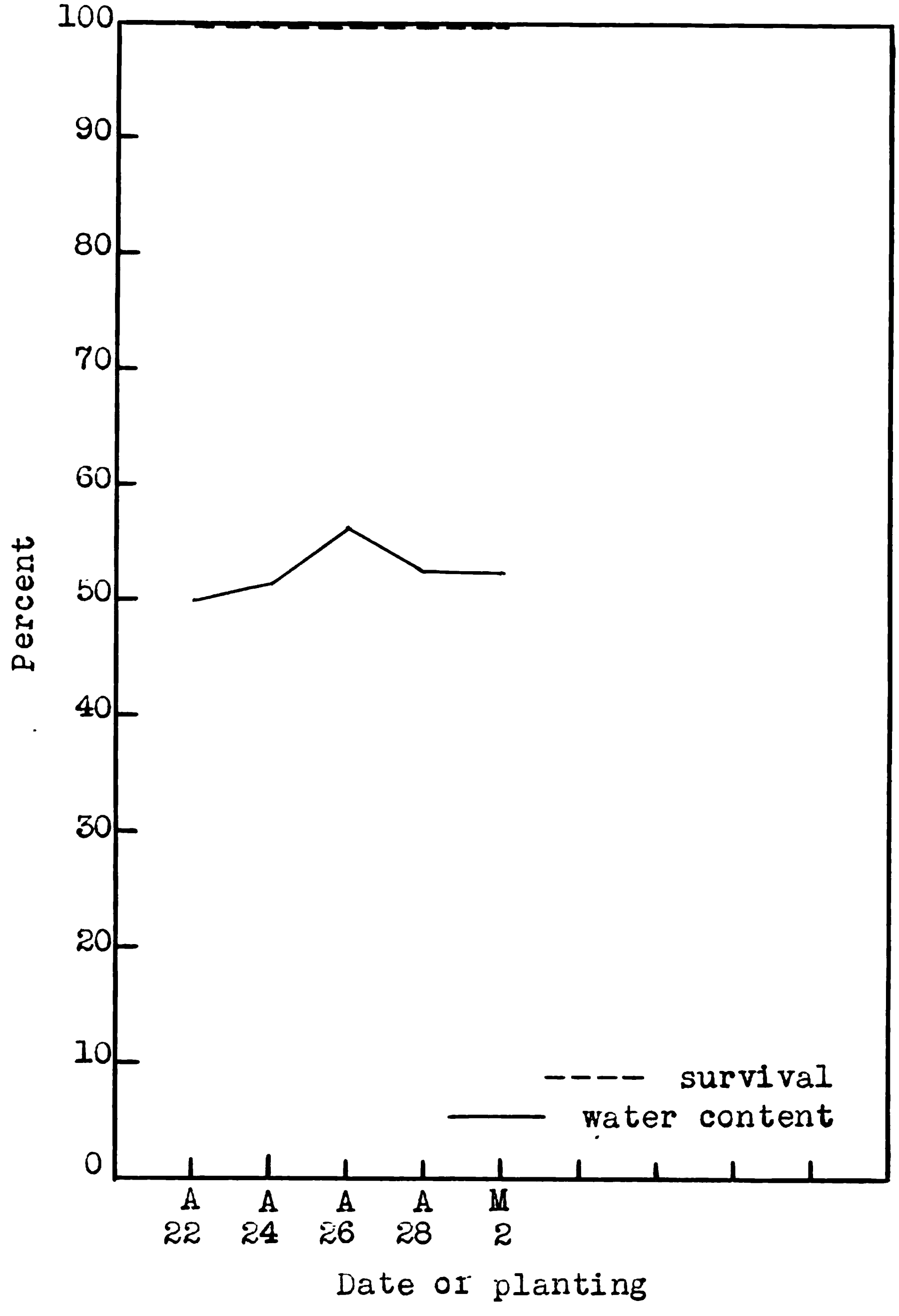

Fig. 11. Treatment II. Water content and survival of Norway spruce seedlings after exposure of tops to rapid transpiration.

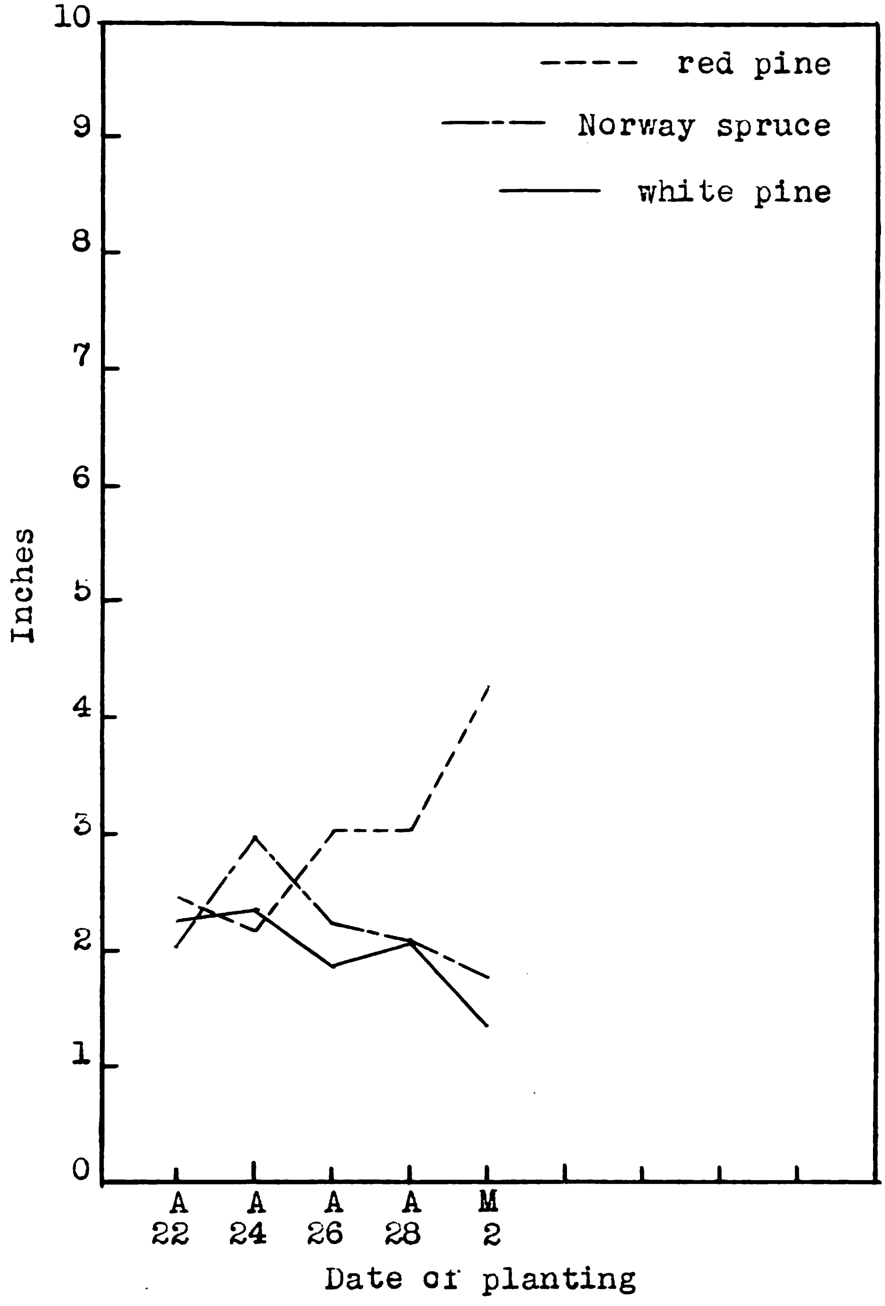

Fig. 12. Treatment II. Height growth of red pine, white pine and Norway spruce seedlings after exposure of tops to rapid transpiration.

time of planting. Red pine made greater height growth than the other two species and showed an increase in height growth with lateness of planting. Evidently the degree of drying to which the red pine was exposed did not seriously damage this species. Figure 12 shows the height growth made by each species.

At the end of the first growing season all trees in this series of plantings had a vigorous appearance and a healthy green color. The lowered height growth may be due to the gradual depletion of carbohydrate reserves which could be expected to take place during the period in which the trees were stored.

TREATMENT III. The Effect of Exposure of Roots and Tops on the Water Content of Seedlings.

All species showed a definite decrease in water content during the 0-14 hour exposure period. There was, however, a significant difference between species in the total per cent of water lost. White pine lost 22 per cent of its normal water content, red pine 14 percent, and Norway spruce 48 percent. Figures 13, 14 and 15 show the trend of water loss for each species.

The rate of water loss was more or less constant for Norway spruce but it slowed down considerably after four hours exposure in the case of white pine and red pine. White pine seemed to resist strongly the further loss of water when water content reached 56 percent. The point at which red pine began strongly to resist water loss was around 55 percent.

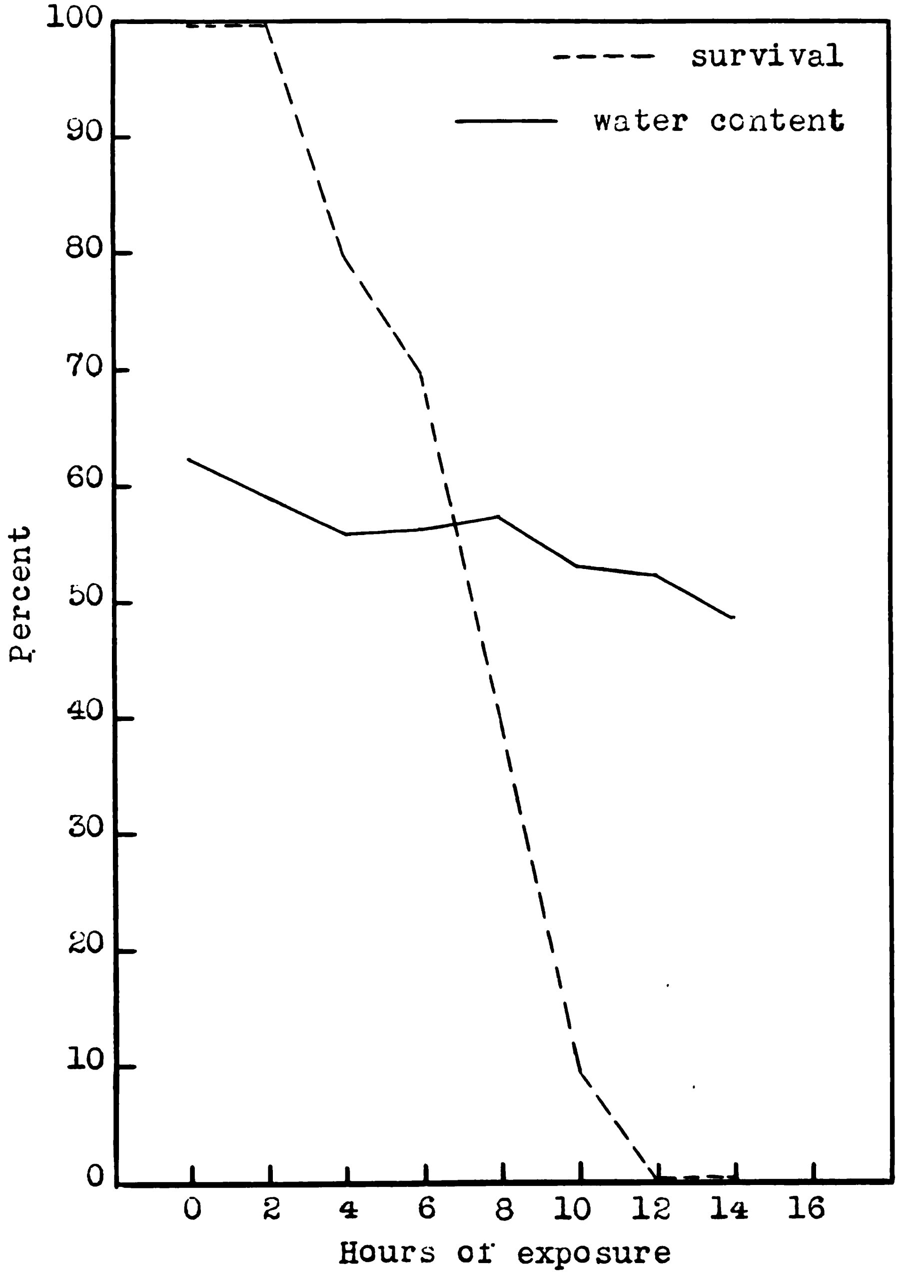

Fig. 13. Treatment III. Water content and survival of white pine seedlings after exposure of tops and roots 0 to 14 hours

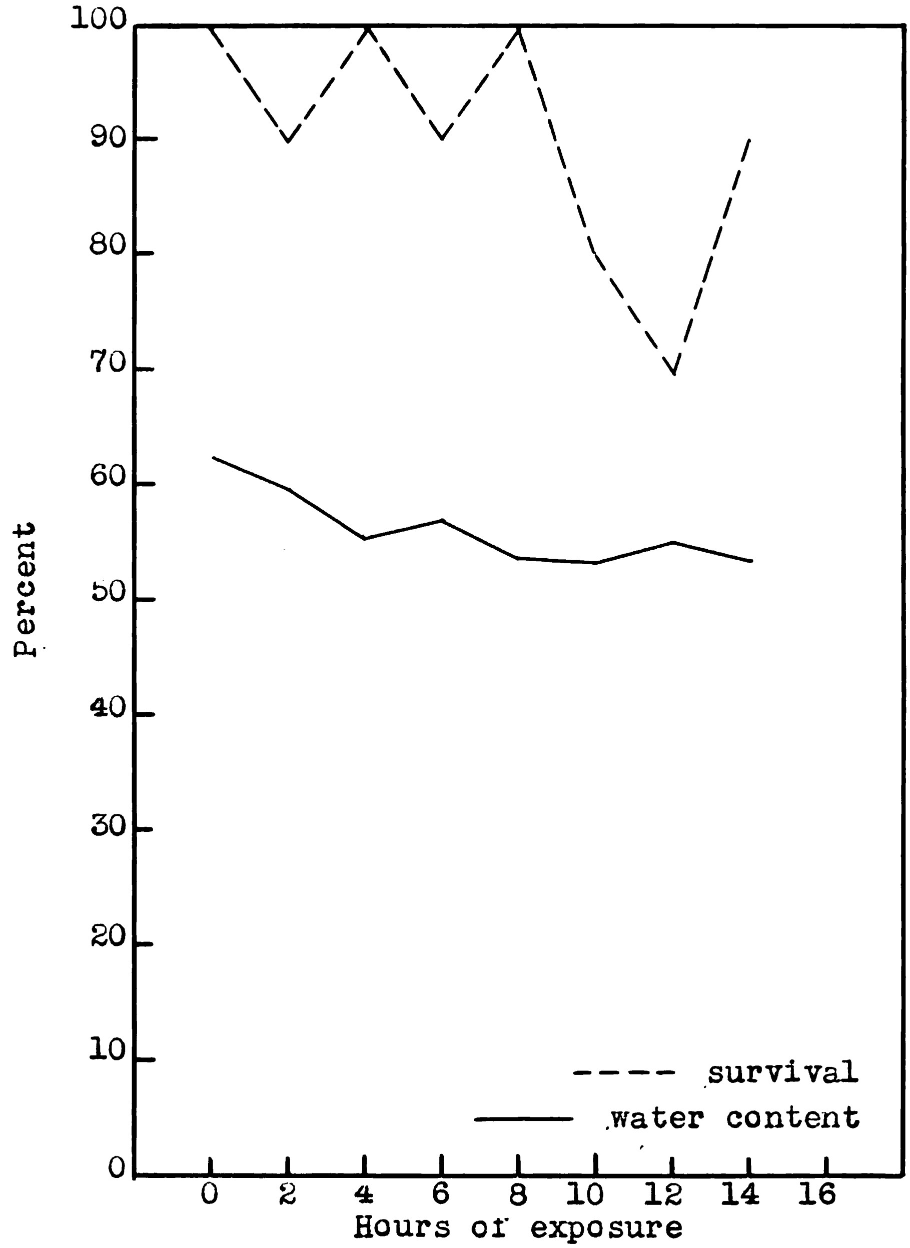

Fig. 14. Treatment III. Water content and survival of red pine seedlings after exposure of tops and roots 0 to 14 hours.

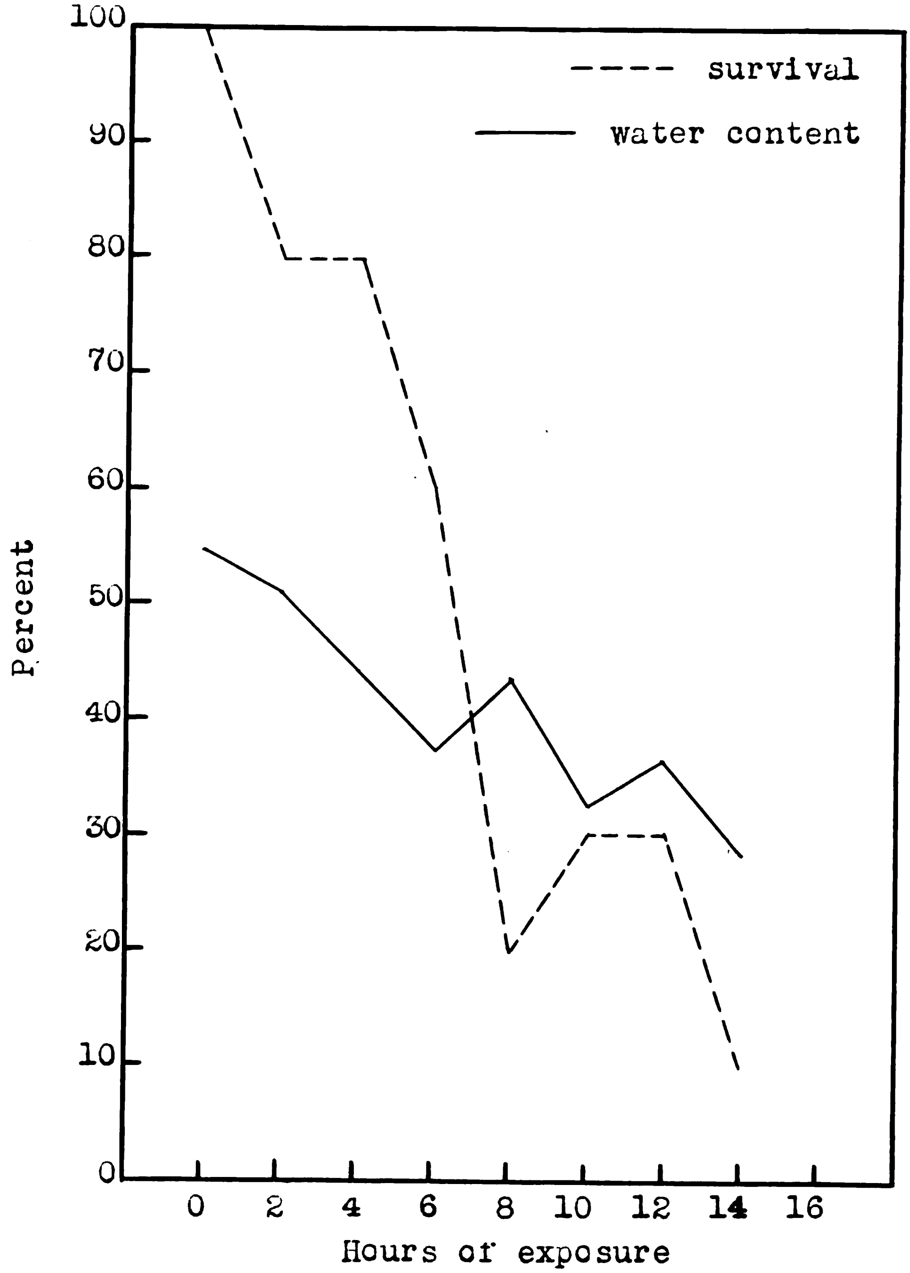

Fig. 15. Treatment III. Water content and survival of Norway spruce seedlings after exposure of tops and roots for 0 to 14 hours

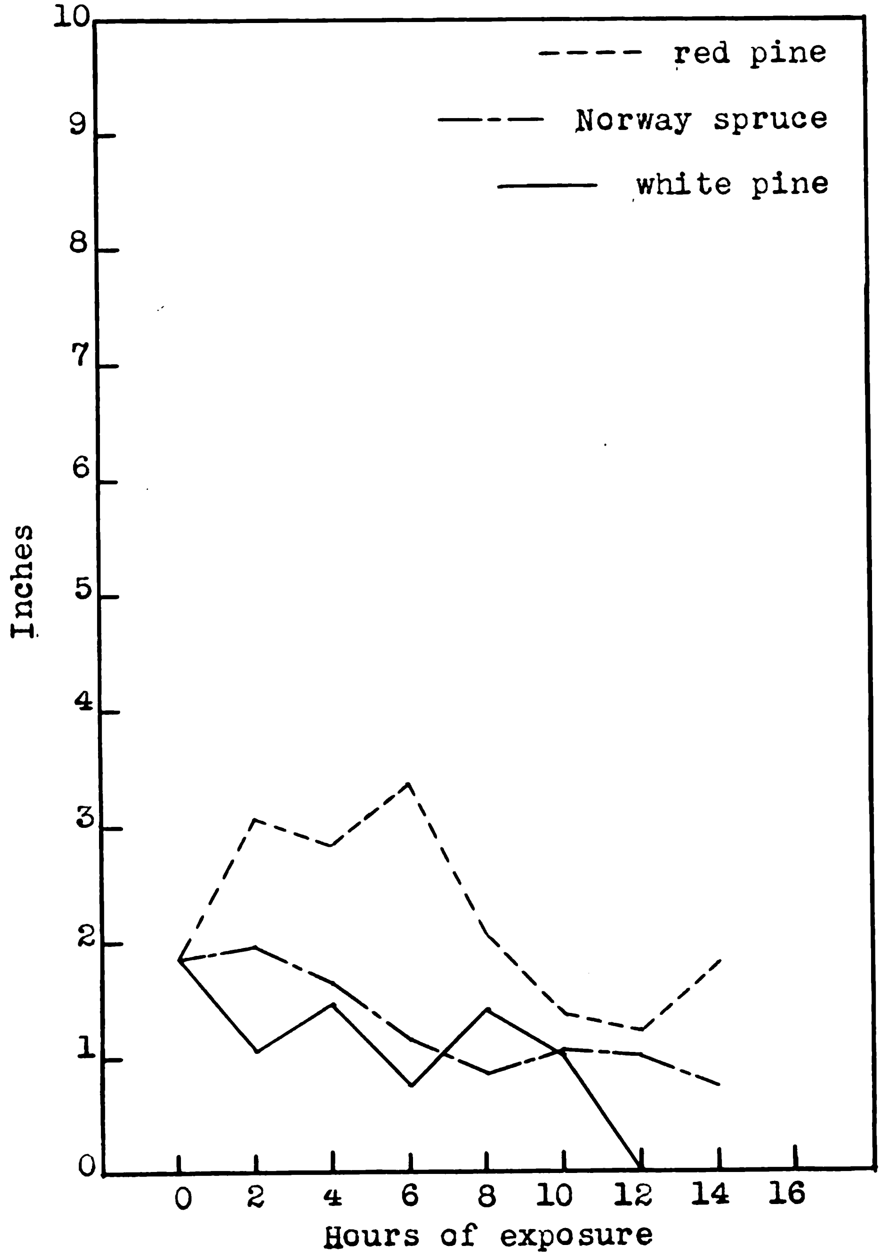

Fig.16. Treatment III. Height growth of red pine, white pine and Norway spruce seedlings after exposure of tops and roots 0 to 14 hours.

Loss in water content was accompanied by sharp increases in mortality except in the case of red pine. Even after drying for 14 hours red pine gave 90 per cent survival. When water content of white pine dropped below 56 per cent, survival fell rapidly. Norway spruce survival dropped rapidly when the water content fell below 37 to 40 per cent. Almost all the white pine and Norway spruce seedlings died after six to eight hours of exposure but red pine still gave high survival after 14 hours exposure. Figures 13, 14 and 15 show the survival data for each species.

Height growth decreased as the water content fell with increased time of exposure. Red pine showed greatest variation in height growth and Norway spruce the least. White pine made the poorest growth, Norway spruce was intermediate in growth rate and red pine best. Growth data for all species are shown in Figure 16.

The appearance of these trees at the end of the first growing season showed clearly the detrimental effects of exposure and loss in water content. After four hours of exposure all trees showed decreased vigor and change from a deep green color to a yellowish green color. The red pine that survived 8 to 14 hours of exposure appeared unthrifty.

<u>TREATMENT IV.</u> <u>The Effect of Exposure of Roots on the Water Content of Seedlings.</u>

The water content of all seedlings decreased throughout the period of exposure. Norway spruce lost 40 per cent of its total water content during the 14 hour exposure period while white pine lost 33 per cent and red pine 19 per cent. Figures 17, 18 and 19 contain the water content data for each species.

Norway spruce lost moisture at a constant rate. White pine seemed to resist further loss at a minimum of about 56 per cent but it did not resist for long. Red pine, strongly resisted water loss at a minimum of 55 per cent.

Survival decreased rapidly with loss in water content and length of exposure except in the case of red pine. This species had a survival of 80 per cent even after 14 hours of exposure. White pine survival did not show very close correlation with water content around the critical water content range, but survival dropped to zero soon after the water content fell below 56 per cent. Norway spruce survival fell to almost zero when the water content dropped below 38-40 per cent. Eight to ten hours of exposure caused almost complete mortality of white pine and Norway spruce but red pine withstood 14 hours exposure without serious loss in survival. Figures 17, 18 and 19 show the survival data for each species.

Height growth of all species was decreased by the loss in water during exposure. There was not much variation in growth in any species throughout the period of exposure. White pine made the poorest growth, Norway spruce was intermediate and red pine best in growth. The growth data for

each species are shown in Figure 20.

When the trees were examined at the end of the first growing season they showed the ill effects of water loss and exposure. Trees that had dried four hours and longer had poor color and low vigor. Red pine that survived 8 to 14 hours exposure appeared unthrifty.

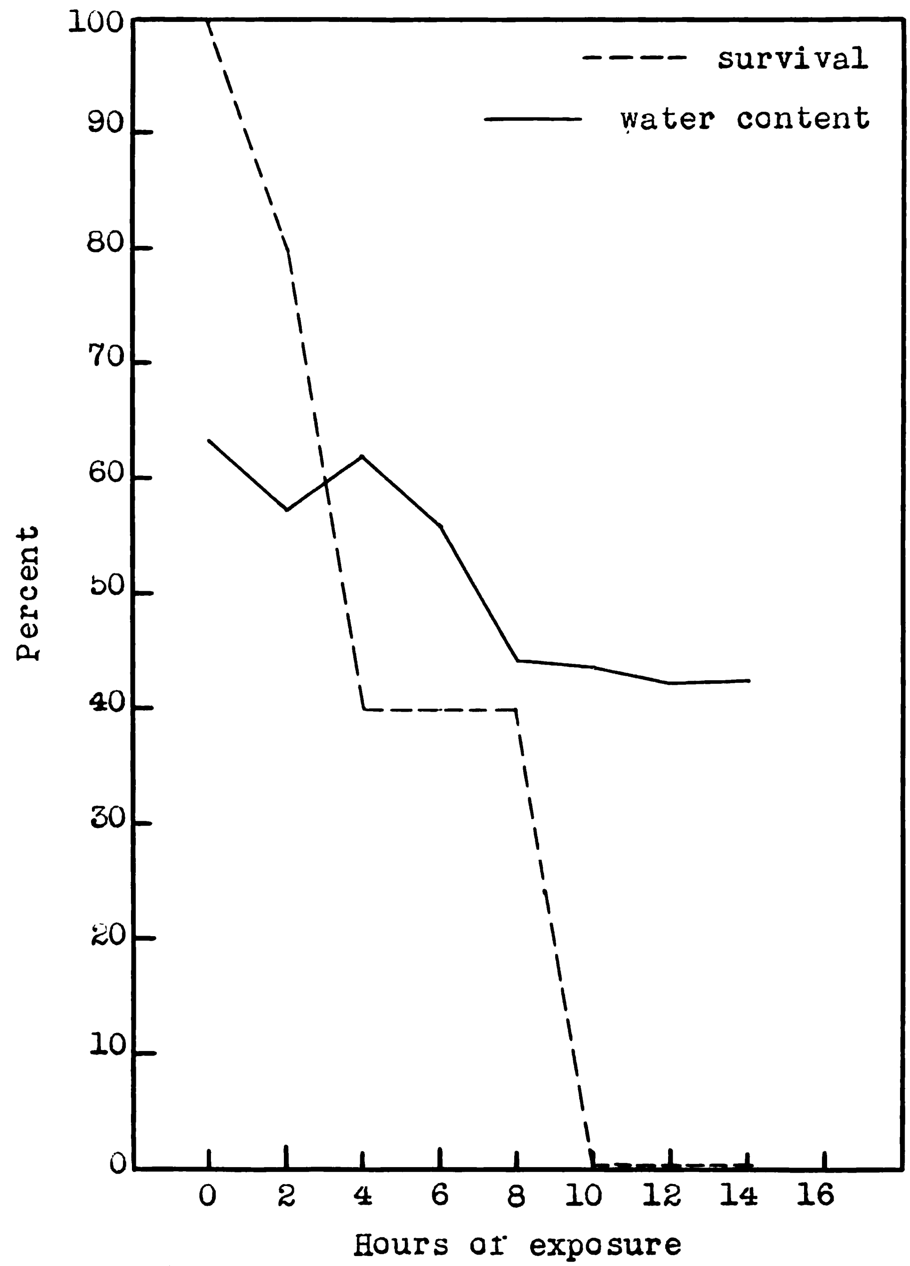

Fig. 17. Treatment IV. Water content and survival of white pine seedlings after exposure of roots for 0 to 14 hours.

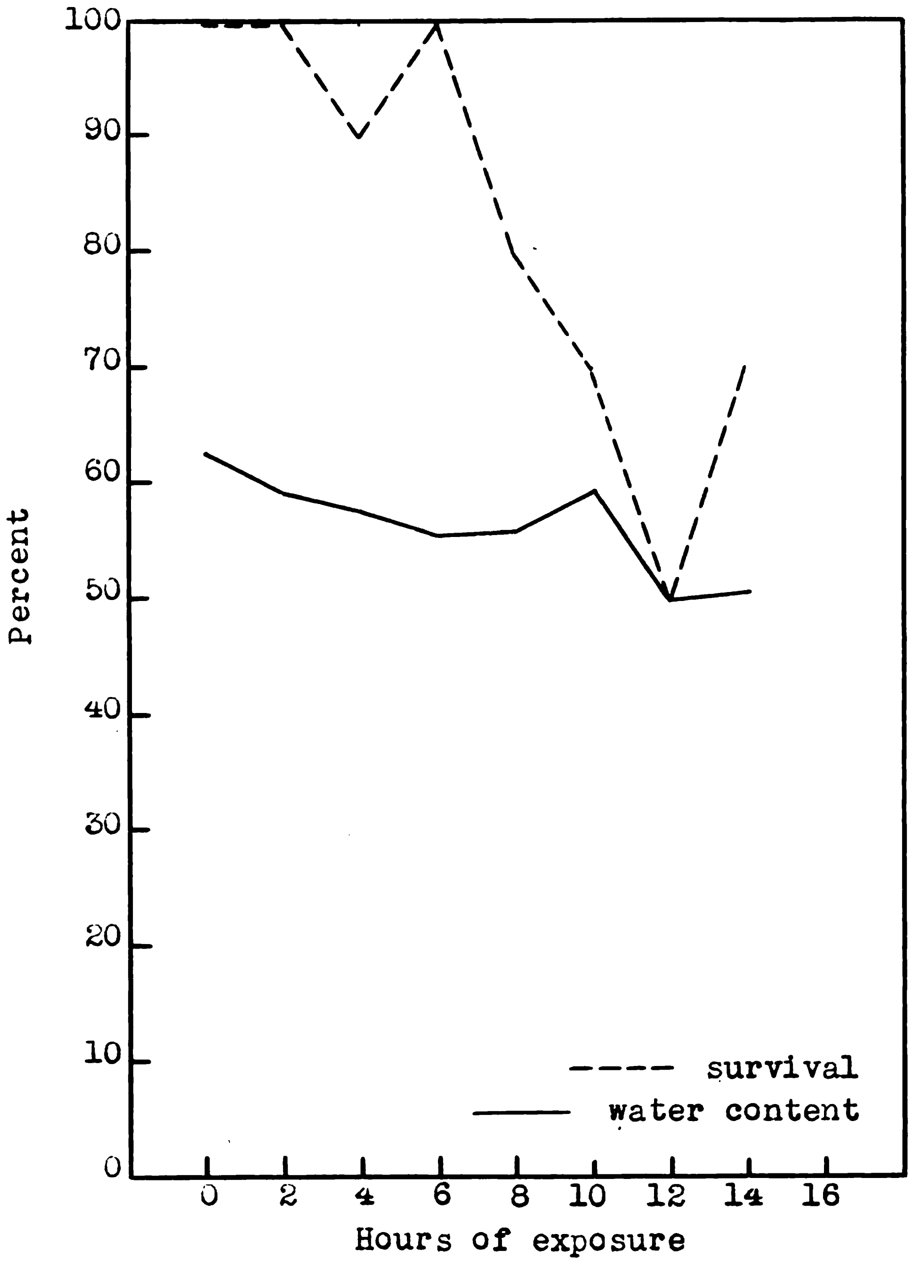

Fig. 18. Treatment IV. Water content and survival of red pine seedlings after exposure of roots for 0 - 14 hours.

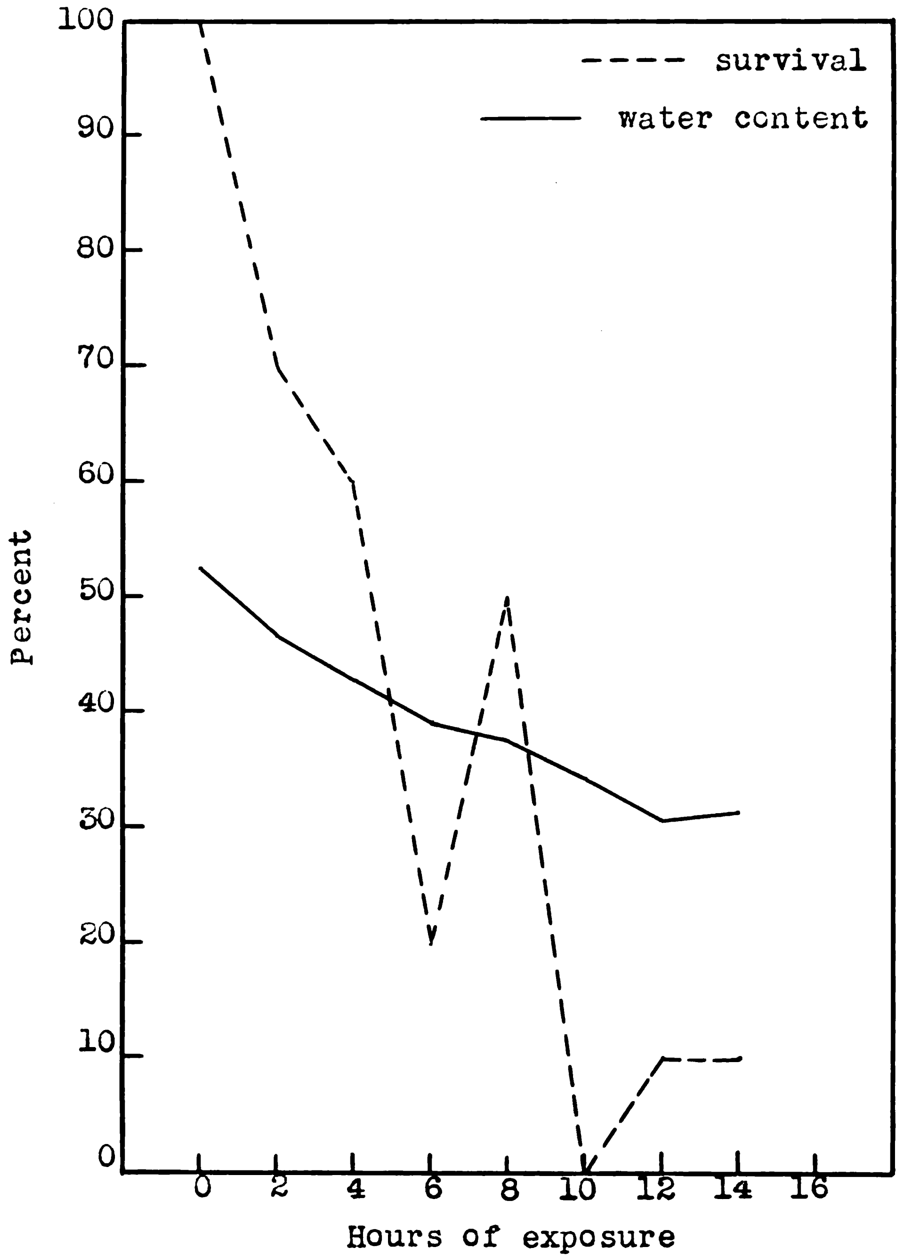

Fig. 19. Treatment IV. Water content and survival of Norway spruce seedlings after exposure of roots for 0 - 14 hours.

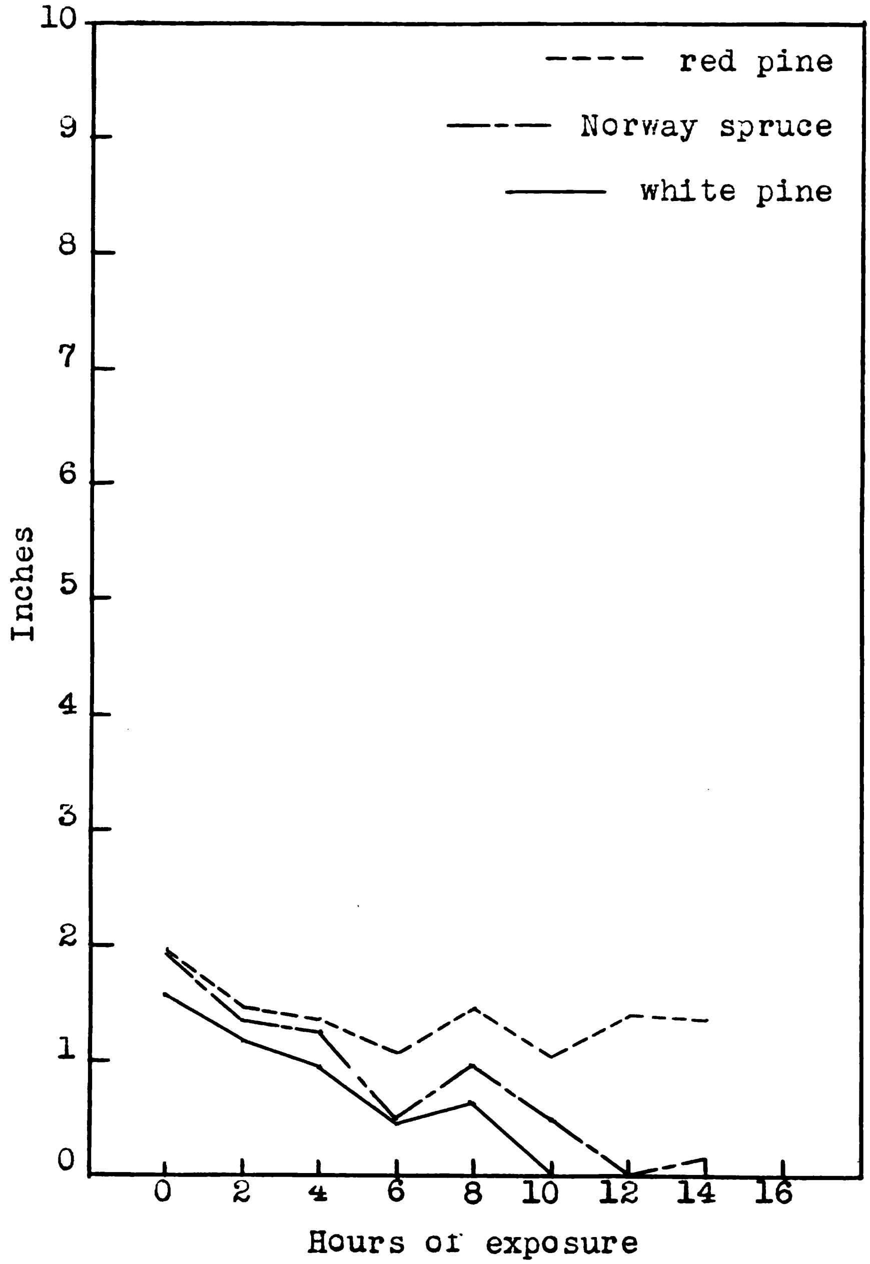

Fig. 20. Treatment IV. Height growth of red pine, white pine and Norway spruce seedlings after exposure of roots for 0 to 14 hours.

CHAPTER V DISCUSSION

The water content data from seedlings stored under cold storage conditions brings out clearly the different water content relationships of the three species. The relatively high water content of the three species is well shown. Seedlings maintained this water content with very little variation while in storage, indicating that water balance was carefully regulated. The low temperature and high relative humidity maintained under storage conditions may not have been conducive to loss of water by the seedlings. Certainly such quantities of water as may have been lost by the seedlings were readily compensated by absorption of water from the sphagnum moss.

Since the seedlings in Lot B were not watered during the eight week cold storage period it may be concluded that water loss by the seedlings in storage was not great. Otherwise available water in the moss would have been exhausted before the end of eight weeks and water contents of the seedlings would not have been maintained. Under storage conditions water content of Lot B, the unwatered lot of seedlings, remained practically the same as water content of Lot A, the watered lot.

A report of the Forest Service (7) states that as a result of tests conducted in Region I the spring planting season could not be prolonged by holding trees in cold storage. Results of this study, however, show that trees gave high survival when planted from cold storage a month after the regular planting season. Perhaps the differences may be due to different methods of packing or storage conditions, or in case of the Forest Service tests, to unfavorable field conditions later in the season. A decrease in vigor was noted, however, with increased time in storage. It may be considered therefore that planting stock will deteriorate when subjected to long periods of cold storage. In the case of white pine, red pine and Norway spruce seedlings, deterioration was not serious over an eight weeks period when moisture content of seedlings was maintained.

Exposure of red pine, white pine and Norway spruce seedlings to conditions favoring rapid transpiration resulted in only slight decreases in water content of these species. This further illustrates ability of the seedlings to maintain a favorable water balance when soil moisture supplies are adequate. The order of drought resistance of the three species was indicated by the amount of water lost under conditions favoring rapid transpiration. Red pine water content was reduced 2 per cent, white pine 3 per cent and Norway spruce 5 per cent. This is the recognized order of drought resistance of these species, red pine being the most drought resistant.

While four hours exposure to conditions favoring rapid transpiration resulted in reductions of water content of from 2 to 5 per cent, survival was not affected. Height growth, however, was reduced slightly by the brief period of drying, indicating that slight drying may have unfavorable physiological effects.

In comparison with drying of tops alone, the same order of rate of drying held for the three species when entire seedlings were exposed to drying. Rate of drying was much more rapid, however, when both roots and tops were exposed. Norway spruce dried more rapidly than white or red pine, and white pine dried more rapidly than red pine. This is in agreement with Laing's (5) results which showed that Norway spruce dried rapidly at room temperature.

Laing suggested that critical water content for the shoots of Norway spruce transplants might be around 100 per cent (dry weight basis) or 50 per cent (green weight basis). Results of this study show that critical moisture content of Norway spruce seedlings may be considerably lower, perhaps 37 to 40 per cent on green weight basis.

White pine showed a critical water content of around 56 per cent while red pine showed a critical water content of around 50 per cent. Although these two species seemed to have about the same critical point, they displayed marked differences in ability to withstand further drying after the critical point had been reached. White pine water content remained at the critical point only a short time then dropped, causing a sharp decrease in survival. Red pine

water content, however, fell to the critical point and remained there throughout the 14 hour exposure period with no serious reduction in survival. This shows definitely the high degree of drought resistance of red pine.

Laing believed that high water content of seedlings would be favorable to survival and suggested that water content of seedlings could be increased by artificial watering before lifting or by shading. From results of this study indicating that water content is close to the maximum under favorable moisture conditions, watering would be of little value unless soil moisture had become distinctly limiting.

Marked reductions in height growth occurred when seedlings were severely dried. All tests with seedlings showing significant water content reductions gave reduced height growth. Since trees with low water content also appeared in poor vigor, it seems that low water content brings about certain unfavorable physiological changes. Perhaps the shortened growing season due to later planting may be a factor in the low vigor of some trees, yet trees with low water content planted earlier in the season exhibited similar low vigor conditions.

In the case of Treatment III in which the roots and tops of the seedlings were exposed from 0 to 14 hours, all trees were planted in the nursery on the same day. Marked differences in vigor existed depending on the degree of drying. Low vigor must be caused therefore by factors other than, or in addition to, shortened growing season. The exact mechanism by which low water content results in reduced vigor and growth is not indicated by this study.

CHAPTER VI SUMMARY AND CONCLUSIONS

During 1938 a series of tests was conducted at Michigan State College to determine the effect of water content on survival and growth of forest planting stock. Various storage and drying treatments were given 3-0 seedlings of red pine, white pine and Norway spruce. After treatment the trees were planted to determine survival and growth results.

1. Water content of red pine, white pine and Norway spruce seedlings was maintained at a high level when the trees were packed in moist sphagnum moss and placed in cold storage over a period of eight weeks.

2. Frequent watering of stored trees failed to raise their water content over that of unwatered checks.

3. Water contents of white pine and red pine during cold storage were very similar,62 to 63 per cent, but higher than for Norway spruce, 56 per cent. Very little variation in water content of seedlings occurred during the eight weeks of storage.

4. Survival of all trees planted from cold storage during the eight week period was consistently high.

5. All the species maintained favorable water contents when the tops were subjected to conditions favoring rapid transpiration for a period of four hours.

6. When subjected to drying conditions, the water content of Norway spruce was reduced much more rapidly than for white pine and the white pine was reduced more rapidly than for red pine.

7. Critical water contents of about 38 per cent, 55 per cent, and 56 per cent of green weight are indicated for Norway spruce, red pine and white pine respectively.

8. The order of drought resistance of the three species is indicated by the rate of water loss under conditions favoring drying.

9. Lowered water contents resulted in decreasing survival rates and decreasing height growths.

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APPENDIX.

A Rapid Method for Making Water Content Determinations.

If water content determinations are to be made to determine the condition of planting stock at the time of planting, some quicker method than oven drying must be used. To be of greatest value it must be possible to obtain the water content of the stock within 24 hours from the time samples are taken. Oven drying is a very slow method taking from four to seven days to dry samples to constant weight. The solvent distillation method using re-flux condensation provides a possible solution to this problem as it is fast and reasonably accurate.

The solvent distillation method is based upon the principle that the boiling characteristics of a liquid are changed when it is boiled in mixture with another liquid with which it is immiscible. There are several factors that make this method especially adaptable to the determination of moisture content: (1) each of two immiscible liquids exerts its own vapor pressure, causing the mixture to boil at a temperature lower than the boiling point of either liquid; (2) The distillate condensed from the vapors produced by the boiling mixture is composed of immiscible and readily separable quantities of water and solvent, permitting the measurement of the actual volume of water removed from the sample; and (3) the boiling point of the solvent is independent of all external physical conditions except atmospheric pressure.

When the moisture content is to be determined the sample is distilled in an extraction flask with some solvent immiscible with water. Upon heating to the boiling temperature of the mixture, water in the sample is driven off as steam and is carried with the solvent vapor into a suitable condenser where both are condensed to liquid and flow into a graduated receiver. Since water has a higher specific gravity than the solvent it collects at the bottom of the receiver where it forms a measurable layer beneath the solvent.

There are several solvents immiscible with water that can be used. Buck and Hughes (2) in California found that xylene gave the best results when determining the moisture content of forest litter. Some tests were made with toluene during the course of this study but it was found that the results were usually lower than the oven dried sample. It is believed that more accurate results could have been obtained with xylene which boils at a higher temperature than toluene. However, with leaves and non-woody tissue toluene gives good results. The official method designated for determining the moisture content of grain and stock feeds (1) by the distillation method specifies the use of toluene.

Moisture content determinations can be made very rapidly by the solvent distillation method. Buck and Hughes found that one hour was sufficient time to remove most of the water from samples of forest litter. In determining the moisture content of grain and stock feed the official method states that one hour is ample time for the moisture to be removed. In the tests made during this study it was also found that practically all the water in the sample was distilled over within an hour's time.

The solvent distillation method has the further advantage of being mobile. It can be set up whereever there is running water for the condenser. Electricity is the safest and best source of heat but gas or alcohol could be used.

The solvent distillation method is presented here as a rapid, accurate method for making moisture content determinations of forest planting stock. It is believed that foresters interested in forest physiology could use this method to advantage in moisture determination work.