Development and Field Performance of Slash and Loblolly Pine Seedlings Produced in Fumigated Nursery Seedbeds and Seedbeds Amended with Organic Residues[1]

E. L. Barnard[2], M. E. Kannwischer-Mitchell[2], D. J. Mitchell[3], and S. W. Fraedrich[4]

Barnard, EL.; Kannwischer-Mitchell, M. E ; Mitchell, D. J.; and Fraedrich, S. W. 1996. Development and Field Performance of Slash and Loblolly Pine Seedlings Produced in Fumigated Nursery Seedbeds and Seedbeds Amended with Organic Residues. In: Landis, T.D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 32-37. Available at: http://www.fcanet.org/proceedings/1996/barnard.pdf

The Montreal Protocol assessment of 1991 identifying methyl bromide as a chemical contributing to the depletion of the stratospheric zone layer and the U.S. Environmental Protection Agency's (EPA) proposal to eliminate the production and use of methyl bromide pursuant to the U.S. Clean Air Act of 1990 (Civerolo, et al.; Smith and Fraedrich 1993) have generated a flurry of activity to identify and assess alternatives to methyl bromide for the control of pests in forest tree nurseries. As part of a national initiative funded by the United States Forest Service (James, et al. 1993), we have grown southern pine seedlings (*Pinus elliottii* Engelm., *P. taeda* L. and *P. palustris* Mill.) in southern forest nurseries in successive years in seedbeds amended with pine bark or composted organic residues, or treated with methyl bromide. Project objectives include the following:

1) assess effects of organic soil amendments on disease suppression and seedling production/quality;
2) evaluate the field outplant performance of treated seedlings;

3) assess comparative costs and benefits;

4) develop methods and baseline data for nursery disease forecasting and/or risk assessment.

Progress reports have been provided periodically (Barnard, et al. 1994; Barnard et al. 1996; Kannwischer-Mitchell, et al. 1994), and this paper updates our results in anticipation of a final report as we enter our fourth, and likely final, project year. The focus of this paper is on seedling development and field performance. Microbiological data and nutrient data for seedlings and soil, collected primarily for analytical purposes, are still being developed and will be published in detail upon completion of the project.

Three nurseries are involved in this project. However, the following unanticipated problems have limited the value of information from longleaf pine at the U.S. Forest Service's Ashe Nursery in Brooklyn, Mississippi.: major infestations of nutsedge (Cyperus spp.); 1.5-year as opposed to annual crop rotations; a confounding influence of a possibly seedborne infection by *Fusarium subglutinans* (Wollenweb. & Reinking) P.E. Nelson, T.A. Toussoun, &

Marasas; and necessary mid-study plot relocations. Accordingly, this paper includes data for only slash pine at the Florida Division of Forestry's Andrews Nursery in Chiefland, Florida, and loblolly pine at International Paper Company's Supertree Nursery in Blenheim, South Carolina.

MATERIALS AND METHODS

Field trials began in the Division of Forestry's Andrews Nursery in 1993 and in International Paper Company's Supertree Nursery in 1994. Fumigated study plots received standard operational treatment with methyl bromide prior to the sowing of each seedling crop. Plots amended with organic residue received annual applications of either pine bark or composted organic materials. Composted organic residues consisted of composted yard waste at Andrews Nursery in 1993 and 1994, aged hardwood bark at International Paper Company's Supertree Nursery in 1994, and a commercially available composted municipal waste from Tennessee (Bedminster, Inc.) in both nurseries in 1995 and 1996. These materials were applied at 1X (2.5 cm layer) or 2X (5.0 cm layer) rates and mechanically incorporated into seedbed soils to a depth of 15-20 cm prior to the sowing of each seedling crop. Check plots received no treatment other than routine soil tillage and seedbed preparation, which was standard across all treatments. All plots were operationally irrigated, fertilized, and treated with topically applied herbicides. No special treatments were applied to any particular plots, with the exception of the 1996 compost plots at Andrews Nursery which received an additional 560 kg per hectare of sulfur to ameliorate a treatment-induced pH problem. Plots were installed as indicated in figures 1 and 2.

Fumigated		Compost (2.5 cm)	
	Pine Bark (5 cm)		Compost (5 cm)
Check		Pine Bark (2.5 cm)	
	Compost (2.5 cm)		Fumigated
Pine Bark (2.5 cm)		Fumigated	
	Pine Bark (2.5 cm)		Pine Bark (5 cm)
Compost (5 cm)		Check	
	Fumigated		Compost (2.5 cm)
Compost (2.5 cm)		Pine Bark (5 cm)	
	Compost (5 cm)		Check
Pine Bark (5 cm)		Compost (5 cm)	
	Check		Pine Bark (2.5 cm)

Figure 1. Field Layout of study plots at the Florida Division of Forestry's Andrews Nursery in Chiefland, FL. Individual treatment plots are three seedbeds wide (3.7 m) by 36.6 m long. Fumigated borders are indicated by shaded areas.

Fum	Ch	Ch	Fum	Com	Fum
Com	Com	PB	PB	Ch	
PB	Fum	Com	Ch	PB	

Figure 2. Field Layout of study plots at International Paper Company's Supertree Nursery in Blenheim, SC. Individual treatment plots are three seedbeds wide (3.7 m) by 12.2 m long. Fumigated borders are indicated by shaded areas (Fum=Fumigated, Com=Compost 2.5 cm, PB=pine bark 2.5 cm, Ch=check).

Seedling stand counts were performed periodically in three permanent subplots in the center of each treatment plot. In addition, seedlings from each treatment plot were systematically sampled at early season, mid-season, and end of season for comparative morphology measurements, nutrient analyses, and rhizosphere microbe assays. Soil samples collected simultaneously with seedling samples were subjected to standard nutrient and nematological assays. Also, soils from the Andrews Nursery plots periodically were assayed for qualitative and quantitative comparisons of soil microbe and pathogen populations.

At the end of each nursery year, seedlings from each treatment plot were outplanted onto operationally prepared reforestation sites in three replicate 50seedling row plots in a randomized complete block design. Survival and growth of these seedlings were periodically monitored and measurements were taken at the end of the first growing season following outplanting.

RESULTS AND DISCUSSION

Treatment effects thus far have not been large. Although interesting and sometimes subtle treatment differences with respect to rhizosphere microorganisms, seedling nutrition, and seedling size, are apparent, few statistically significant differences were consistent among treatments across study years. Organic residue amendments have clearly influenced soil organic matter and pH. For example, soil organic matter in composted yard waste-amended soils (2X rate) in the Andrews Nursery were above 2.0% after two seedling crops, while that in all other soils was between 0.5 and 1.0%. Similarly, seedbed soil pH values in the Andrews Nursery were well above 6.5 after 2 years of amending with composted yard waste, whereas pH values in all other treatments were approximately 5.0. However, across the board, differences in seedling quality and field performance have been minimal. Tables 1-4 provide a summary of our seedling quality and performance data to date. Field performance data for the 1995 nursery seedling crops will be collected during the winter of 1996-97, and 1996 crop data are still being collected.

Table 1. Slash pine seedling production and morphology at the Division of Forestry's Andrews Nursery in Chiefland, Florida.[z]

Measurement	Check	Methyl Bromide	Pine Bark (2.5 cm)	Pine Bark (5.0 cm)	"Compost" (2.5 cm)	"Compost" (5.0 cm)
1993 Crop Year						
Seedlings per 929 cm^2 (1 ft^2)	15.3 b	20.0 a	17.6 ab	17.7 ab	18.0 ab	18.2 ab
Height (cm)	19.5 c	25.2 a	21.8 bc	22.5 ab	23.6 ab	21.1 bc
Root Collar Diameter (mm)	4.6 a	4.9 a	4.5 a	4.4 a	4.7 a	4.6 a
Shoot/Root Ratio	2.4 a	2.9 a	2.8 a	2.4 a	2.9 a	2.5 a
1994 Crop Year						
Seedlings per 929 cm^2 (1 ft^2)	20.9 a	22.1 a	22.2 a	22.1 a	21.4 a	20.4 a
Height (cm)	24.6 c	29.1 a	26.2 bc	24.9 bc	29.3 ab	27.9 bc
Root Collar Diameter (mm)	5.2 a	4.8 a	4.8 a	5.2 a	5.1 a	5.4 a
Shoot/Root Ratio	3.1 ab	3.6 a	3.3 ab	3.0 bc	3.6 a	3.4 ab
1995 Crop Year						
Seedlings per 929 cm^2 (1 ft^2)	24.3 bc	26.2 ab	27.3 a	25.2 abc	23.4 bc	22.7 c
Height (cm)	23.9 b	28.6 a	25.7 b	23.6 b	28.4 a	25.7 b
Root Collar Diameter (mm)	4.7 bc	4.7 abc	4.4 cd	4.2 d	5.2 a	4.9 ab
Shoot/Root Ratio	3.6 ab	4.3 a	3.5 b	3.4 b	3.8 ab	3.5 b

[z]Mean seedling counts based on twelve subplot counts per treatment. All other means based on measurements of 160 seedlings per treatment. Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

Table 2. Loblolly pine seedling production and morphology at International Paper Company's Supertree Nursery in Blenheim, South Carolina.[z]

Measurement	Treatment: Check	Methyl Bromide	Pine Bark (2.5 cm)	"Compost" (2.5 cm)
1994 Crop Year				
Seedlings per 929 cm^2 (1 ft^2)	28.8 a	26.4 ab	24.7 ab	23.8 ab
Height (cm)	33.6 ab	35.3 a	33.3 ab	31.7 ab
Root Collar Diameter (mm)	5.0 ab	5.1 ab	5.4 a	4.6 a
Shoot/Root Ratio	3.9 a	4.1 a	3.5 b	3.6 b
1995 Crop Year				
Seedlings per 929 cm^2 (1 ft^2)	23.3 ab	23.9 a	21.4 b	24 a
Height (cm)	28.7 b	28.6 b	27.2 b	31.5 a
Root Collar Diameter (mm)	4.2 a	4.1 a	4.2 a	4.4 a
Shoot/Root Ratio	3.2 b	3.3 b	3.5 b	4.2 a

[z]Mean seedling counts based on twelve subplot counts per treatment. All other means based on measurements of 160 seedlings per treatment. Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

Table 3. First-year field outplant performance of slash pine seedlings from the Division of Forestry's Andrews Nursery in Chiefland, Florida.[z]

Measurement	Check	Methyl Bromide	Treatment: Pine Bark (2.5 cm)	Treatment: Pine Bark (5.0 cm)	Treatment: "Compost" (2.5 cm)	Treatment: "Compost" (5.0 cm)
1993 Seedling Crop						
Survival (%)	100 a	99.2 a	99.3 a	99.2 a	99.3 a	99.7 a
Height (cm)	56.7 ab	53.4 b	59.4 ab	60.7 ab	59.9 ab	62.6 a
Root Collar Diameter (mm)	20.7 a	19.1 a	20.3 a	21.9 a	20.8 a	22.2 a
Plot Volume Index[x]	121.7 ab	100.0 b	123.6 ab	146.1 ab	129.5 ab	157.0 a
1994 Seedling Crop						
Survival (%)	99.6 a	98.8 a	100.0 a	99.0 a	99.2 a	99.4 a
Height (cm)	51.1 a	52.9 a	55.4 a	53.3 a	55.1 a	55.8 a
Root Collar Diameter (mm)	15.1 a	14.6 a	15.9 a	16.4 a	16.1 a	17.3 a
Plot Volume Index[x]	58.9 a	59.5 a	72.7 a	71.6 a	72.2 a	83.6 a

[z]Mean seedling counts based on twelve, 50-tree plots per treatment. Mean heights based on 25 seedlings per plot (= 300 seedlings per treatment). Mean root collar diameters based on 15 seedlings per plot (1=180 seedlings per treatment). Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

Table 4. First- year field outplant of loblolly pine seedlings from International Paper Company's Supertree Nursery in Blenheim, South Carolina.[z]

Measurement	Check	Methyl Bromide	Pine Bark (2.5 cm)	"Compost" (2.5 cm)
		Treatment		
1994 Seedling Crop				
Survival (%)	97.0 a	97.5 a	95.5 ab	97 a
Height (cm)	52.9 a	53.4 a	51.4 ab	48.8 b
Root Collar Diameter (mm)	8.6 ab	9.0 a	8.2 b	8.1 b
Plot Volume Index[x]	19.0 ab	21.3 a	16.5 b	15.7 b

[z]Mean seedling counts based on twelve, 50-tree plots per treatment. Mean heights based on 25 seedlings per plot (= 300 seedlings per treatment). Mean root collar diameters based on 15 seedlings per plot (1=180 seedlings per treatment). Treatment means for each variable followed by the same letter do not differ significantly (p 0.05).

Of interest is the fact that serious root disease problems have not occurred in our study plots, despite the fact that plots at the Andrews Nursery were purposely located in a compartment with a history of charcoal root rot caused by *Macrophomina phaseolina* (Tassi) Goid. In fact, the only indication of any root disease present in our plots, and this has been relatively inconsequential, has been scattered damping-off, apparently caused by species of *Fusarium*, *Pythium*, *Rhizoclonia* (or Rhizoctonia-like fungi), and possibly other fungi. In the 1993 seedling crop at Andrews Nursery, damping-off, apparently due in large measure to *Pythium myriotylum* Drechs., resulted in a statistically significant reduction in seedling numbers in our check plots as compared to methyl bromide-treated plots (table 1). This difference was not maintained in the 1994 and 1995 seedling crops, however, even though treatment plots have been maintained in the same locations throughout the study.

Organic residues used as soil amendments in this study were not selected because of their particular perfection or demonstrated utility. Instead, they were selected because of their ready availability and potential utility with respect to suppression of soilborne pathogens (Hoitink and Fahy 1986; Pokorny 1982). Rates of application have been arbitrary, but one of our objectives has been to sufficiently load soils typically deficient in organic matter to induce over time beneficial changes in soil microflora. Data are still being collected and analyzed with respect to soil microbial responses, but on a macro level it appears that pine bark is generally preferable as an amendment to the composted materials used in our studies.

The lack of root disease development to date has pretty much precluded meaningful evaluation of our organic residue amendments with the respect to suppression of disease development. Nonetheless, the lack of disease development and the failure of seedlings in fumigated soils to develop or perform better than those in unfurnigated soils even those soils not receiving any amendment, raises legitimate questions regarding the need for and cost-effectiveness of the routine use of methyl bromide for root disease control in these two test nurseries.

Much more can (and will) be said regarding the issue of methyl bromide fumigation in forest tree nurseries. To date our data are inconclusive, discouraging, or encouraging depending upon one's point of view and the particular data being considered. At the least, our data, to be summarized in detail upon project completion, will provide a substantial and useful baseline from which to continue discussions and consider new approaches.

---

[1]*This paper also appears in the Proceedings of the third Meeting of the International Union of Forest Research Organizations' Working Party on Diseases & Insects in Forest Nurseries. Gainesville, FL. May 19-24, 1996*

[2]*Forest Pathologist and Project Research Scientist, respectively, Florida Division of Forestry Florida Department of Agriculture & Consumer Services P.O. Box 147100, Gainesville, FL 32614-7100; Tel: 3521372-3505; Fax: 3521955-2301.*

[3]*Professor, Department of Plant Pathology, University of Florida, Gainesville, FL 32611.*

[4]*Research Plant Pathologist, USDA Forest Service, 320 Green Street, Athens, GA 30602.*

ACKNOWLEDGMENTS
The authors express their appreciation to Charles Affeltranger, Ernie Ash, Steve Gilly, Michelle Cram, Chuck Gramling, International Paper Co. and Jefferson Smurfit Corporation for invaluable support rendered to this effort. Funding for this work has been provided by the U.S.D.A. Forest Service, Region 8, Forest Health.

LITERATURE CITED

Barnard, E.L.; Kannwischer-Mitchell, M.E.; Mitchell, D.J.; Fraedrich, S.W. 1996. Progress and trends: Southeastern regional component of a national technology development effort evaluating nursery management and seedling development without dependence on methyl bromide. Southwide Forest Disease Workshop, Clemson, SC. January 22-25, 1996. (Abstr.)

Barnard, E.L.; Mitchell, M.E.; Mitchell, D.J.; Fraedrich, S.W. 1994. Evaluating the efficacy of organic soil amendments as alternatives to methyl bromide for control of soilborne pathogens in forest tree nurseries. Southwide Forest Disease Workshop, Asheville, NC. June 7-9, 1994. (Abstr.)

Civerolo, E.L.; Narang, S.K.; Ross, R.; Vick, K.W.1 Greczy, L. (eds). 1993. Alternatives to methyl bromide: Assessment of research needs and priorities. Proceed ings from the U.S.D.A. Workshop on Alternatives to Methyl Bromide. Arlington, VA. June 29-July 1, 1993. 85 p.

Hoitink, H.A.J.; Fahy, P.C. 1986. Basis for the control of soilborne plant pathogens with composts. Annual Review of Phytopathology 24:93-114.

James, R.L.; Hildebrand, D.M.; Frankel, S.J.; Cram, M.M.; O'Brien, J.G. 1993. Alternative technologies for management of soil-borne diseases in bareroot forest nurseries in the United States. Pages 91-96 in Landis, T.D. (Tech. Coord.) Proceedings: Northeastern and Intermountain Forest and Conservation Nursery Associations. U.S.D.A. Forest Service, GTR RM-243. 158 p.

Kannwischer-Mitchell, M.E.; Barnard, E.L.; Mitchell, D.J.; Fraedrich, S.W. 1994. Pages 12-15 in Landis, T.G. and Dumroese, R.K. (Tech. Coords.). National Proceedings: Forest and Conservation Nursery Associations. U.S.D.A. Forest Service. GTR RM-257. 319 p.

Pokorny, F.A. 1982. Pine bark as a soil amendment. Pages 131-139 in Brissette, J. and Lantz, C. (compilers), Proceedings: 1982 Southern Nursery Conferences. U.S.D.A. Forest Service. Technical Publication R8-TP4. 312 p.

Smith, R.S. Jr.; Fraedrich, S.W. 1993. Back to the future pest management without methyl bromide. Tree Planters' Notes 44:87-90.