ECTOMYCORRHIZAS AND QUALITY OF NURSERY STOCK[1]

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The effect of ectomycorrhizas on the quality of nursery stock should be viewed in the light of solar radiation, potent eradicants, and liquid fertilizer treatments.

During recent time, some findings have indicated a negative correlation between high levels of nitrogen and phosphorus and susceptibility of trees to ectomycorrhizal infection (*6*)[2]. Suggestions also have been made that the production of mycorrhizal short roots is favored by low or moderate soil fertility, and a high frequency of ectomycorrhizal infection was reported in nursery stock raised on soils with a low supply of available phosphorus (*1*). These findings deliver to nursery managers the message that a high level of soil fertility decreases the abundance of mycorrhizal short roots, and perhaps deteriorates the quality of the tree planting stock produced. This supposition is supported by a survey conducted in Minnesota (*7*) involving outplanted red pine with different percentages of ectomycorrhizas. In this survey, the survival of outplanted trees with ectomycorrhizal roots ranging from 0 percent to 10 percent was 62 percent, whereas the survival of trees with ectomycorrhizas exceeding 20 percent was 81 percent. While not questioning the results of this particular trial, we think that the relationship between nursery soil fertility, abundance of mycorrhizal short roots, and the performance potential of planting stock requires a careful reexamination. Such reexamination is essential in the interest of silviculture as well as the foresters entrusted with the production of tree planting stock, a crop now worth more than $50,000 per acre.

Mycorrhizal short roots; their ephemeral nature

The terms mycorrhizal short roots or ectomycorrhizas are applied to wartlike appendages or offshoots produced by fungal hyphae on the surface of tree roots. In most cases, the penetration of the hyphae is confined to spaces between the cortical cells and the tree roots thus acquire "intercellular" or "ectocellular" mycorrhizas. Under certain conditions, especially in poor soils, fungal hyphae manage to find their

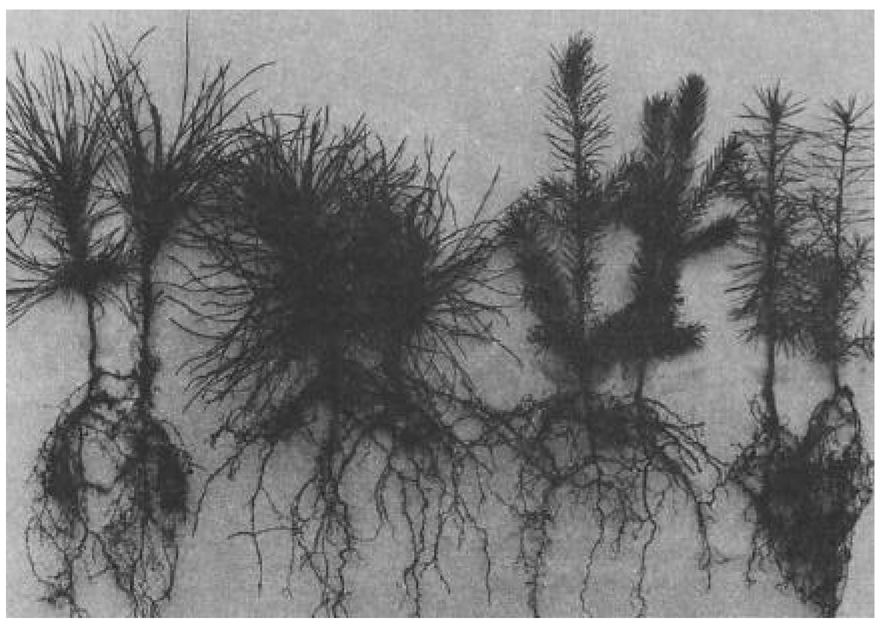

Figure 1. – *Two-year-old nursery stock with mycorrhizal root systems produced on soils of a very high level of fertility, including supplies of available phosphorus pentoxide of about 400 Ibs/a and of available potassium exceeding 500 Ibs/a. From left to right: ponderosa pine, lodgepole pine, Engelmann spruce, and Douglas-fir (Coeur d'Alene Nursery, Idaho).*

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[2] Italic numbers in parentheses refers to Literature Cited at the end of this article.

way into the cells and thus give rise to roots with "ectendocellular" mycorrhizas. The short roots showing either histology present an obvious display of the existing root-fungus union, and they have received the lion's share of attention by students of mycorrhizas. The justification of this concentrated effort may be questioned.

Short roots are largely accessories of trees which receive prolonged, direct sunlight. They are especially abundant in trees raised in nurseries and greenhouses, and in trees of open forest stands. Shading by tree crowns drastically reduces the abundance of short roots and may even suppress their development completely.

The effect of shading on the reduction or total annihilation of short roots is conspicuously revealed in natural reproduction established under the dense canopy of a mother stand. This has been found to be true in the forests of Idaho where examinations of naturally reproduced seedlings of ponderosa pine and Douglas-fir revealed no or very few short roots.

The disappearance of short roots or their drastic reduction is also prevalent in trees of forest plantations. During the Wisconsin all-state survey of coniferous plantations, examinations were made of jet-excavated roots of many red pine and white pine sample trees aged from 15 to 30 years (*10*). Regardless of the productivity ratings of the soils, roots exhibited abundant surface mycelia and terminal, mycelia-aggregated clusters, but no or very few short roots (*9*). All these observations left the impression that short roots are symptoms of a measles-like children's disease, inflicted by exposure to full sunlight.

Abundance of short roots and soil fertility

Conclusions that a high level of nursery soil fertility, particularly a high supply of available phosphorus, depresses the development of mycorrhizal short roots and lowers the performance potential of planting stock are not entirely sound and are not free from danger. In the hands of people unfamiliar with problems of soil fertility and plant nutrition, undue attention to short roots may lead to the production of inferior, inadequately nourished planting stock.

Whether short roots are attributes of vigorous trees, ephemeral sunlight-induced auxiliaries, or semi-parasitic developments is a moot question. An excessive abundance of short roots may indicate a reduced production by trees of fungicidal sub stances such as resins and tannins (*11*), and a decreased resistance of stock which permits the entrance of fungi into the roots. This possibility is supported by the predisposition of trees on very poor soils to permit penetration of fungal hyphae not only between, but also inside the cortical cells, thus forming ectendocellular mycorrhizas (*2*). The linkage of poor soils, a predominant cover of disease-predisposed hard pines, and ectendocellular mycorrhizas, suggests another relationship—damping-off, a root rot disease frequently associated by German foresters with depleted soil fertility, or "soil tiredness."

Under conditions of nursery growth, the abundance of short roots depends primarily on the supply of radiant energy received by trees during the growing season, but not necessarily on the level of soil fertility. Figure 1 features 2-year-old seedlings of ponderosa pine, lodgepole pine, Engelmann spruce, and Douglas-fir with short roots and mycelial clusters produced on basalt-derived soils with the following average levels of fertility: total N—0.089 percent; available P_2O_5 –389 lbs/a; available K_2O—507 lbs/a; exchangeable Ca—6.20 meq/100 g; exchangeable Mg—1.03 meq/100 g.

The inferences of the detrimental influence of available phosphorus in nursery soils are without foundation. A supply of available phosphorus pentoxide as high as 500 lbs/a, or about 200 lbs/a of elemental phosphorus, is of no significance as a toxicant in the root zone weighing more than 2 million pounds. In order to detect the effect of a high supply of available phosphorus on the uptake of other nutrient elements, or on the balance of nutrition, analyses were performed of the foliage of average 2-year-old ponderosa pine seedlings of similar size and weight. The analyzed trees were raised in the U.S.D.A. Forest Service's Coeur d'Alene nursery in Idaho on ferromagnesian soils with supplies of available native phosphorus pentoxide of approximately 200 and 700 Ibs/a. The results of analyses, given in Table 1, show a slightly higher uptake of nutrients by trees raised on more fertile soils with an extremely high content of available phosphorus, but no excessive values or disruption of nutrient ratios. The ratios of nitrogen and the four major nutrient elements are expressed by the following quotients: N/P—6 and 6; N/K—1.8 and 1.7; N/Ca—3.3 and 2.3; N—Mg-9.9 and 9.5 for the 200 and 700 Ib/a phosphorus levels, respectively. An excess of available phosphorus may be detrimental to nursery stock in extremely rare cases when it coincides with a shortage of available zinc, or with some other critical deficiency.

The concern about the high fertility of nursery soils seems to be particularly out of place at this time when nearly all nursery soils are treated with potent, often destructive pesticides (*3, 4*). Some of these materials at high concentrations eradicate mycorrhizas and arrest the growth of trees, but when applied at reduced concentrations, they may still annihilate short roots as well as most rootlets and yet induce an exuberant, highly harmful stimulation of tree crowns imparting to trees calamitous top-root ratios (fig. 2). This is the aspect of nursery stock production in which the development of roots, be they short, long, or intermediate, requires meticulous attention (*5*).

Table 1. – *Average contents of nutrient elements in the foliage of average, equal size, 2-year-old ponderosa pine seedlings raised on soils with widely different supplies of available phosphorus (U.S. Dep. Agric. For. Serv. Coeur d'Alene Nursery, Idaho)*

Location of stock and soils' supply of avail. P_2O_5	N	P	K	Ca	Mg	Na	B	Fe	Cu	Zn
	- -	(Percent)		- -	- -	- - Parts per million - - - - - -				
Fields 1 & 2 B : Sec. 33 & 34 200 lbs/acre	1.69	0.27	0.95	0.52	0.17	0.02	15.6	492	3.59	42.1
Fields 5 & 6 B : Sec. 26 & 28 700 lbs/acre	1.80	0.30	1.11	0.79	0.19	0.0	20.8	682	5.12	88.0

Appraisal of the abundance of mycorrhizal short roots and of the quality of nursery stock

For several reasons, it is difficult to expect that a record of the relative abundance of short roots of nursery stock will provide information of silvicultural significance.

Because of the transient effects of radiation, potent eradicants, and liquid fertilizer treatments, the density of short roots may not have any relation to either soil fertility or to the important, often concealed, properties of trees. A record of short roots alone does not take into account the intracellular mycelia which may be of ecological importance. An appraisal of the performance potential of planting stock on the basis of a single, not too dependable characteristic is likely to provide misleading information. This is especially probable when the record expresses the tally of short roots as percentages of feeder rootlets, or any roots. The percentages are not reliable values in this type of analyses and are apt to provide a totally misconstrued picture of root morphology and root absorbing capacity.

Counting of rootlets is a tedious and costly procedure which has no or a very distant relation to the performance potential of trees. A more rational approach toward an appraisal of the quality of planting stock is provided by avenues traced by plant geneticists (*8*) and widened by silvicultural surveys (*12*). A rigorous appraisal of the stock quality requires a complete analysis including not only external but also internal attributes of trees. But even simple and rapid determinations of the height-diameter and top-root ratios, or as practiced now in the Forest Service's Wind River nursery of Washington of the ratio of water volumes displaced by tops and roots, provide objective criteria of the stock's potential to cope with adverse effects of drought, frost, winter-kill, and snow press. In appraisal of rapidly growing stock, a simple determination of the specific gravity of the stems delineates the normal and fertilizer- or eradicant-forced development. As a supplement to other properties of trees, the record may well include the relative abundance of short roots according to the following scale (*12*): superabundant —3 ; abundant—2; sparse—1; absent—0. And it should never be forgotten that an excessive development of ectomycorrhizas often indicates some concealed discrepancies in the composition of nursery soil and in nutritional balance of seedlings.

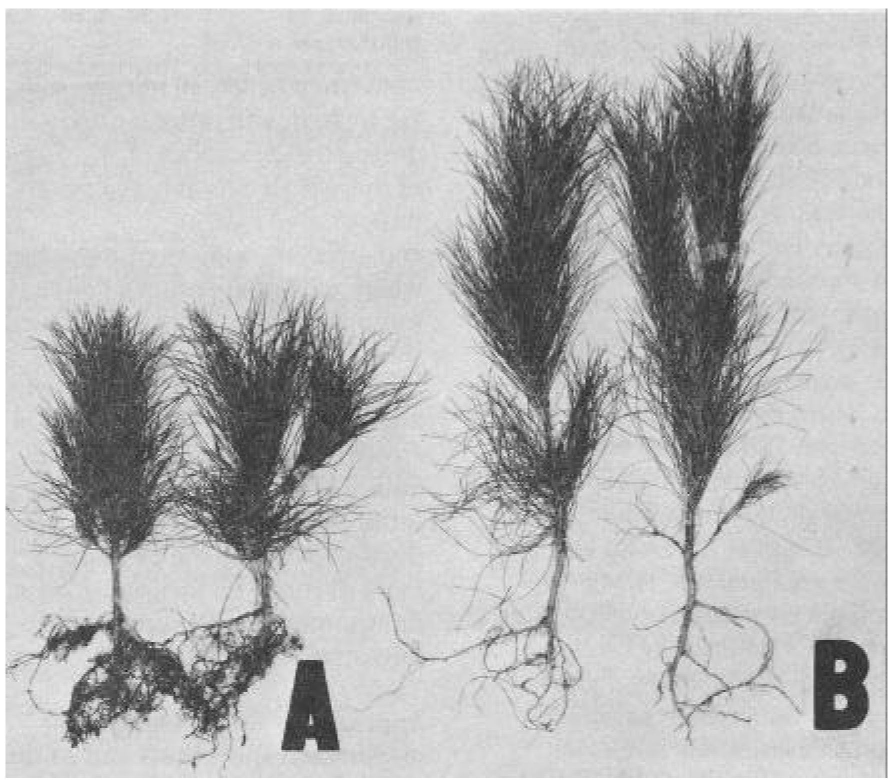

Figure 2. – *Effect of Vapam on the growth and morphology 3-year-old red pine seedlings. A – seedlings raised in eradicant-free soil. 8 – seedlings raised in soil that received 60 Ibs of SMDC per acre, a treatment which imparted to trees abnormally larger crowns, but drastically reduced root systems devoid of mycorrhizal short roots (Hayward State Nursery, Wis.).*

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