Mycorrhizal Response

1. Alvarez, I.F. and R.G. Linderman. 1983. Effects of ethylene and fungicide dips during cold storage on root regeneration and survival of western conifers and their mycorrhizal fungi. Canadian-Journal-of-Forest-Research 13(5): 962-971.

Keywords: nursery operations
tree/stand health
mycorrhizal response

Abstract: Survival and growth of Pseudotsuga menziesii, Pinus ponderosa and Abies concolor seedlings, and survival of mycorrhizal fungi on their roots were assessed after cold storage with or without 5 p.p.m. ethylene in combination with 4 root treatments: washed, dipped in Truban [etridiazole] or Benlate sol. or not treated. Ethylene treatment resulted in increased survival, apical bud burst, and new root formation in the greenhouse if roots had not been washed or dipped in fungicide. None of the gas storage or root treatments greatly affected seedling survival in the field. Root washing decreased seedling vigour, especially in fir. None of the root treatments or gas storage conditions affected root fungal populations; bacterial and actinomycete populations appeared to be affected and the response varied according to host species. Pisolithus tinctorius, which formed mycorrhizae with 10-20% of the short roots of the seedlings, did not survive cold storage. Thelephora spp. and an ectendomycorrhizal fungus both survived cold storage and rapidly colonized roots newly formed on seedlings planted after cold storage.

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2. Alvarez, I.F. and J.M. Trappe. 1983a. Dusting roots of Abies concolor and other conifers with Pisolithus tinctorius spores at outplanting time proves ineffective. Canadian-Journal-of-Forest-Research 13(5): 1021-1023.

Keywords: planting operations
site preparation
mechanical preparation
growth
tree/stand health
mycorrhizal response

Abstract: Dusting roots of Abies concolor, Abies magnifica var. shastensis, Pseudotsuga menziesii and Pinus ponderosa with Pisolithus tinctorius (Pt) spores when planted out produced no Pt mycorrhizae at the end of the first growing season. In the 3rd yr occasional Ptmycorrhizae had formed on A. concolor. Inoculations reduced seedling survival in some cases. High rates of spore application may have desiccated roots of the true firs and spore amounts applied need careful attention. Soil scarification and ripping significantly promoted growth of A. concolor seedlings compared with scarification alone.

OSU Link
Non-OSU Link

3. Alvarez, I.F. and J.M. Trappe. 1983b. Effects of application rate and cold soaking pretreatment of Pisolithus spores on effectiveness as nursery inoculum on western conifers. Canadian-Journal-of-Forest-Research 13(3): 533-537.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Ponderosa pine, Douglas fir, Shasta red (Abies magnifica var. shastensis), and white fir (Abies concolor) seedlings were inoculated in a bare root nursery with basidiospores of Pisolithus tinctorius. The spores were applied at 3 rates with or without cold/wet pretreatment of 7 or 21 days. Pretreatment did not affect spore efficiency as inoculum. Only ponderosa pine increased growth in response to inoculation. Inoculations in the greenhouse with a wider range of spore application rates revealed that a higher concn. of spores was needed to induce an increase in growth and mycorrhiza formation of Douglas fir than ponderosa pine. These levels were much higher than those used in nursery inoculations.

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Non-OSU Link

4. Amaranthus, M.P. and D.A. Perry. 1987. Effect of soil transfer on ectomycorrhiza formation and the survival and growth of conifer seedlings on old, nonreforested clear-cuts. Canadian-Journal-of-Forest-Research 17(8): 944-950.

Keywords: planting operations
tree/stand health
growth
mycorrhizal response

Abstract: Small amounts (150 ml) of soil from established conifer plantations and mature forest were transferred to planting holes on 3 sites in the Klamath Mts., S. Oregon and N. California. The sites had been clear felled and burned 8-27 yr earlier and unsuccessfully reforested. At Cedar Camp, a high alt. (1720 m) southerly slope with sandy soil, transfer of soil from a Douglas fir plantation increased first-yr survival of Douglas fir seedlings by 50%, mycorrhizal formation and b.a. growth. Soil from mature forest did not enhance survival and growth. Soil transfer was less effective on 2 sites at lower alt. with clayey soils. Douglas fir seedlings at Crazy Peak showed similar, but less well defined, patterns to those at Cedar Camp. All Pinus lambertiana seedlings at Wood Creek survived well and were generally unaffected by soil transfer. Results suggest that adequate mycorrhizal formation is critical to seedling growth and survival on cold, droughty sites. Transfer of soil from a suitable source may offset the decline in native mycorrhizal fungi if reforestation is delayed.

OSU Link
Non-OSU Link

5. Amaranthus, M.P. and D.A. Perry. 1989a. Interaction effects of vegetation type and Pacific madrone soil inocula on survival, growth and mycorrhiza formation of Douglas-fir. Canadian-Journal-of-Forest-Research 19(5): 550-556.

Keywords: planting operations
growth
tree/stand health
mycorrhizal response

Abstract: One-yr-old non-mycorrhizal Douglas fir (Pseudotsuga menziesii) seedlings were planted in 1985 in cleared blocks within 3 adjacent vegetation types in SW Oregon, viz., whiteleaf manzanita (Arctostaphylos viscida), annual grass meadow, and an open stand of Oregon white oak (Quercus garryana). Within subplots in each block, either pasteurized or unpasteurized soil from a nearby Pacific madrone (Arbutus menziesii) stand was transferred to the planting holes of the seedlings; control seedlings received no madrone soil. Second-year survival averaged 92, 43 and 12% for seedlings planted on the manzanita, meadow and oak sites, respectively. Growth differences generally paralleled survival differences. Added madrone soil, whether pasteurized or unpasteurized, did not influence survival.Unpasteurized madrone soil substantially increased the growth of seedlings on the manzanita site, but not in the meadow or oak stand. Pasteurized madrone soil did not affect growth in any of the vegetation types. Unpasteurized madrone soil nearly tripled the number ofmycorrhizal root tips forming on seedlings and resulted in formation of a new mycorrhiza type on the manzanita site, although it had little or no effect on the meadow or oak sites. These results suggest that manzanita and madrone impose a biological pattern on soils that stimulates Douglas fir growth and survival, and support results of other studies indicating that root symbionts and rhizosphere organisms mediate interactions among plant species.

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Non-OSU Link

6. Amaranthus, M.P. and D.A. Perry. 1989b. Rapid root tip and mycorrhiza formation and increased survival of Douglas-fir seedlings after soil transfer. New-Forests 3(3): 259-264.

Keywords: planting operations
mycorrhizal response
root development
tree/stand health

Abstract: In order to re-inoculate soil with mycorrhizal fungi, small amounts (about 150 ml) of soil from an established Douglas fir (Pseudotsuga menziesii) plantation were added to planting holes when Douglas fir seedlings were planted on an old, unrevegetated clearcut in the Klamath Mountains of Oregon. Seedlings were lifted throughout the growing season to determine the influence of soil transfer on the rate of root tip initiation and mycorrhiza formation. Six weeks after planting, seedlings receiving plantation soil had formed 62% more root tips than controls; however, no statistically significant differences were apparent 15 weeks after planting. By that time, a small percentage of root tips were visibly mycorrhizal; seedlings receiving transferred soil had the most colonization (13.6 vs. 3.5 per seedling, p <less or =>0.05). Of seedlings receiving transfer soil, 36.6% survived the first growing season, compared to 11.3% of control seedlings. At this high altitude, soils often remain frozen well into spring, leaving only a brief period between the time when soils become warm enough for root growth and the onset of summer drought. Under these conditions, the rapid root growth and mycorrhiza formation stimulated by plantation soil increases the ability of seedlings to survive the first growing season.

OSU Link
Non-OSU Link

7. Battista, C.d., D. Bouchard, F. Martin, B. Genere, J.M. Amirault and F.l. Tacon. 2002. Survival after outplanting of the ectomycorrhizal fungus Laccaria bicolor S238N inoculated on Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) cuttings. Annals-of-Forest-Science 59(1): 81-92.

Keywords: nursery operations
mycorrhizal response

Abstract: Selected strains of ectomycorrhizal fungi can be inoculated in forest nurseries to improve survival and growth of seedlings or cuttings after field transplantation. The survival of the American strain Laccaria bicolor S238N on Douglas fir (Pseudotsuga menziesii) cuttings was evaluated in nursery and field conditions (Oregon, USA) three years after outplanting using morphological and PCR/RFLP of nuclear rDNA spacers. The comparison of the mycorrhizal status of Douglas fir cuttings at the end of the nursery phase and two years after outplanting show several behaviours among the ectomycorrhizal fungi naturally occurring in the nursery or artificially introduced. The naturally occurring Rhizopogon type disappeared after outplanting, while the inoculated strain Laccaria bicolor S238N and an unknown type (1/2 ITS ribotype) survived and competed with the naturally occurring fungi of the outplanting site. Only one indigenous type (1/3 ITS ribotype) seemed occurring in the outplanting site where Cenococcum geophilum was almost completely absent.

OSU Link
Non-OSU Link

8. Berch, S.M. and A.L. Roth. 1993. Ectomycorrhizae and growth of Douglas-fir seedlings preinoculated with Rhizopogon vinicolor and outplanted on eastern Vancouver Island. Canadian-Journal-of-Forest-Research 23(8): 1711-1715.

Keywords: nursery operations
mycorrhizal response
growth

Abstract: Ectomycorrhizal colonization of container-grown Douglas fir (Pseudotsuga menziesii) inoculated with Rhizopogon vinicolor was determined after cold storage and one growing season after outplanting (in March 1988) on a clear felled area on eastern Vancouver Island, British Columbia. Inoculated Douglas fir seedlings were taller than noninoculated controls when outplanted, but perhaps because of browse damage, no growth differences were found after one growing season in the field. R. vinicolor colonized all of the inoculated but none of the control seedlings examined after cold storage. Volunteer Thelephora terrestris colonized almost half of the control and 10% of the inoculated seedlings before outplanting. After one field season, inoculated and control seedlings were colonized by 15ectomycorrhizal fungi each, only eight of which were found on both. R. vinicolor persisted on the roots of inoculated plants, but was also present in the field soil since the control seedlings also bore these mycorrhizas after one growing season. The relative abundance of T.terrestris decreased from the nursery to the field. The other common ectomycorrhizas in the field included Mycelium radicis atrovirens, Cenococcum geophilum and types resembling Tuber and Endogone.

OSU Link
Non-OSU Link

9. Busse, M.D., G.O. Fiddler and A.W. Ratcliff. 2004. Ectomycorrhizal formation in herbicide-treated soils of differing clay and organic matter content. Water, Air, and Soil Pollution 152:23-34.

Keywords: release treatments
chemical release
growth
tree morphology
tree/stand health
soil properties
mycorrhizal response

Abstract: Herbicides are commonly used on private timberlands in the western United States for site preparation and control of competing vegetation. How non-target soil biota respond to herbicide applications, however, is not thoroughly understood. We tested the effects of triclorpyr, imazapyr, and sulfometuron methyl on ectomycorrhizal formation in a greenhouse study. Ponderosa pine, Douglas-fir, and white fir seedlings were grown in four forest soils ranging in clay content from 9 to 33% and organic matter content from 3 to 17%, and treated with commercial formulations of each herbicide at 0, 1.0, and 2.0 times the recommended field rate. Many of the possible herbicide-soil combinations resulted in reduced seedling growth. Root development was particularly sensitive to the three herbicides, with an average of 51% fewer root tips compared to the control treatment. The ability of mycorrhizal fungi to infect the remaining root tips, however, was uninhibited. Mycorrhizal formation was high, averaging 91% of all root tips, regardless of herbicide, application rate, soil type, or conifer species. In agreement, soil microbial biomass and respiratory activity were unaffected by the herbicide treatments. The results show that these herbicides do not alter the capability of mycorrhizal fungi to infect roots, even at concentrations detrimental to seedling growth.

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Non-OSU Link

10. Castellano, M.A. and J.M. Trappe. 1985. Ectomycorrhizal formation and plantation performance of Douglas-fir nursery stock inoculated with Rhizopogon spores. Canadian-Journal-of-Forest-Research 15(4): 613-617.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Basidiospores (0, 106, 107 or 108) of 7 species of hypogeous, ectomycorrhizal fungi were applied to 1-msuperscript 2 plots sown with 4 conifer species
(Pseudotsuga menziesii, Pinus lambertiana, Abies concolor and Tsuga heterophylla) in a bare-root nursery inOregon. Inoculation with either Rhizopogon vinicolor or R. colossus succeeded with 2 provenances of Douglas-fir only. For R. vinicolor, the high spore-application rate produced the most mycorrhizae on the greatest number of seedlings. For R. colossus, the high spore-application rate produced the most mycorrhizae on the greatest number of seedlings of one seed source, while the

medium rate did better with the other. Stem height and root collar diameter of seedlings did not differ significantly between treatments and controls. Douglas-fir seedlings inoculated or not inoculated with spores of R. vinicolor were outplanted at 2 yr old in southwestern Oregon. After 2 yr, inoculated seedlings had significantly greater survival, stem height, root collar diameter, and biomass than noninoculated seedlings. Although new feeder roots of both noninoculated and inoculated seedlings were colonized by indigenous fungi, R. vinicolor persisted on the old root systems of inoculated seedings and colonized new feeder roots.

OSU Link
Non-OSU Link

11. Castellano, M.A. and J.M. Trappe. 1991. Pisolithus tinctorius fails to improve plantation performance of inoculated conifers in southwestern Oregon. New-Forests 5(4): 349-358.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Bare root seedlings of Douglas fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta), white fir (Abies concolor), and grand fir (Abies grandis) were inoculated with Pisolithus tinctorius and subjected to standard nursery and cold storage practices. At age 2 years, seedlings were assessed for mycorrhizal status, and were planted out on a variety of sites in SW Oregon. After 1, 2 and 3 growing seasons root collar diameter and current year's shoot growth were measured (or a lateral branch if browsing had damaged main shoot). Results showed that inoculated seedlings performed no better than those which had not been intentionally inoculated but which had formed mycorrhizae with indigenous, nursery fungi (e.g. Thelephora terrestris, and possibly Inocybe spp.). Climate, planting sites and nursery practices in the Pacific Northwest differ drastically from those in the southeastern United States, where P. tinctorius has increased plantation survival and growth. It is concluded that further research is necessary on P. tinctorius and nursery inoculation of tree seedlings in thePacific Northwest.

OSU Link
Non-OSU Link

12. Chanway, C.P. 1997. Inoculation of tree roots with plant growth promoting soil bacteria: an emerging technology for reforestation. Forest-Science 43(1): 99-112.

Keywords: nursery operations
tree/stand protection
growth
tree/stand health
mycorrhizal response

Abstract: Results from studies performed with beneficial asymbiotic tree root associated bacteria are reviewed in this article in relation to the possible uses of such microorganisms for artificial forest regeneration. The review includes sections on plant growth promoting bacteria for pine (Pinus spp.), spruce (Picea spp.), Douglas fir (Pseudotsuga menziesii) and hemlock (Tsuga heterophylla). Seedling root systems are colonized heavily by asymbiotic soil bacteria, many of which have the potential to influence

plant growth significantly. A heterogeneous group of these microorganisms is well known for their ability to colonize roots and stimulate growth of agricultural plant species, sometimes doubling seedling biomass accumulation only a few weeks after inoculation, but more usually resulting in less spectacular biomass gains (e.g., 15%-30% greater than uninoculated controls within a growing season). Plant growth promoting soil bacteria may exert such effects through a variety of mechanisms, and include microorganisms that stimulate seedling emergence or infection by symbiotic fungi and bacteria. Other plant beneficial soil bacteria possess biological control activity or are capable of transforming plants genetically. Inoculation of tree seedlings with such bacterial before outplanting would be an inexpensive, environmentally benign, and easily applied nursery treatment, but comparatively little work has been performed with these microorganisms in forestry. Recent results with various tree species, however, indicate that seedling performance can be significantly enhanced through bacterial inoculation of root systems: pine and spruce biomass increased 32%-49% 1 yr after inoculation and outplanting at a reforestation site. In addition, infection by desired species of ectomycorrhizal fungi can also be enhanced by inoculation with certain strains of root colonizing bacteria.

OSU Link
Non-OSU Link

13. Coleman, M.D., C.S. Bledsoe and B.A. Smit. 1990. Root hydraulic conductivity and xylem sap levels of zeatin riboside and abscisic acid in ectomycorrhizal Douglas fir seedlings. New-Phytologist 115(2): 275-284.

Keywords: nursery operations
nursery fertilization
tree morphology
tree physiology
mycorrhizal response

Abstract: The hypothesis that root hydraulic conductivity (LP) of ectomycorrhizal root systems is greater than that of non-mycorrhizal systems, and different to that of vesicular-arbuscular (VA) mycorrhizas was tested in a greenhouse experiment, by measuring hydraulic qualities of roots while accounting for seedling size and P content. Plant growth substances (abscisic acid and zeatin riboside) expressed from roots during the experiments were also measured. Douglas fir (Pseudotsuga menziesii) seedlings inoculated with the ectomycorrhizalfungi Laccaria bicolor and Hebeloma crustuliniforme, and non-inoculated seedlings infected naturally with Thelephora were grown under 3 rates of P fertilization (1, 10 and 100 micro M P). After 9 months, seedling morphology, tissue P concn., LP and plant growth substanceconcn. in xylem sap were measured. Increased tissue P and decreased root/shoot ratio correlated with increased LP in each mycorrhizal treatment; when adjusted for the effect of these 2 factors, LP of Laccaria and Hebeloma seedlings was still lower than that of Thelephoraseedlings. In a subsequent experiment, LP of seedlings with Hebeloma and Rhizopogon vinicolor mycorrhizas was compared with that of non-mycorrhizal seedlings (grown at 100 mM P) and no differences were found among treatments. The lack of an ectomycorrhizal effect on LP is quite different from the enhancement of host LP by VA mycorrhizas. Zeatin riboside concentrations of Thelephora- and Hebeloma-infected seedlings were similar, yet higher than with Laccaria. There was no relationship between plant growth substances and LP inectomycorrhizal Douglas fir, despite lower zeatin riboside concentrations for Laccaria-inoculated plants.

OSU Link
Non-OSU Link

14. Colinas, C., R. Molina, J. Trappe and D. Perry. 1994a. Ectomycorrhizas and rhizosphere microorganisms of seedlings of Pseudotsuga menziesii (Mirb.) Franco planted on a degraded site and inoculated with forest soils pretreated with selective biocides. New-Phytologist127(3): 529-537.

Keywords: planting operations
fertilization
soil properties
mycorrhizal response

Abstract: Inoculation of planting holes with small amounts of soil from a mature forest or a plantation can improve formation of ectomycorrhizas on Pseudotsuga menziesii seedlings in degraded clearcuts in southwestern Oregon. To determine the component(s) of transferred soil responsible for increased ectomycorrhiza formation, soil from a clearcut, a mature forest and a plantation was treated with one of the following: (1) fertilizer to test for the effect of nutrients, (2) dimethoate and carbofuran to test for the effect on microarthropods or nematodes, (3) fumagillin to test for the effect on protozoa, (4) captan to test for the effect on fungi, (5) penicillin and oxytetracycline to test for the effect on bacteria, (6) pasteurization to test for the effect of active forms of organisms, (7) Tyndallization to test for the effect of resting forms of organisms, or (8) water as a control. The effect was studied of inoculation with soil subjected to these treatments on number and types of ectomycorrhizas, on length of active mycelium, and on number of active bacteria in the rhizosphere. Inoculation with untreated forest or plantation soils increased the number of ectomycorrhizas but did not change the mycorrhizal types present. Most agents had different effects in different soils. Inoculation with pasteurized and Tyndallized clearcut and plantation soils increased the number ofRhizopogon- and Thelephora-type ectomycorrhizas and decreased the number of active bacteria, as did untreated forest soil. It is hypothesized that the role of the soil transfer is to provide a rhizosphere environment free from a deleterious organism present in the clearcut. In this environment, beneficial organisms present in the clearcut or brought in with the seedling from the nursery can proliferate.

OSU Link
Non-OSU Link

15. Duponnois, R., J. Garbaye, D. Bouchard and J.L. Churin. 1993. The fungus-specificity of mycorrhization helper bacteria (MHBs) used as an alternative to soil fumigation for ectomycorrhizal inoculation of bare-root Douglas-fir planting stocks with Laccaria laccata. Plant and Soil 157:257-262.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Mycorrhization helper bacteria (MHBs) isolated and selected from the Douglas fir (Pseudotsuga menziesii)-Laccaria laccata symbiotic system have previously been shown to be fungus-

specific: they promote ectomycorrhizal establishment of Laccaria laccata but inhibit mycorrhizal formation by other fungi. In this paper, two experiments in a nursery producing 2-yr-old bare rooted Douglas fir planting stock confirmed the specificity of MHBs (9 strains were tested) under field conditions. Mycorrhizal formation by Laccaria laccata, and the closely related L. bicolor was promoted by the specific MHBs tested, but mycorrhizal formation by Hebeloma cylindrosporum and a contaminant white fungus was inhibited; the strain of Paxillus involutus used was only poorly infective and not affected by MHBs. The experiments also showed that, by selectively helping the introduced L. laccata against the resident symbionts, MHBs are an interesting alternative (safer and easier) to soil fumigation for the success of routine controlled mycorrhization of planting stock in forest nurseries. The MHB strain BBc6 (a Pseudomonas fluorescens) is suggested as a suitable candidate for this system.

OSU Link
Non-OSU Link

16. Frey Klett, P., J.L. Churin, J.C. Pierrat and J. Garbaye. 1999. Dose effect in the dual inoculation of an ectomycorrhizal fungus and a mycorrhiza helper bacterium in two forest nurseries. Soil Biology and Biochemistry 31:1555-1562.

Keywords: nursery operations
growth
carbon allocation
mycorrhizal response
soil properties

Abstract: Disinfected soil at two Douglas-fir (Pseudotsuga menziesii) bare-root forest nurseries was inoculated with three doses (8 X105, 8 X107 and 8 X109 cfu [colony forming units]/m2) of the rifampicin-resistant mycorrhiza helper bacterium Pseudomonas fluorescensstrain BBc6R8 and the ectomycorrhizal fungus Laccaria bicolor strain S238N. In one of the two nurseries, two doses of fungal inoculum (50 and 100 mg/m2 dry weight (DW) mycelium entrapped in alginate beads at the constant dose of 1 litre/m2) were tested. For all bacterial treatments the density of P. fluorescens BBc6R8 in the soil, determined by dilution plating, dropped below the detection limit (10-2 cfu/g DW soil) 2 weeks after inoculation. Fifteen weeks after inoculation, the introduced bacterium was detected by enrichment only in the treatments inoculated with the highest bacterial dose. Two years after inoculation, P. fluorescens BBc6R8 was not detected in the soil of any of the bacterial treatments. Five months after inoculation and sowing, bacterial inoculation significantly increased the percentage of mycorrhizal short roots on plants inoculated with either low or high amounts of L. bicolor, in one of the nurseries. The lowest bacterial dose increased mycorrhizal colonization from 45 to 70% in plants inoculated with the low amount of fungal inoculum, and from 64 to 77% in plants inoculated with the high amount of fungal inoculum. The lowest bacterial dose increased mycorrhizal colonization more than the highest bacterial dose. The same L. bicolor mycorrhizal index (70%) was obtained with 50 mg/m2 DW mycelium plus the bacterium than with twice this fungal dose and no bacterium (64%). Two years after inoculation, the height of the mycorrhizal Douglas-firs in the other nursery was significantly increased by the lowest bacterial dose (from 40.7 to 42.6 cm). It was indicated that co-inoculating a helper bacterium together with an ectomycorrhizal fungus is an efficient way to optimize controlled mycorrhization techniques for the production of high-quality Douglas-fir planting stocks. It was confirmed that BBc6R8 acts at a low population density (less than 10-2 cfu/g soil), this contrasts with most PGPR [plant growth promoting rhizobacteria?] effects where the minimal inoculation dose of 105 cfu/g soil is required to obtain the beneficial effect.

OSU Link
Non-OSU Link

17. Gagnon, J., C.G. Langlois, D. Bouchard, F.l. Tacon and F. Le Tacon. 1995. Growth and ectomycorrhizal formation of container-grown Douglas-fir seedlings inoculated with Laccaria bicolor under four levels of nitrogen fertilization. Canadian Journal of Forest Research 25:1953-1961.

Keywords: nursery operations
nursery fertilization
growth
carbon allocation
tree physiology
tree morphology
mycorrhizal response
soil properties

Abstract: Container-grown Douglas fir (Pseudotsuga menziesii) seedlings were inoculated at the time of sowing with a Laccaria bicolor mycelial suspension produced in a fermentor. They were grown in a peat moss-vermiculite substrate under four levels of N fertilization (7.2, 14.4, 21.6 and 28.7 mg/seedling per season (N1, N2, N3 and N4, respectively)) to determine the N level suitable for both ectomycorrhizal development and seedling growth. After 18 weeks in the greenhouse, seedlings inoculated with L. bicolor had 44%, 32%, 44% and 5% of their short roots mycorrhizal when fertilized with N1, N2, N3 and N4, respectively. Only when they were fertilized with N4 did the L. bicolor seedlings have significantly greater shoot height than the controls. For the other growth parameters, they were not significantly different from control seedlings for any of the N levels. After 18 weeks, regardless of the level of N, seedlings inoculated with L. bicolor had significantly lower N concentrations (%) and contents (mg/seedling) than the uninoculated ones. Consequently, for the same production of biomass, the mycorrhizal seedlings had taken up less N than the nonmycorrhizal ones. The efficiency of applied N, expressed in terms of produced biomass, decreased when the N fertilization increased; mycorrhizal and nonmycorrhizal seedlings did not tend to be different. The efficiency of the absorbed N also decrease with the level of applied N, but less rapidly, and tended to be greater for the mycorrhizal seedlings than for the nonmycorrhizal ones. Therefore, the mycorrhizal infection improved the utilization of the absorbed N. N3 was the best of the four N levels used, since it was the only one that maximized both the ectomycorrhizal formation and the growth of the seedlings. In other words, a total seedling N concentration of 1.6% and a substrate fertility of 52 p.p.m. N are appropriate to optimize both the ectomycorrhizal development and the growth of Douglas fir seedlings.

OSU Link
Non-OSU Link

18. Hung, L.L.L. and R. Molina. 1986. Use of the ectomycorrhizal fungus Laccaria laccata in forestry. III. Effects of commercially produced inoculum on container-grown Douglas-fir and ponderosa pine seedlings. Canadian-Journal-of-Forest-Research 16(4): 802-806.

Keywords: nursery operations
mycorrhizal response

Abstract: In greenhouse experiments, a commercial vegetative inoculum of L. laccata formed ectomycorrhizas on both Douglas fir and ponderosa pine. In trials at container nurseries at Lebanon, Oregon, L. laccata successfully formed ectomycorrhizas on Douglas fir, but roots of ponderosa pine seedlings were heavily contaminated with Thelephora sp. It is concluded that commercially produced inoculum of L. laccata can be used operationally in container nurseries, though further tests are needed to assess the competitive effect of Thelephorasp. and the performance of inoculated seedlings after planting in the field.

OSU Link
Non-OSU Link

19. Hung, L.L.L. and J.M. Trappe. 1987. Ectomycorrhizal inoculation of Douglas-fir transplanted container seedlings with commercially produced inoculum. New-Forests 1(2): 141-152.

Keywords: nursery operations
mycorrhizal response
growth

Abstract: Commercially produced vegetative inocula of Laccaria laccata and Hebeloma crustuliniforme successfully formed ectomycorrhizae with Douglas fir transplanted container (plug + 1) seedlings. After 4.5 months in containers, 83% and 90%, respectively, of short roots were mycorrhizal. L. laccata- or H. crustiliniforme-inoculated seedlings had significantly more mycorrhizal and total short roots than Pisolithus tinctorius-inoculated (4% mycorrhizal root tips) or uninoculated control seedlings. No significant differences were detected in seedling growth at the end of the container phase. After transplantation and growth in nursery beds for 17 months, mean new short root colonization of all seedlings was 80%. H. crustuliniforme persisted as a dominant mycorrhizal fungus on seedlings initially inoculated with this fungus. L. laccata-inoculated seedlings had 40% of their short roots colonized by L. laccata and another 40% by the native fungi Rhizopogon and Thelephora spp. All mycorrhizae of control seedlings and those inoculated with P. tinctorius were formed by fungi native to the nursery beds. A significant fungal treatment effect was detected for shoot height only. Control seedlings were significantly taller than L. laccata-inoculated seedlings after transplanting.

OSU Link
Non-OSU Link

20. Lavender, D.P. and R.B. Walker. 1981. Nitrogen and related elements in nutrition of forest trees. In Proceedings: Forest Fertilization Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 15-22.

Keywords: fertilization
tree physiology
soil properties
mycorrhizal response

Abstract: This paper discusses the principal inorganic ions used by forest trees and their respective roles in tree physiology, their common range of concentration in coniferous foliage, and the general

symptoms associated with their deficiency. The factors governing effective concentrations of each ion at an active metabolic site are redistribution or internal nutrient cycling, nutrient uptake, and soil status (temperature, moisture, and concentration of each nutrient). Also described are endogenous patterns of nutrient storage and translocation, and the possible effects of fertilizers upon them and upon the mechanisms of ion uptake, especially the effect of pH change associated with urea applications upon the mycorrhizal complement of western hemlock (Tsuga heterophylla).

OSU Link
Non-OSU Link

21. Lu, S., K.G. Mattson, J.B. Zaerr and J.D. Marshall. 1998. Root respiration of Douglas-fir seedlings: effects of N concentration. Soil-Biology-and-Biochemistry 30(3): 331-336.

Keywords: nursery operations
nursery fertilization
growth
carbon allocation
tree morphology
tree physiology
mycorrhizal response

Abstract: Six-month-old Douglas-fir (Pseudotsuga menziesii) seedlings were grown at three N concentrations and with controlled root temperatures in Oregon, USA. Measurements of root respiration were conducted on undisturbed root systems by passing humidified air with 1000 micro l/litre CO2 through root boxes onto an infrared gas analyser. The effects of N on soil respiration were sought by examining total root respiration rate per seedling, specific root respiration rate/g root dry wt, and root dry wt after N fertilization. Total respiration rates of seedlings grown at 50 mg N/litre concentration were significantly higher than those grown at 10 or 200 mg N/litre. Seedlings grown at N concentration of 200 mg/litre had significantly smaller roots than those grown at the two lower N concentrations. The specific respiration rate increased as N concentration was increased from 10 to 50 mg N/litre, but remained constant as N was further increased from 50 to 200 mg/litre. The increase of total respiration rate with the increase in N concentration from 10 to 50 mg/litre was attributed to the increase in specific respiration, whereas the subsequent decrease in total respiration with the increase in N concentration from 50 to 200 mg/litre was attributed to the decrease in root dry wt. The depression of soil respiration after the addition of N fertilizers to relatively fertile soil may be explained by reduced root and mycorrhizal mycelial growth.

OSU Link
Non-OSU Link

22. Massicotte, H.B., L.E. Tackaberry, E.R. Ingham and W.G. Thies. 1998. Ectomycorrhizae establishment on Douglas-fir seedlings following chloropicrin treatment to control laminated-root rot disease: assessment 4 and 5 years after outplanting. Applied-Soil-Ecology 10(1/2): 117-125.

Keywords: tree/stand protection
mycorrhizal response

Abstract: Laminated-root rot, caused by Phellinus weirii, is a serious disease affecting Douglas fir [Pseudotsuga menziesii] and other commercially important species of conifers in northwestern North America. The effect of chloropicrin (used to control Phellinus weirii) onnontarget organisms, including ectomycorrhizae, is uncertain. A study was carried out to examine ectomycorrhizal development on Douglas firs after the application of chloropicrin. The study was carried out in Matlock, Washington, USA, 4.5 and 5.5 years following chloropicrin application. In areas around stumps treated with 20% and 100% of the labelled dosage and in areas around non-treated stumps, chloropicrin did not adversely affect the formation of ectomycorrhizae on young Douglas fir seedlings by naturally occurring fungi. No significant effect on the abundance or type of mycorrhizas were detected. In this study chloropicrin did not affect these mycorrhizal associations, for at least 5 years following application.

OSU Link
Non-OSU Link

23. Molina, R. and J. Chamard. 1984. Use of the ectomycorrhizal fungus Laccaria laccata in forestry. II. Effects of fertilizer forms and levels on ectomycorrhizal development and growth of container-grown Douglas-fir and ponderosa pine seedlings. Canadian-Journal-of-Forest-Research 13(1): 89-95.

Keywords: nursery operations
nursery fertilization
mycorrhizal response
growth

Abstract: [See FA 44, 2464] Seedlings were grown in peat/vermiculite medium with or without pre-germination inoculation with L. laccata, using three rates of soluble NPK fertilizer (low, high, and a combination of low changed to high) or full or half strength of a slow-release fertilizer. Ectomycorrhizal development was excellent for both hosts regardless of fertilizer treatment; ectomycorrhizal short roots averaged 93.6% for Douglas fir and 94.5% for ponderosa pine. Inoculation did not affect the size of Douglas fir but significantly reduced growth of ponderosa pine at low fertility.

OSU Link
Non-OSU Link

24. Owston, P.W., W.G. Thies and W. Fender. 1986. Field performance of Douglas-fir seedlings after treatment with fungicides. Canadian-Journal-of-Forest-Research 16(6): 1369-1371.

Keywords: nursery operations
tree/stand protection
tree/stand health
growth
mycorrhizal response

Abstract: Douglas fir seedlings grown in containers with pasteurized or unpasteurized potting mixture, and treated in the nursery with benomyl, captan, fenaminosulf or ethazol [etridiazole], or left untreated (control) were planted out in the Cascade Range, western Oregon. The seedlings from all treatments

appeared to be in similar condition at the time of planting, except for variations in ht. After 7 yr, seedlings grown in pasteurized potting mixture had better survival than those grown in unpasteurized mixture. Benomyl-treated seedlings in pasteurized potting mixture had significantly better survival than control seedlings in pasteurized mixture and seedlings treated with ethazol and grown in unpasteurized potting mixture had significantly lower survival than control seedlings in unpasteurized mixture. Ht. differences after 7 yr were n.s.d. between treatments. Benomyl, captan and ethazol appeared to have no detrimental effect on the development of mycorrhizas after planting non-mycorrhizal seedlings. There were insufficient seedlings to determine the effects of fenaminosulf onmycorrhizas.

OSU Link
Non-OSU Link

25. Parke, J.L., R.G. Linderman and C.H. Black. 1983a. The role of ectomycorrhizas in drought tolerance of Douglas-fir seedlings. New-Phytologist 95(1): 83-95.

Keywords: nursery operations
tree/stand protection
photosynthesis
tree physiology
mycorrhizal response

Abstract: Pseudotsuga menziesii seedlings were watered daily or conditioned to cyclic drying and re-wetting of the soil. Net photosynthesis rates of mycorrhizal and non-mycorrhizal seedlings watered daily were similar but drought-stressed mycorrhizal seedlings fixed CO2 at a rate 10 times that of non-mycorrhizal ones. Total leaf water potentials of mycorrhizal plants were lower than those of non-mycorrhizal plants but they recovered more rapidly. Non-mycorrhizal seedlings and those inoculated with 4 ectomycorrhizal fungi were allowed to dry, then re-watered and compared for their ability to tolerate and recover from drought. Those inoculated with Rhizopogon vinicolor were the least affected by drought. Net photosynthetic rate of R.-inoculated seedlings 24 h after re-watering was 7 times greater than that of non-mycorrhizal seedlings. The transpiration rate of R.-inoculated seedlings was low before desiccation, declined rapidly during the drought period and, after re-watering, quickly resumed a rate higher than that for other treatments.

OSU Link
Non-OSU Link

26. Parke, J.L., R.G. Linderman and J.M. Trappe. 1983b. Effects of forest litter on mycorrhiza development and growth of Douglas-fir and western red cedar seedlings. Canadian-Journal-of-Forest-Research 13(4): 666-671.

Keywords: site preparation
mechanical preparation
prescribed fire
mycorrhizal response
growth

Abstract: Preparation of forest regeneration sites for conifer planting often includes slash burning or physical removal of soil organic matter. Experiments were conducted to determine if organic matter contributes to the mycorrhizal fungus inoculum potential in forest soils and to compare the growth of Douglas fir and western red cedar (Thuja plicata) in untreated or pasteurized soils from undisturbed or cleared and burned forest sites with and without addition of untreated or pasteurized litter. Mycorrhizas were abundant on Douglas fir seedlings grown in undisturbed forest soil but developed similarly on red cedar seedlings in either type of soil. Litter and humus were found to include inoculum of both vesicular-arbuscular (VA) and ectomycorrhizal fungi. Litter amendment usually enhanced growth of host seedlings, but growth enhancement could not be fully attributed to addition of mycorrhizal inoculum or nutrients provided by litter. These findings suggested that other biological factors stimulated the growth of conifer seedlings and (or) activity of mycorrhizal fungi.

OSU Link
Non-OSU Link

27. Pilz, D. and R.M. Znerold. 1986. Comparison of survival enhancement techniques for outplanting on a harsh site in the western Oregon Cascades. Tree-Planters' Notes 37(4): 24-28.

Keywords: nursery operations
planting operations
growth
tree/stand health
mycorrhizal response

Abstract: Bare rooted 2+0 seedlings of Pseudotsuga menziesii survived and grew better during the first year than container-grown 1+0 stock on a droughty site. After 3 yr, survival still differed significantly, but height growth did not. Shading improved survival and growth. Application of a liquid suspension of spores of Pisolithus tinctorius was ineffective and no mycorrhizas developed from this fungus.

OSU Link
Non-OSU Link

28. Pilz, D.P. and D.A. Perry. 1984. Impact of clearcutting and slash burning on ectomycorrhizal associations of Douglas-fir seedlings. Canadian-Journal-of-Forest-Research 14(1): 94-100.

Keywords: site preparation
prescribed fire
mycorrhizal response

Abstract: The results of field and greenhouse studies. Twelve ectomycorrhizal types were found in 3 western Cascade Mountain sites in Oregon on seedlings planted in soils on burned and unburned portions of clear felled areas and on undisturbed forest. Rhizopogon sp. and an unidentified brown type consistently formed at least two-thirds of the ectomycorrhizal root tips. Regardless of soil origin, more ectomycorrhizae formed in clear-felled areas than in undisturbed forest (primarily due to more brown mycorrhizae). Soil origin did not affect total numbers of ectomycorrhizae; however, more different types formed in undisturbed forest soils than in clear-felled soils, irrespective of aboveground

environment. More nonmycorrhizal tips occurred in clear-felled soils. Seedlings grown in the same soils formed the same proportions of Rhizopogon and brown types in field and greenhouse, but not the same proportions of less common ectomycorrhizal types. Soil pasteurization increased root-tip numbers. Inoculated soils (1 part nonpasteurized: 9 parts pasteurized) produced as manyectomycorrhizae as nonpasteurized field soils and generally fewer tips than pasteurized soils. Formation of major (but not minor) ectomycorrhizal types on all sites was influenced more by aboveground changes that accompany clear felling and site preparation than by alterations in soil chemistry or biology.

OSU Link
Non-OSU Link

29. Trappe, J.M. 1983. Effects of the herbicides bifenox, DCPA, and napropamide on mycorrhiza development of ponderosa pine and Douglas fir seedlings in six western nurseries. Forest-Science 29(3): 464-468.

Keywords: nursery operations
mycorrhizal response

Abstract: The herbicides were each applied (for weed control) at 2 rates to beds of seedlings in nurseries in California, Oregon and Washington. Seedlings were lifted 7-8 months after sowing and the roots examined for mycorrhizae. No herbicide treatment significantly reduced the proportion of feeder roots colonized or the number of mycorrhizal types, compared with controls. Ponderosa pine seedlings treated with DCPA [chlorthal-dimethyl] had a significantly greater proportion of mycorrhizal feeder roots than those treated with the other herbicides (but n.s.d. from controls), and a significantly greater mean number of mycorrhizal types than controls or the napropamide treatment. Douglas fir seedlings treated with napropamide had significantly more mycorrhizal types than those treated with DCPA or bifenox(but were n.s.d. from controls).

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