Mycorrhizal

and

Survival of Douglas-Fir Seedlings

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SUMMARY

Correlation was sought between abundance of mycorrhizae on Douglas-fir seedlings and their survival in field plantations.

One possible indication of dormancy desirable for lifting from nursery beds could be the varying seasonal abundance of ectotrophic mycorrhizae on roots of seedlings. No direct correlation between percentage of mycorrhizae and survival in field was found; however, a conclusion was that when 60 per cent or more of the roots of seedlings have mycorrhizae, survival in field is enhanced, and reforestation should be aided.

Data interpreted here, and in a concurrent study by Lavender, should aid in selecting favorable periods for lifting and planting Douglas-fir.
INTRODUCTION

Failures or high mortality in plantings of Douglas-fir seedlings have stimulated studies to determine means of attaining increased survival.

The present study was undertaken to determine, first, if there was any relationship between abundance of mycorrhizae in Douglas-fir and survival in field plantations, and second, if there was any relationship between abundance of mycorrhizae on Douglas-fir and number of active root tips.

In an accompanying study, Lavender (6)*, related dormancy and date of lifting Douglas-fir to number and percentage of active root tips on seedlings suitable for out-planting. Moreover, Lavender discussed effect of date of lifting and duration of storage upon field-survival potential and physiology of Douglas-fir seedlings.

The physiological significance of ectotrophic mycorrhizae has been demonstrated by Björkman (1), Melin (8), Mikola (9), Hatch (3), Salankis (11), and others. "Mycorrhizal formation is a sign that energy-giving nourishment is in the host plant," according to Kelly (5).

Increased absorptive capacity of mycorrhizae has been regarded by Hatch (3) as one of their major beneficial characteristics. Production of auxins which influence proliferation of roots also appears significant (11).

In conifers, possession of mycorrhizae is dependent upon edaphic, or soil, factors (5). Variations in a uniform soil of forest nurseries would appear to be reduced to a minimum. Björkman (1) maintains that mycorrhizae are conditioned by an excess of carbohydrates in the roots. Since carbohydrates should increase as a plant approaches dormancy, a suggested hypothesis was that mycorrhizae would be most abundant when roots of the host plant had an excess of stored food. There is no evidence to support this hypothesis for Douglas-fir, but Hepting (4) found increased concentration of carbohydrates in the roots of shortleaf pine during the winter. Thus, there may be a monthly increase in the number or percentage of mycorrhizae. With this premise as a basis, the roots of seedlings grown in nurseries were examined periodically for presence of ectotrophic mycorrhizae.

*Numbers in parentheses indicate similarly numbered references.
METHODS AND PROCEDURE

During the three years from 1959 to 1961, seedlings were lifted from the nursery every two weeks from late August until early December, and then again in February of the succeeding year. One hundred seedlings were out-planted in each of two areas immediately after lifting. Survival in the field was measured each fall for plantings of the previous fall; winter, or spring. Each month from September to December, and again in February, mycorrhizal development and activity of roots were determined for a lot of seedlings immediately after lifting. From 5 to 10 seedlings were selected at random from each group as they were dug for out-planting. Roots of the seedlings were washed in running water to remove debris and excess soil. They were examined under a binocular microscope (12X to 20X) while the roots were immersed in a shallow watch-glass of water.

Two planting sites were selected in the Tillamook burn (Sec 34, T2N, R7W, Willamette Meridian) and in the Cascade mountains northeast of Salem, Oregon (Sec 18, T7S, R3E, Willamette Meridian) on Butte creek. The investigations were conducted over a period of three years, both in controlled-environment facilities of the Forest Research Laboratory and in out-planting areas. Severe damage by animals nullified usefulness of the area on Butte creek after the first year.

Ectotrophic mycorrhizae (Figures 1. 2) were counted and tallied according to depth of occurrence, color, and type (whether digitate, forked, racemose, or clustered). Racemose and mycorrhizal clusters were considered as multiples and were recorded as the number of individual mycorrhizal root tips observed. There was no precedent for this procedure, but because of the increased absorptive surface and production of auxin, this procedure appeared more applicable than tallying racemose or mycorrhizal clusters as single units.

Samples of mycorrhizal roots also were sectioned and stained by Max Halber, microtechnician, for determining presence or absence of the "Hartig net". This procedure was not followed systematically throughout the study, but provided occasional verification. Lateral roots were excised for increased accuracy in counting mycorrhizae; hence, the seedlings analyzed were not out-planted.

Data presented in Figures 3, 4, and 5 show considerable variation in the number of mycorrhizae from month to month, but these variations were not consistent from year to year. When the percentage of roots with mycorrhizae was calculated on the basis of total root tips, the correlation with survival in field was still variable within the year, as is shown clearly in the figures.
The total height of seedlings, length and width of the root system, color of the seedling, and diameter of stem were recorded. Clearly transparent root tips were tallied. In some instances, short roots also were counted.* Presence and appearance of terminal buds were noted as further indications of dormancy. The data assembled were correlated finally with survival in field.

To simplify data, the effect of storage prior to planting was not included, and survival was based on seedlings transplanted within 24 hours after lifting. The reader may refer to Lavender (6) for additional explanation on above phenomena.

RESULTS

The majority of mycorrhizae observed were white and gray in color and occurred most commonly in racemose or coralloid clusters (Figure 1). A small and highly variable percentage was identified as Cenococcum graminforme (Sow.) Fred. and Winge, originally recognized by Melin (8) as dark-brown or black mycorrhizae. These usually were digitate, but occasionally were forked (Figure 2).

Percentages of survival and mycorrhizae and number of mycorrhizae are shown for each year in Figures 3, 4, and 5. To minimize variations in edaphic and environmental factors, mycorrhizal counts and data on survival for the Tillamook plantation were averaged for the three-year period, 1959-1962. After August, the monthly percentage of mycorrhizae approximated the percentage of surviving seedlings until January, when survival was from 7 to 10 per cent higher (Figure 6). These data do not show that the number of mycorrhizae followed a regular seasonal trend as described by McDougall (7) and Masui (6). They found that mycorrhizal formation reached a maximum in late summer or early fall and declined thereafter to a minimum during the winter months. In the present study, mycorrhizal counts varied greatly, but were usually lowest in the spring and generally high during the rest of the year. No counts were made during May, June, and July.

*Counts of short roots in this test cannot be considered absolutely accurate because of loss during digging and handling.
Figure 1. Most mycorrhizae seen were white and gray clusters.

Figure 2. *Cenococcum graniforme* were dark and usually digitate.
Figure 3. Relationship of survival of Douglas-fir seedlings to number and percentage of roots with mycorrhizae after one season in the field in 1960.

Figure 4. Relationship of survival of Douglas-fir seedlings to number and percentage of roots with mycorrhizae after one season in the field in 1961.
Figure 5. Relationship of survival of Douglas-fir seedlings to number and percentage of roots with mycorrhizae after one season in the field in 1962.

Figure 6. Relationship of survival of Douglas-fir seedlings to percentage of roots with mycorrhizae after one season in the field during three years of the study.
DISCUSSION

Surprisingly, no regular, periodic correlation was found between number or percentage of ectotrophic mycorrhizae and survival of out-planted seedlings. Survival of out-planted stock is influenced by edaphic and many other varying environmental factors (2). A good illustration is shown by the variation in survival between the plantations at Butte creek and in the Tillamook burn in 1959-60 (Figure 3). In some months, survival was better at Butte creek than in the Tillamook plantation, and in other months, the relationship was reversed. High survival was shown consistently in both areas for stock lifted during mid-winter months.

There was no consistent monthly trend shown by number or percentage of mycorrhizae, perhaps because of marked periodic fluctuations in precipitation throughout the different lifting periods. In the early part of the fall, in particular, amount of precipitation appeared to have direct influence on growth of new roots and also on mycorrhizal formation. Abundance of C. graniforme has been reported to be related to soil moisture (12, 13).

Considering the few seedlings examined for mycorrhizae and the limitation of planting sites, more consistent results for mycorrhizal associations probably could not be expected. As McArdle (10) has pointed out, "A large number of seedlings must be used... to eliminate experimental error and to offset the inherent differences... in certain tree species." This suggestion is particularly true of Douglas-fir, which is well-recognized for its high degree of variability.

A tentative conclusion was that, when Douglas-fir seedlings possess 60 per cent or more ectotrophic mycorrhizae, they are dormant enough for lifting with reasonable assurance of high survival when properly handled and carefully transplanted.
REFERENCES


FOREST RESEARCH LABORATORY

The Forest Research Laboratory, Oregon State University, is part of the Forest Research Division of the Agricultural Experiment Station. The industry-supported program of the Laboratory is aimed at improving and expanding values from timberlands of the State.

A team of forest scientists is investigating problems of growing and protecting the timberland crop, while wood scientists endeavor to make the most of the material produced.

The current report stems from studies of forest management.

PURPOSE

Develop the full potential of Oregon's timber resource by:

increasing productiveness of forest lands with improved practices.

improving timber quality through intensified management and selection of superior trees.

reducing losses from fire, insects, and diseases—thus saving timber for products and jobs.

Keep development of the forest resource in harmony with development of other Oregon resources.

PROGRAM

REGENERATION through studies of producing, collecting, extracting, cleaning, storing, and germinating seed, and growing, establishing, and protecting seedlings for new forests.

YOUNG-GROWTH MANAGEMENT through studies of growth and development of trees, quality of growth, relationship of soils to growth, methods of thinning, and ways of harvesting to grow improved trees.

FOREST PROTECTION through studies of weather and forest fire behavior to prevent fires, of diseases and insects to save trees, and of animals to control damage to regrowth.

TREE IMPROVEMENT through studies of variation, selection, inheritance, and breeding.
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