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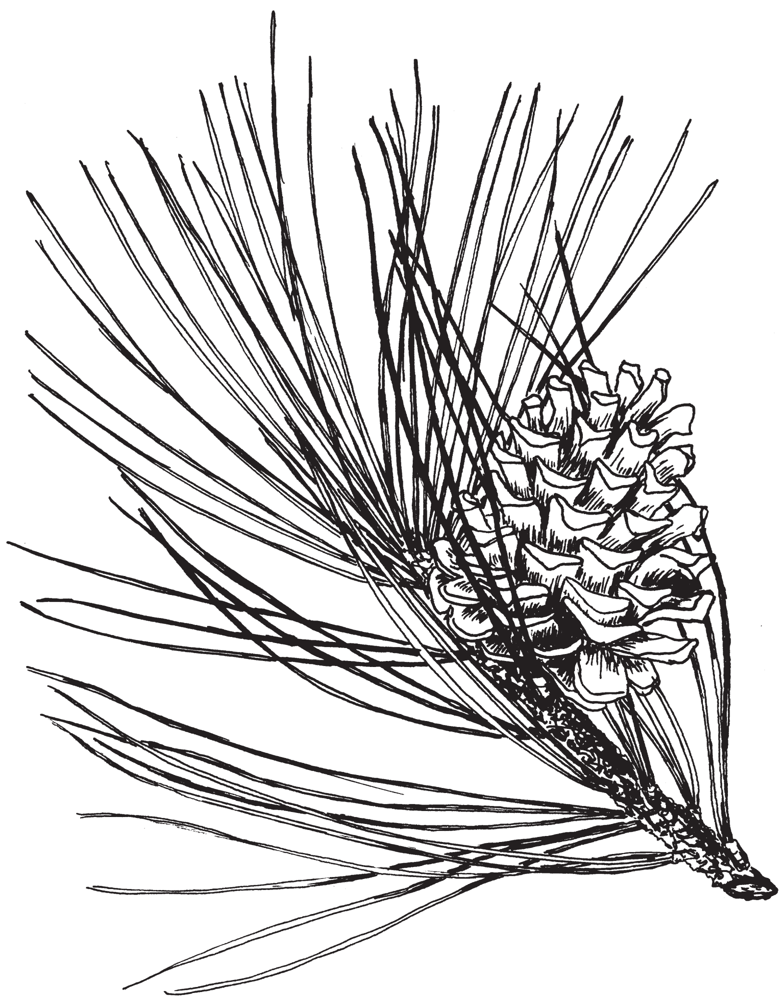

Ponderosa pine drawing by Lorraine Ashland, College of Natural Resources, University of Idaho.

Effect of Organic Amendments on Douglas-Fir Transplants Grown in Fumigated Versus Non-Fumigated Soil

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Abstract: We transplanted one-year old Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) seedlings into compost-amended soil that had either been spring-fumigated with a methyl bromide/chloropicrin combination or left unfumigated. Seedling nutrient, pathology, morphology, and packout measurements were significantly better for those transplanted into fumigated rather than non-fumigated soil, regardless of compost treatment. Among seedlings transplanted into non-fumigated soil, those grown in the biosolid and bark-based composts had the highest average number of packable seedlings.

Keywords: seedlings, root disease, methyl bromide, compost, pest management

Introduction

Many bareroot forest nurseries have traditionally relied on the injection and tarping of the soil fumigant methyl bromide as an integral part of their pest management programs. Methyl bromide was listed as a Class 1 ozone depleting substance in 1991, and was officially phased out in 2005 under the Montreal Protocol (MBTOC 2006). Some agricultural sectors, such as bareroot forest nurseries, including the Washington Department of Natural Resources Webster Nursery, continue to use methyl bromide under limited quarantine pre-shipment or critical use exemptions (Haase 2009). Meanwhile, registered fumigants that serve as potential alternatives to methyl bromide have recently come under stricter regulation based on the potential for human inhalation exposure (EPA 2009). In 2008, we conducted a pilot trial of composts to determine disease suppression as part of a larger research effort to identify chemical and non-chemical alternatives to methyl bromide.

Forest nurseries have traditionally used organic amendments to maintain or improve soil physical and chemical parameters (Rose and others 1995; Davis and others 2006). Incorporating organic amendments has also been shown to stimulate functional groups of bacteria, fungi, and other soil organisms that, in turn, suppress soil pathogens in crops such as snap peas and corn (Stone and others 2004). Modes of fungal pathogen suppression include direct antagonism, competitive exclusion, and induced systemic resistance (Hoitink and Fahy 1986).

Several trials in conifer forest nurseries have specifically examined the use of organic amendments to suppress soil pathogens. In direct comparisons with a methyl bromide control, Stevens (1996) reported incorporation of 1.3 cm (0.5 in) yardwaste compost resulted in poor pre-plant control of root rots caused by *Fusarium* spp. and *Pythium* spp., and inferior seedling density and morphology in a 1+0 Douglas-fir (*Pseudotsuga menziesii*) crop. Elevated nitrogen (N) levels in the compost were implicated in disease outbreaks. Hildebrand and others (2004) found that incorporation of aged sawdust (with delayed N application) benefited conifer seedlings over mature composts in USDA Forest Service nursery trials. Although pre-plant soil pathology did not correlate well with resulting favorable seedling morphology, they commented that slowly decomposing organic soil amendments, such as sawdust, may tend to favor the growth of competitive soil saprobes to the detriment of soil pathogens that use simple organic substrates. In a southern forest nursery, Barnard and others (1997) similarly found that higher carbon to nitrogen (C:N) ratio materials, like composted pine bark, resulted in better disease suppression and superior packout morphology in comparison to lower C:N compost materials. However, still other forest nursery studies have documented suppression of conifer root pathogens (such as *Cylindrocladium* spp.) through application of low C:N materials like human sewage composted with sawdust (biosolids) and mushroom compost (Hunter and others 1997).

Materials and Methods

Organic Amendments

With the assistance of experts in the field, we identified four reproducible, scalable, high-quality organic amendments that are made within a reasonable distance from the nursery. These organic amendments covered some of the range of materials previously used in forest nursery trials:

1) *woody*—primarily made from woody landscape debris;
2) *bark*—Douglas-fir bark material (0.6-cm [0.25-in] screen);
3) *yard/food*—made from municipal yard, food, and food-soiled paper waste;
4) *biosolid*—a processed sewage sludge composted with 3 parts Douglas-fir sawdust.

All amendments were raised to pile temperatures of at least 71 °C (160 °F) at least three times and turned in a minimum 45-day process. Selected nutrient and compost quality results, conducted by a certified compost testing lab (Soiltest, Moses Lake, WA), are listed in Table 1. All amendments passed a CO_2 evolution test, and Solvita® tests (Earthcare Limited, Coventry, UK) revealed that the amendments were only slowly decomposing prior to incorporation. Only the yard/food and biosolid composts passed a maturity test (cucumber seed germination test).

Fumigation and Organic Amendment Application

The trial field had a Yelm sandy loam with 3.4% organic matter and was cover-cropped in winter wheat for 2 years, then left bare fallow the year prior to the trial. Fumigation took place 13 April 2008, and consisted of a "spring mix" of 80% methyl bromide and 20% chloropicrin at a rate of 336 kg/ha (300 lb/ac) fumigant applied. We incorporated each of the compost types 3 weeks later, and included a no-compost control. There were four replications of each compost treatment in fumigated and non-fumigated soil in a split-plot design, with fumigation as the whole plot and compost treatment as the split plot (Figure 1). Plot sizes were 9 m (30 ft) long by 1 bed width (1.2 m [4 ft]). Compost applications were applied at a rate of 44 dry tonnes/ha (20 tons/ac) by weight (180 to 189 m^3/ha [95 to 100 yd^3/ac] by volume, equivalent to a surface application of approximately 2-cm [0.75-in] depth). Composts were incorporated into the soil to a depth of 18 cm (7 in). One-year old Douglas-fir seedlings (1+0 bareroot) were then transplanted during the next several days into the amended soils and cultured according to operational practices for the 1+1 stocktype. Operational practices include regular supplemental nitrogen applications in addition to preplant soil fertilization.

Prior to incorporation, the compost amendments used in our trial were assayed by Dr Robert James (USDA Forest Service, retired, now with Plant Disease Consulting Northwest, Vancouver, WA) to check that we were not introducing pathogens that pose significant risk to Douglas-fir seedlings into the nursery. *Fusarium* spp. and *Cylindrocarpon* spp. were not detected, and *Pythium* spp. were detected at very low levels in the woody amendment.

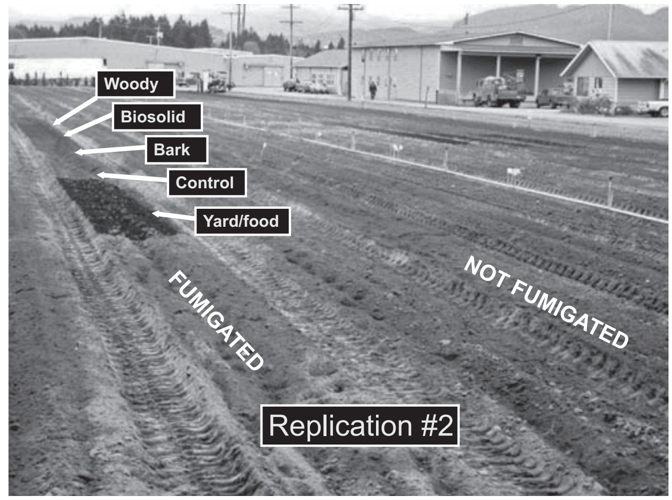

Figure 1. Trial layout. There were four replications of each compost treatment in fumigated and unfumigated soil.

Assessments

Foliar nutrient concentration (Soiltest, Moses Lake, WA, with needle weights taken at Webster Nursery for content calculations) and root pathology measurements (Plant Disease Consulting Northwest, Vancouver, WA) were taken monthly from May through September 2008, and at final harvest (February 2009). Height, stem diameter, root volume, shoot volume, and packable seedling counts were also taken at harvest. Weed evaluations were abandoned due to an uncharacteristic lack of pressure. Outplant evaluation of packable seedlings at two forest sites in southwest Washington, as well as at a nursery garden plot, is ongoing and will be reported on later. We used SAS® software (SAS Institute Incorporated, Cary, NC) for analysis of variance (ANOVA) to identify statistical differences among treatments.

Results

Root fungal analysis revealed significantly lower levels of *Fusarium* spp. (Figure 2A) and *Cylindrocarpon* spp. (Figure 2B), and higher levels of beneficial *Trichoderma* spp. (Figure 2C) from seedlings across all compost treatments in fumigated plots from June onwards. Late September trends of lower *Fusarium* spp. and significantly higher *Trichoderma* spp. levels for the bark compost compared to other composts in unfumigated soils disappeared by the last sampling in February 2009. Due to high variability, the late-season downward trend in *Cylindrocarpon* spp. in the unfumigated woody compost was not significantly different from other amendments in unfumigated soils.

At the late June and late July sampling dates, foliar N concentration was significantly higher for seedlings grown in fumigated soils (Figure 3). Foliar N content (concentration x weight of 100 dried needles) was also significantly higher for seedlings in fumigated plots from June onwards (data not shown). Foliar N did not vary significantly among compost types.

Table 1. Compost amendment descriptions.

Compost type	C:N	pH	EC (mmhos/cm)	Total %N	EPA 503 metals	CO_2 evolution	Bioassay maturity
Woody	34	7.4	0.21	1.10	Pass	Stable	Immature
Bark	132	3.9	0.24	0.37	Pass	Stable	Immature
Yard/Food	18	8.1	0.77	1.67	Pass	Stable	Mature
Biosolid	21	6.8	1.24	1.84	Pass	Stable	Mature

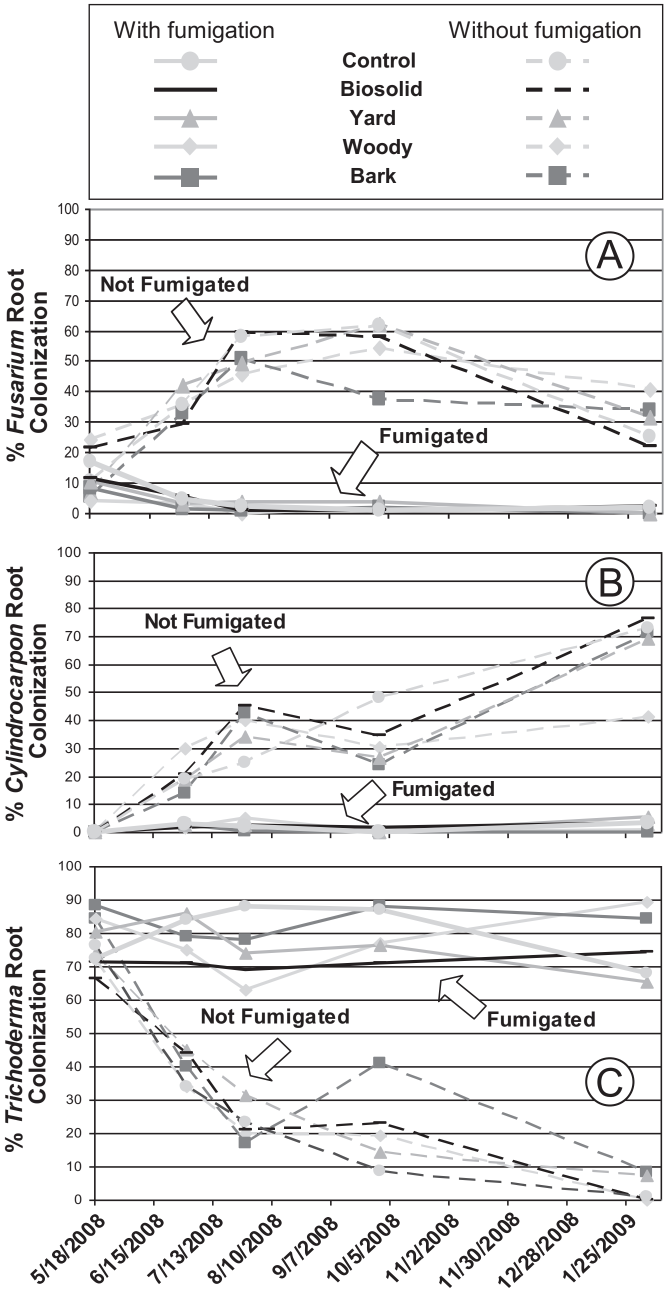

Figure 2. Root fungal analysis revealed significantly lower levels of *Fusarium* spp. (A) and *Cylindrocarpon* spp. (B) and higher levels of beneficial *Trichoderma* spp. (C) from seedlings across all compost treatments in fumigated plots from June onwards.

End-of-season morphology yielded significantly larger height, stem diameter, and shoot volumes for seedlings grown in fumigated versus unfumigated plots, regardless of compost treatment. Root volumes were not significantly different (Table 2). Figures 4a and 4b show dramatic aboveground morphology differences between selected fumigated and unfumigated control plots. Packout averages based on minimum 5-mm stem diameter and 25-cm (10-in) height standards averaged 95.2% across all treatments in fumigated soils versus 83.3% for all seedlings in unfumigated soils (Figure 5). Among seedlings transplanted into unfumigated soil, those grown in the biosolid and bark-based composts had the highest average packable seedlings, though were not significantly different from the unfumigated control. However, only the fumigated biosolid treatment had a significantly

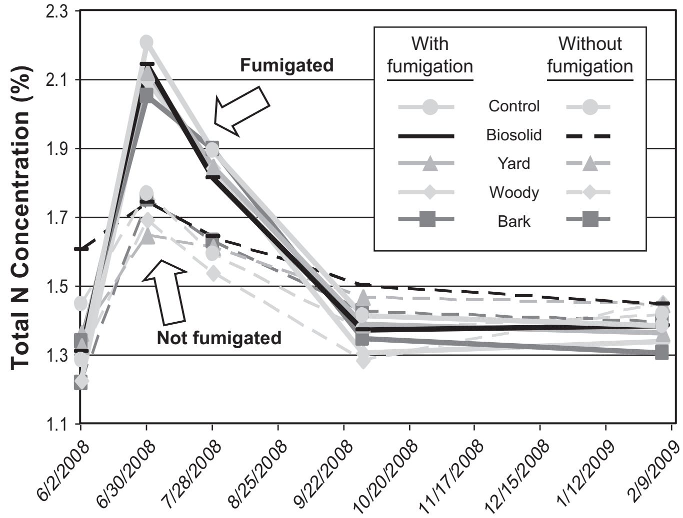

Figure 3. Foliar N concentration levels for compost treatments in fumigated versus non-fumigated plots. At the late June and late July sampling dates, foliar N concentration levels were significantly higher for seedlings grown in fumigated soils.

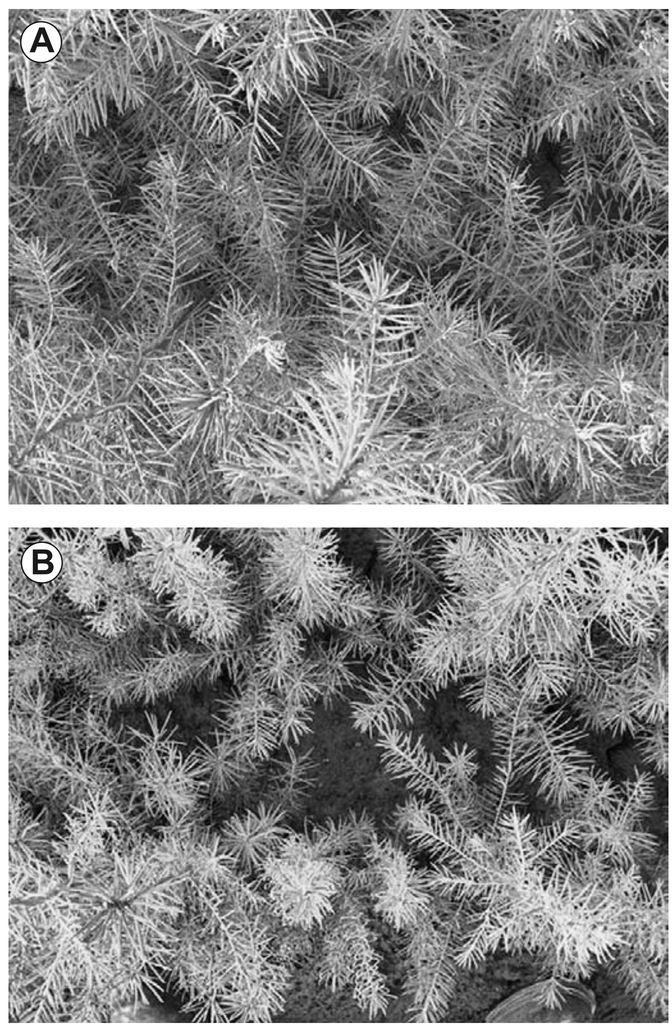

Figure 4. End of season fumigated control plot (A). End of season unfumigated control plot (B). Note terminal stunting, relatively short needle length, and poor lateral branch development.

Table 2. Height, stem diameter, shoot volume, and root volume at end of season (February 2009). Averages within a column and followed by the same letter are not significantly different (*P* = 0.05).

Whole plot	Split plot	Height (cm)*	Stem diameter (mm)	Shoot volume (cc)*	Root volume (cc)*
Fumigated soil	Woody	48.6a	6.9a	58a	19a
	Bark	47.9a	6.9a	56a	19a
	Yard/food	50.5a	7.1a	60a	19a
	Biosolid	49.2a	7.1a	60a	19a
	Control	48.9a	7.2a	61a	19a
Unfumigated	Woody	38.8b	5.8b	35b	16a
	Bark	40.9b	6.2b	43b	17a
	Yard/food	39.1b	5.9b	38b	17a
	Biosolid	41.0b	6.3b	38b	17a
	Control	41.3b	6.3b	37b	16a

*1 cm = 0.4 in; 1 cc = 0.06 in^3

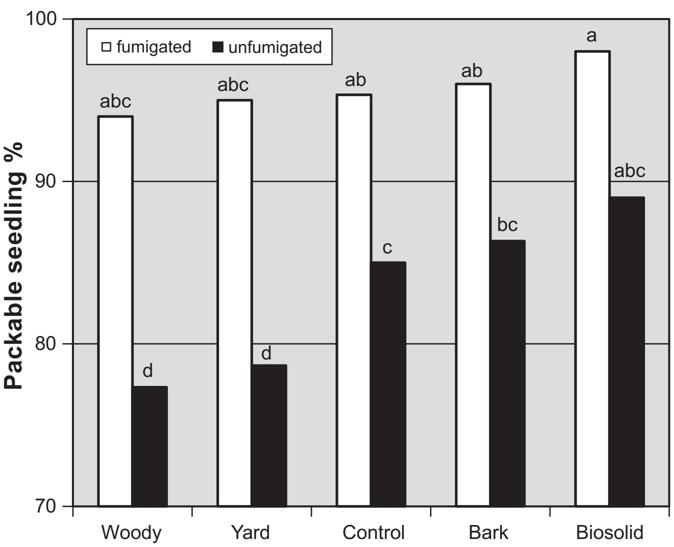

Figure 5. Packout averages based on minimum 5-mm stem diameter and 25-cm (10-in) height standards averaged 95.2% across all treatments in fumigated soils versus 83.3% for all seedlings in unfumigated soils. Means followed by the same letter are not significantly different. Among seedlings transplanted into unfumigated soil, those grown in the biosolid and bark-based composts had the highest average packable seedlings, though were not significantly different from the unfumigated control. However, only the fumigated biosolid treatment had a significantly higher packout than the unfumigated bark treatment. The unfumigated biosolid treatment was not significantly different in packout tally than any of the fumigated treatments.

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Discussion

The overriding pathology and nutrition treatment effects clearly were due to fumigation and not to compost treatment. Expected nitrogen tie-up in seedlings from higher C:N materials did not take place. Pairing the nutrient and pathology data, seedlings grown in all of the non-fumigated treatments may have struggled to take up nitrogen at the peak of the growing season due to root systems weakened by root rot fungi. Hamm and others (1990) note that even minor disease of fine feeder roots may limit nutrient uptake in Douglas-fir and other conifer seedlings.

Fumigated plots, regardless of subsequent compost treatment, were associated with season-long high populations of *Trichoderma* spp., some of which are known to be beneficial to Douglas-fir. Rapid post-fumigation colonization by *Trichoderma* spp. and other beneficial fungi and bacteria may be, in part, responsible for the positive growth response associated with fumigation (James 2003).

The timing of compost application preceded transplanting by only 1 to 6 days. Typically, organic amendments are incorporated several weeks or months prior to transplanting or sowing of a crop (Rose and others 1995). Darby (2003) correlates increased microbial activity from organic amendment incorporation over time with increasing disease suppression in a study involving corn root rot in Oregon. A follow-up timing trial of compost incorporation is warranted. Nonetheless, the short turnaround in this trial was expected to show favorable results for the higher C:N treatments because these types of amendments have shown optimal disease suppression in the first 3 months following incorporation (Stone and others 2004).

The high packout of the unfumigated bark, particularly biosolid treatments, is balanced by the fact that even these packable seedlings remain inferior in size and with higher pathogen loads than seedlings from fumigated plots. Outplanting performance of these trees is being tracked and will be reported elsewhere. At the very least, this trial quantified the dramatic increase in root disease and subsequent decrease in seedling size and packout that occurs when soil fumigation is eliminated from our current production system. Although weed pressure was uncharacteristically low in this study, methyl bromide is perhaps valued as much for its herbicidal properties as for its fungicidal properties in Pacific Northwest nurseries, where it was first introduced as an herbicide (Landis and Campbell 1989). In a 2009 trial at our nursery, weed biomass and weed timing measurements are significantly higher in non-fumigated versus fumigated plots (Khadduri 2009).

A number of changes to cultural practices will most likely need to be made to deal with root rot pathogens that affect Douglas-fir seedlings in the absence of fumigation (Linderman and others 1994). Our nursery will evaluate combined treatments from this and other pilot trials in the coming years (for example, high-glucosinolate seed meal biofumigation of a previously fallow field combined with an organic amendment incorporation). The several years or rotations it may take to build up disease-suppressive soils (Bailey and Lazarovits 2003), combined with the necessity of avoiding crop falldowns in the interim to meet economic demands, remain a fundamental challenge.

Chemical alternatives trialed at the nursery include fumigants tested under lower-permeability plastics. These plastics trap fumigants in soil very effectively and allow for reduced rates of active ingredient. Combined with ongoing herbicide and fungicide trials, these chemical alternatives represent the best short-term solution to the loss of methyl bromide fumigation at this time.

References

Bailey KL, Lazarovits G. 2003. Suppressing soil-borne diseases with residue management and organic amendments. Soil and Tillage Research 72(2):169-180.

Barnard EL, Kannwischer-Mitchell B, Mitchell DJ, Fraedrich SW. 1997. Development and field performance of slash and loblolly pine seedlings produced in fumigated nursery seedbeds and seedbeds amended with organic residues. In: Landis TD, South DB, technical coordinators. National proceedings, forest and conservation nursery associations. Portland (OR): USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-GTR-389. p 32-37.

Darby HM. 2003. Soil organic matter management and root health [PhD dissertation]. Corvallis (OR): Oregon State University.

Davis AS, Jacobs DF, Wightman KE, Birge ZKD. 2006. Organic matter added to bareroot nursery beds influences soil properties and morphology of *Fraxinus pennsylvanica* and *Quercus rubra* seedlings. New Forests 31:293-303.

[EPA] Environmental Protection Agency. 2009. Implementation of risk mitigation measures for soil fumigant pesticides. Federal Register: 3 June 2009, Volume 74, Number 105. URL: http://www.epa.gov/oppsrrd1/reregistration/soil_fumigants/ (accessed 21 Aug 2009).

Haase DL. 2009. The latest on soil fumigation in bareroot forest nurseries. Forest Nursery Notes 29(2):22-25.

Hamm PB, Campbell SJ, Hansen EM. 1990. Growing healthy seedlings: identification and management of pests in northwest forest nurseries. Corvallis (OR): Forest Research Laboratory, Oregon State University. 110 p.

Hildebrand DM, Stone JK, James RL, Frankel SJ. 2004. Alternatives to preplant soil fumigation for western forest nurseries. Portland (OR): USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-GTR-608. 27 p.

Hoitink HAJ, Fahy PC. 1986. Basis for control of soilborne plant pathogens with composts. Annual Review of Phytopathology 24:93-114.

Hunter BB, Hall T, Lyons MT, Bell TK. 1997. Preplant nursery soil additions of forest soils, commercial sewage and mushroom composts and basamid (dazomet) to control the fungal pathogen, *Cylindrocladium scoparium*. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. URL: http://mbao.org/1997airc/045hunter.pdf (accessed 21 Aug 2009).

James RL. 2003. Comparing three methods of assaying soil *Fusarium* and *Trichoderma* populations for integrated pest management in forest nurseries. Missoula (MT): USDA Forest Service, Northern Region, Forest Health Protection. Forest Health Report 03-3. 13 p.

Khadduri N. 2009. [Unpublished data]. Olympia (WA): Washington Department of Natural Resources Webster Nursery.

Landis TD, Campbell SJ. 1989. Soil fumigation in bareroot tree nurseries. In: Landis TD, technical coordinator. Proceedings, Intermountain Forest Nursery Association; 1989 August 14-18; Bismarck, ND. Fort Collins (CO): USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-184. p 13-28.

Linderman R, Dixon W, Fraedrich S, Smith RS Jr. 1994. Alternatives to methyl bromide: assessment of research needs and priorities for forestry, nursery, and ornamental crops. Tree Planters' Notes 45:43-47.

[MBTOC] Methyl Bromide Technical Options Committee. 2006. Report of the Methyl Bromide Technical Options Committee United Nations Environment Programme (UNEP). ISBN: 978-92-807-2827-9. 453 p.

Rose R, Haase DL, Boyer D. 1995. Organic matter management in forest nurseries: theory and practice. Corvallis (OR): Oregon State University, Nursery Technology Cooperative. 65p.

Stevens TS. 1996. The use of chemical fumigants and potential alternatives at Weyerhaeuser Mima Nursery. In: Landis, TD, South, DB, technical coordinators. National proceedings, forest and conservation nursery associations. Portland (OR): USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-389. p 144-149.

Stone AG, Scheuerell SJ, Darby HM. 2004. Suppression of soilborne diseases in field agricultural systems: organic matter management, cover cropping, and other cultural practices. In: Magdoff F, Weil R, editors. Soil organic matter in sustainable agriculture. Boca Raton (FL): CRC Press. p 131-177.