Soil Tillage Practices and Root Disease Management[1]

Jennifer Juzwik[2], R. R. Allmaras[3], and K. M. Gust[4]

Juzwik, J.; Gust, K.M.; Allmaras, R. R. 1997. Soil Tillage Practices and Root Disease Management. In: Landis, T.D.; Thompson, J. R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 23-28. Available at: http://www.fcnanet.org/proceedings/1997/juzwik.pdf

Abstract - Field studies were conducted in North Central states nurseries to investigate the soil conditions resulting from operational tillage and their potential effect on root disease development. Compacted soil layers, or hard-pans, were found in pine fields of two nurseries that use rotary tillers after sub-soiling but prior to sowing and use moldboard plows for incorporating cover crop residue. Water flow through undisturbed soil in rotary tiller associated pans (110 to 15-cm depth) was slower than in non-compacted soils above and below the pan and compared to non-compacted areas of the fields. Vertical distribution profiles of soil-borne *Fusarium* spp. at each of five nurseries reflected the type of tillage implement used to incorporate cover crop material that ultimately served as substrate for fungal population increase. When a moldboard plow was used for incorporation and soil fumigation subsequently conducted, depth of fumigation was found to be inadequate for reducing *Fusarium* levels below 18 cm in methyl bromide - chloropicrin, metam sodium, and dazomet (when incorporated by rotary tiller) treated fields. Implications of these results to management of root disease in pine fields are discussed.

INTRODUCTION

Root disease can cause significant mortality of conifer nursery seedlings and negatively affect growth and quality of live seedlings remaining for lifting and shipping. Cultural practices, especially those involving soil management, are important in managing root diseases. Practices that influence the occurrence and level of these diseases include soil tillage, soil water management, mulching, sowing of infested seed, fertilization, and soil fumigation (Sutherland and Anderson 1980). The latter is the pest management option often selected for use in bare-root nursery fields with a history of root disease. However, the availability and use of a single pest management tool that focuses on the pest(s) may lead nursery managers away from considering the cultural conditions that may have led to the disease situation (Sullivan 1997). For example, tillage implements may produce compacted soil layers that impede internal drainage in a soil profile. Prolonged periods of wet soil conditions may then promote root rot development (Juzwik et al. 1994).

Studies were conducted in five forest nurseries in three North Central states from 1994 - 96 to: 1) investigate physical and biological soil conditions resulting from standard cultural practices and their relationship to root disease development, and 2) investigate effects of incorporation implement on dazomet fumigation efficacy. Results and application of these studies are summarized in this paper.

SOIL COMPACTION AND IMPEDED DRAINAGE

Resistance of nursery soils to penetration was measured at 15 mm increments from the soil surface to a 42 cm depth in 2 + 0 pine fields at three nurseries in 1994 - 95. Soils in the surveyed fields ranged from loamy sands (Minnesota nursery) to sandy loams (Wisconsin nursery) to sand soils (Michigan nursery). The fields were irrigated to approach saturation and systematic measurements were made with a highly sensitive cone penetrometer within 2 hours after irrigation ceased.

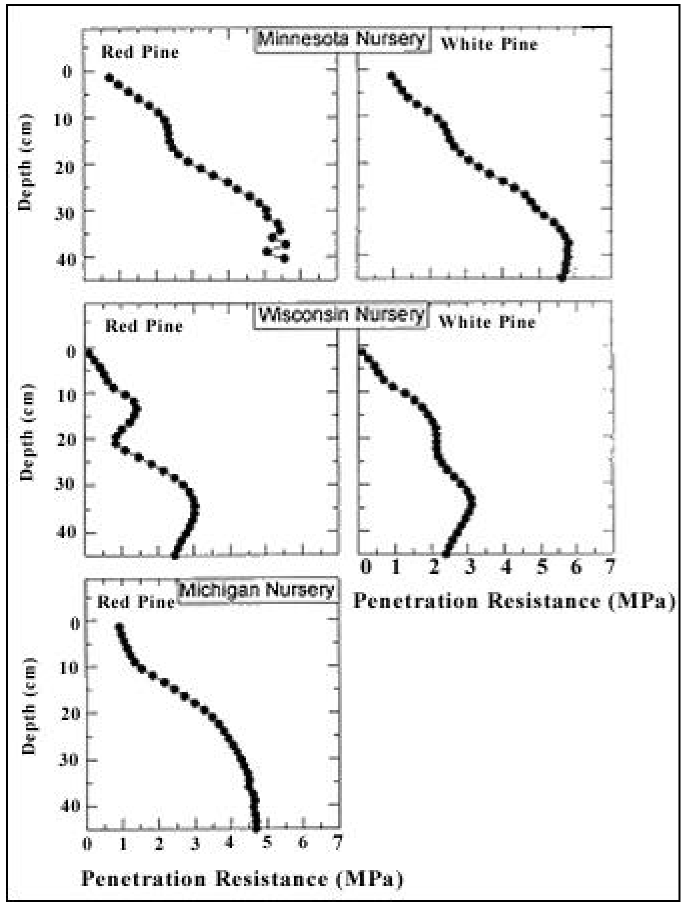


Figure 1. Penetrometer resistance as a function of soil depth under 2+0 pine seedlings at three bareroot tree nurseries.

Significant increases in the force required to insert the cone penetrometer at a controlled slow speed is indicative of compacted soil layers. The penetrometer readings through the vertical soil profile in four fields at the Minnesota and Wisconsin nurseries revealed two peaks of increased resistance (Figure 1). No such peaks were evident in the Michigan field. A gradual increase in resistance is expected in all fields due to increasing overburden weight as soil depth increases.

The compacted layer detected at approximately 10 to 15 cm depth in the Minnesota and Wisconsin fields were attributed to use of rotary tillers in the fields. The pans were formed after only one or two tillage events that occurred just prior to establishment of the pine crop, but after sub-soiling had been performed. The second compacted layer occurred between 30 and 36 cm and was most evident in the Wisconsin nursery fields. These hard-pans were attributed to the use of moldboard plows (30 cm maximum operating depth) for incorporation of cover crops in the two nurseries. These pans tended to persist despite sub-soiling operations conducted after cover crop incorporation. The lack of distinct compacted layers in the Michigan nursery field is attributed to the sole use of a tandem, double-gang disc for all soil tillage operations. In summary, then, the differences in pan occurrence and depth reflected the different tillage implements used at the nurseries for at least five years.

Depending on the severity of the compaction within observed compacted soil layers, downward water movement may be retarded enough to ultimately contribute to higher disease severity in areas of fields where such compaction occurs (Schwalm 1973; Juzwik et al. 1994; Juzwik and Rugg 1996). Root disease was observed in a portion of the white pine field at the Minnesota nursery in which penetrometer measurements had been taken. Rate of water movement through the soil profile in affected portions of the field was compared with that in adjacent unaffected areas. Undisturbed soil cores (5 cm long x 5 cm diameter) were removed from five different layers in the vertical profile and rate of water movement through the cores was determined in the laboratory for measuring saturated hydraulic conductivity, or K_{sat} (Klute and Dirksen 1986). The K_{sat} measurements for soils in the affected areas were significantly lower (i.e. slower rate of water flow) in all depth increments tested than those for the same depth increments in soils of the unaffected plots (Table 1).

Table 1. Rate of water flow (K_{sat}) through undisturbed soil cores taken from different depths in white pine field of the Minnesota nursery.

Soil Depth (cm)	Root Disease Affected Plots (cm/hr)	Non-Affected Plots (cm/hr)
0-5	14.3	20.9
5-10	14.8	19.9
10-15	13.8	20.1
15-20	11.6	18.8
23-28	11.7	18.9

The rate of vertical water movement through soils in the Wisconsin nursery was also examined using the same methodology. The K_{sat} in the 8 to 13-cm depth increment (the tiller attributed compacted layer previously mentioned) in the white pine field was significantly lower (ave. 14.4 cm/hr) than the value expected for the soil type when no soil compaction is found (ave. 18.4 cm/hr).

In summary, the K_{sat} data for white pine fields in both nurseries suggest that impeded drainage following significant irrigation or rainfall events can cause sufficient physiological stress to predispose seedlings to disease development (Allmaras et al. 1988).

COVER CROP RESIDUE PLACEMENT AND BUILD-UP OF SOIL-BORNE *FUSARIUM*

Populations of *Fusarium* spp. were determined for soils in the same nursery fields used for the penetration resistance studies. The number of propagules (colony forming units, cfu) in 6-cm depth increments for the 0 to 42-cm depth zone were determined for the five 2 + 0 pine fields.

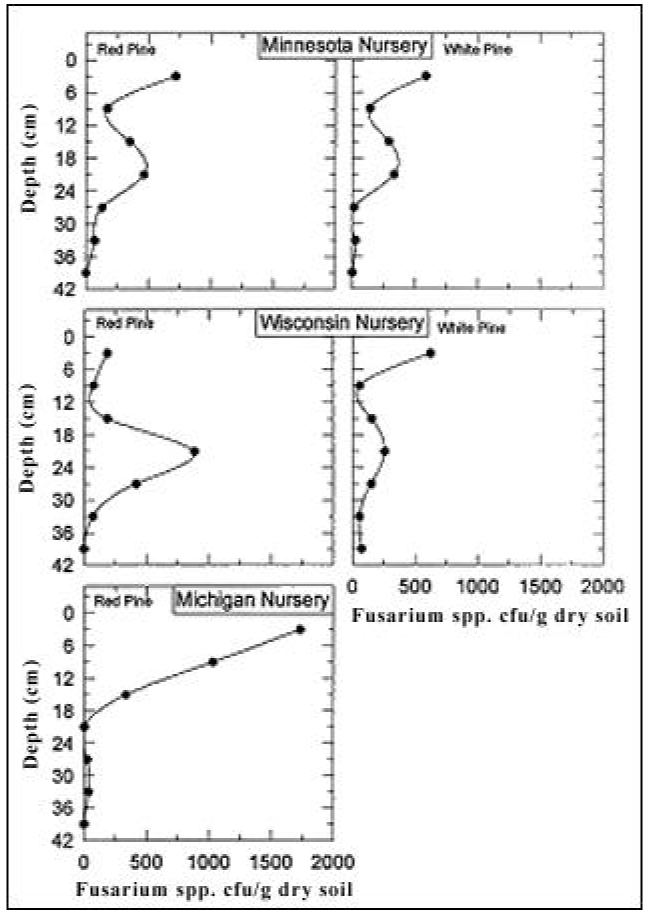


Figure 2. Populations of *Fusarium* spp. in bulk from various depths in 2+0 pine seedling plots in three bareroot forest tree nurseries.

The vertical *Fusarium* population profiles were similar in the Minnesota and Wisconsin nursery fields, while a different profile was found for the Michigan field (Figure 2). Operational fumigation had been conducted in the Minnesota (metam sodium) and the Wisconsin nursery (methyl bromide - chloropicrin) prior to sowing of the pine crop. Fumigation was not used in the Michigan field.

The population peaks observed in the 0 to 6-cm layer in the Minnesota and Wisconsin fields were attributed to build-up in *Fusarium* spp. that occurred after soil fumigation and is explainable by: 1) re-infestation via blowing soil and infested seed (Vaartaja 1962; Ocamb and Juzwik 1993), and 2) subsequent proliferation of introduced *Fusarium* on carbon sources from growing seedling roots and surface mulch.

The deeper population peak (18 to 24-cm depth) is attributed to: 1) *Fusarium* that survived fumigation treatment (probably because propagules were below the effective fumigation zone), and 2) build-up of the *Fusarium* on carbon sources from cover crop material incorporated by moldboard plows prior to fumigation and sowing of the pine crop. Previous studies (e.g. Staricka et al. 1991) have shown that the majority of surface residue incorporated by moldboard plows is deposited just above the maximum working depth of the implement.

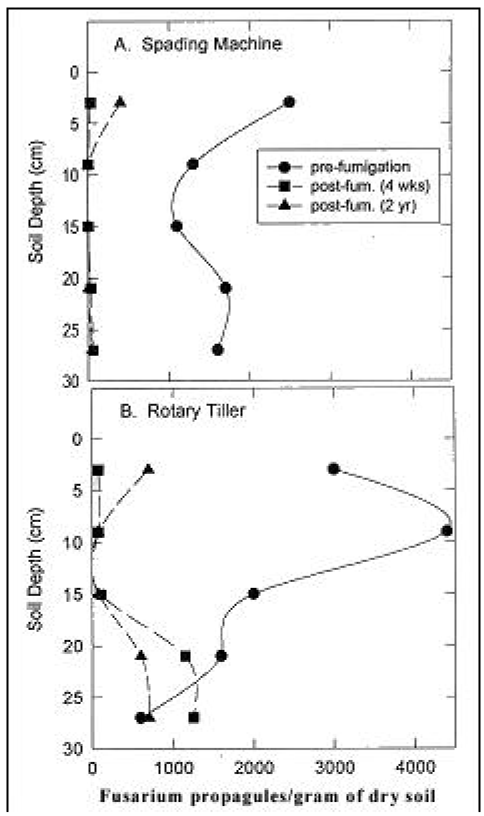
The vertical *Fusarium* population profile in the Michigan nursery was highest at the soil surface and decreased to negligible levels in the 18 to 24 cm depth increment. This observed pattern is attributed to several events. First, the absence of fumigation is one reason for the higher levels of *Fusarium* observed in the 0 to 18-cm zone. Secondly, the surface mulch and proliferating roots of seedlings during the 1 + 0 and 2 + 0 years served as substrate for *Fusarium* build-up in the upper depth increments. Finally, the cover crop material incorporated by a disc also served as substrate for *Fusarium* increase. Incorporation patterns of surface residue by a disc differs from the incorporation patterns characteristic of moldboard plows (Staricka et al. 199 1; Thompson et al. 1994). The steadily declining *Fusarium* population observed from 0 to 21 -cm depth is consistent with the decreasing concentration of incorporated cover crop material with depth when a disc is used for incorporation.

In summary, vertical distribution profiles of soil-borne *Fusarium* spp. at each nursery reflected the type of tillage implement used to incorporate cover crop material which ultimately served as substrate for fungal population increase. Negligible levels of *Fusarium* spp. were found below the maximum depth of tillage implement disturbance in all locations.

FUMIGATION DEPTH AND SOIL-BORNE FUNGAL POPULATION PROFILES

The effect of maximum fumigation depth on vertical distribution of *Fusarium* populations in nursery soils was determined during dazomet incorporation trials conducted at a second Wisconsin nursery and a second Michigan nursery in 1994 and 1995.

In the Wisconsin nursery trial, 560 kg/ha of dazomet was applied to the soil surface with a Gandy spreader in a field slated for white pine seedling production. The granular material was immediately incorporated into the sandy loam soil (with soil moisture content at 60% of field capacity) using either a rotary tiller with 22 cm long bent tines or a spading machine with six 13 cm wide by 18 cm long spades. The surface was then rolled and a water seal maintained for two weeks using overhead irrigation. Populations of *Fusarium* spp. in the soil were determined immediately prior to fumigation (mid-August), four weeks after fumigation, and in August of the second growing season of the white pine crop.



The operational incorporation depth of the spading machine was known to be twice that of the rotary tiller used (Juzwik et al. 1997). The deeper dazomet incorporation by the spading machine resulted in excellent and sustained reduction in *Fusarium* propagules from 6 to 30 cm (Figure 3). In contrast, the rotary tiller incorporation of dazomet resulted in similar and sustained reduction in fungal populations only between 6 and 18 cm. Since white pine roots often reach and exceed 18 cm early in the 2 + 0 year in this particular nursery, root rot would be expected to occur in the lower portion of seedlings growing in such a field. Furthermore, one of the reasons dazomet fumigation may not give adequate control of root rot in forest nurseries may be due to the use of similar rotary tillers for product incorporation.

Knowledge of the vertical distribution of potential pathogenic fungi in nursery soil would be useful in determining fumigant rate and depth required when fumigation is utilized. In the Hayward trial field, significant levels of Fusarium spp. (> 500 CFU/gram of dry soil) were detected from 0 to 30-cm depth. This deep distribution is probably due to the fact that a moldboard plow was used to incorporate cover crop residue in that particular field prior to fumigation. Thus, just knowing that a moldboard plow was used for residue incorporation would suggest that fumigation depth required for effective *Fusarium* control would be 25 cm or greater.

Figure 3. Vertical profile of *Fusarium* spp. soil populations before and after fumigation in Hayward Nursery dazomet incorporation trial. A. Spading machine has 25 cm effective incorporation depth. B. Rotary tiller has 12 cm effective incorporation depth.

Results of a second fumigation trial conducted at Toumey nursery, Watersmeet, MI, support this reasoning. Specifically, the pre-fumigation populations of *Fusarium* in the soil were significant only between 0 and 15 cm (Figure 4). This reflects the fact that a disc was used to incorporate cover crop residue prior to the fumigation. In comparing dazomet incorporation results for the three different implements tested at Toumey, all were equally as effective in placing dazomet in the 0 to 15-cm soil zone as shown by the similar reductions in *Fusarium* levels four weeks after fumigation and one year later during the 1 +0 growing season of the white pine crop.

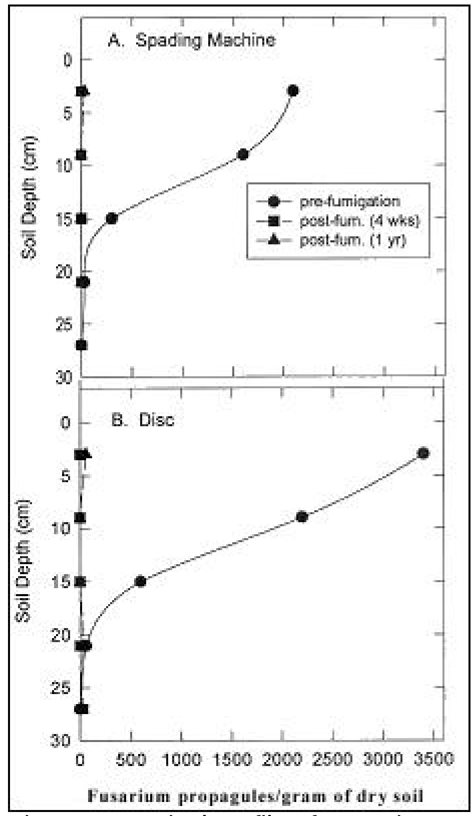


Figure 4. Vertical profile of *Fusarium* spp. soil populations before and after fumigation in Toumey Nursery dazomet incorporation trial. A) Spading machine has 25 cm effective incorporation depth. B) Disc has 15 cm effective incorporation depth.

In summary, consideration should be given to where pathogenic organisms are most likely building up in the soil profile before fumigation is used. Extensive survey of vertical soil-borne fungal populations in nursery fields scheduled for fumigation is not feasible or practical. However, results of these studies suggest that by just considering what tillage implements are used to incorporate residues will give a good idea of maximum depth of fumigation required for control of potential pathogens. Likewise, Staricka et al. (1991) could predict the depth of crop residue placement merely by knowledge of the tillage tool(s) used. Ideally, shallower residue distribution such as that associated with disc incorporation would be desirable for fields scheduled for chemical fumigation. A lower rate of chemical fumigation would also be possible if one is dealing with soil volume in the 0 to 15-cm soil zone compared to higher rate needed for effective fumigation of a greater soil volume contained in the 0 to 30-cm zone.

CONCLUSIONS

Nursery managers could use tillage to control depth placement of cover crop residue and subsequent buildup of fungal propagules, adjust tillage practices to prevent tillage pans within the seedling root zone (Allmaras et al. 1994), and maintain near field capacity soil moisture levels for seedling growth in their integrated management of root disease in pine crops. Consideration of tillage practices effects on residue placement can also be the basis for more effective and wise use of chemical fumigation.

ACKNOWLEDGMENTS
This paper is based on a portion of an M.Sc. thesis submitted to the Department of Plant Pathology, University of Minnesota, by K.M. Gust (Gust 1996). The technical assistance of John Borkenhagen, Paul Castillo, Gary Dinkel, Tom Hill, Dick Johnson, Ron Overton, Dwayne Stenlund and Spencer Stone in the set-up and execution of these studies is gratefully acknowledged. These studies were partially funded by USDA Forest Service NE Area S&PF and NAPIAP.

---

[1]Juzwik, J.; Gust, K.M.; Allmaras, R. R. 1997. Soil Tillage Practices and Root Disease Management. In: Landis, T.D.; Thompson, J. R., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 23-28.

[2]USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, MN 55108; Tel: 612/649-5114; Fax: 612/649-5285; e-mail: juzwi001@maroon.tc.umn.edu).

[3]USDA Agricultural Research Service, 439 Borlaug Hall, University of Minnesota, St. Paul, MN 55108; Tel: 612/625-1742; e-mail: (allmaras@soils.umn.edu).

[4]former Graduate Student, Dept. of Plant Pathology, 495 Borlaug Hall, University of Minnesota, St. Paul, MN 55108.

LITERATURE CITED
Allmaras,R.R., Kraft, J.M., and Miller,D.E. 1988. Soil compaction and incorporated crop residue effects on root health. Ann. Rev. Phytopath. 26:219-243.

Allmaras, R.R., Juzwik, J., Overton, R.P. and Copeland, S.M. 1994. Soil compaction: Causes, effects, management in bareroot nurseries. pp. 19-32. In: Proc. Northeastern and Intermountain Forest and Conservation Nursery Association, Aug. 2-5,1993, St. Louis, MO, USDA For. Serv. Gen. Tech. Rep. RM-243.

Gust, K.M. 1996. Conifer root pathogen populations in relation to soil characteristics and cultural practices in three bareroot forest tree nurseries. M.Sc. Thesis, Univ. of Minnesota, St. Paul, MN. 67 pp.

Juzwik, J., Menes, P.J., and Rugg, D.J. 1994. Soil moisture and *Fusarium* root rot of white pine seedlings. pp. 85 - 90. In: Proc. Northeastern and Intermountain Forest and Conservation Nursery Association, Aug. 2-5, 1993, St. Louis, MO, USDA For. Serv. Gen. Tech. Rep. RM-243.

Juzwik, J., Ocamb, C.M., and Cease, K.R. 1995. Effect of covercropping and fumigation on *Fusarium* species populations in bareroot nursery soils. Phytopathology 85:1198.

Juzwik, J., and Rugg, D.J. 1996. Seedling mortality and development of root rot in white pine seedlings in two bare-root nurseries. Can. J. Plant Path. 18:335-341.

Juzwik, J., Stenlund, D.L., Allmaras, R.R., Copeland, S.J., and McRoberts, R.E. 1997. Soil & Tillage Res/41:237-248.

Klute, A., and Dirksen, C. 1986. Hydraulic conductivity and diffusivity: Laboratory methods. In: A. Kulte (ed.) Methods of Soil Analysis. Part 1. 2nd ed., Agron. Monogr. 9. ASA and SSSA, Madison, WL

Ocamb, C.M., and Juzwik, J. 1993. Seed-borne *Fusarium* species in untreated white pine seed. Phytopathology 83:1411.

Schwalm, J.M. 1972. Root rot in seedlings triggered by wet weather and poor drainage. Tree Planters' Notes 24:18.

Staricka, J.A., Allmaras, R.R., and Nelson, W.W. 199 1. Spatial variation of crop residue incorporated by tillage. Soil Sci. Soc. Am. J. 55:1668-1674.

Sullivan, S. 1997. Improving IPM. American Nurseryman 186(8):2429.

Sutherland, J.R., and Anderson, R.L. 1980. Seedling disease and insect problems related to nursery soil conditions in North America. pp. 182 - 190. In: L.P. Abrahamson and D. H. Bickelhaupt (eds.), Proc. North American Forest Tree Nursery.

Thompson, Jr., L., Skroch, W.A., and Beasley, E.O. 1994. Pesticide incorporation: distribution of dye by tillage implements. AG-250, NC Coop. Ext. Serv., NC State Univ., Raleigh, NC. 32 pp.

Vaartaja, 0. 1964. Survival of *Fusarium, Pythium,* and *Rhizoctonia* in very dry soil. Can. Dep, Agric. Sci. Serv. Bimon. Prog. Rep. 20:3.