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Management Cooperative

RESEARCH REPORT 09-06

EFFECT OF METHYL BROMIDE ALTERNATIVES ON SEEDLING QUALITY AND PATHOGENIC SOIL FUNGI AT THE PLUM CREEK JESUP NURSERY

2007 – 2008

STUDY 1: SEEDLING QUALITY

by
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INTRODUCTION

The study reported herein is a portion of the USDA – ARS Area-wide Pest Management Project for Methyl Bromide Alternatives – South Atlantic Region, and part of a long-term continuing effort by the Auburn University Southern Forest Nursery Management Cooperative to identify and evaluate soil fumigants as an alternative to methyl bromide (MBr). Fumigation with methyl bromide has been the most commonly used method for producing high quality, pest-free forest tree seedlings in the southeastern United States. This large scale study compares seven soil fumigants using operational application techniques and normal nursery management practices over two growing seasons at the Plum Creek Nursery in Jesup, GA. Information gathered from these studies should be used by nursery managers in the southern US to select a MBr alternative that could be useful in the production of forest tree seedlings in their nurseries

METHODOLOGY

A soil fumigation trial was established in the forest seedling nursery at Plum Creek in Jesup, GA to look at alternative fumigants for the production of forest tree seedlings over a two-year rotation. Soil fumigation treatments included MBr and six alternatives that are currently available for large-scale use (Table 1). With the exception of New Pic+, soil fumigants were selected based on results of small plot studies previously conducted by the Nursery Cooperative. New Pic+ is a reformulation of Pic+ which was tested previously in Texas at the Indian Mound Nursery (Research Report 08-07).

The soil fumigation trial occupied 4 acres out of a total 51 production acres (Tables 2 & 3) within the nursery. Fumigants were shank-injected in April 2007 and covered with 1 mm High Density Polyethylene Tarp (Cadillac Plastics Inc.) as broadcast/flat tarp. The trial was laid out in nursery sections consisting of nine seedling beds between irrigation pipelines with each bed approximately 610' long. Because of the bed length, each nursery bed was split into two plots of 305' each. The experimental design was a randomized complete block that was replicated four times in five nursery sections. Each nursery section had three fumigant plots. The nursery sowed a single family of loblolly pine (*Pinus taeda*) seed in late April 2007 that were lifted in mid November 2007. The second seedling crops' sowing occurred in late April 2008 with seedlings lifted in November 2008.

Seedling and soil samples were collected from the center seedling bed of each 3-bed soil fumigant plot. In 2007 and 2008 soil samples were collected pre-sowing, post-sowing, mid-summer and just prior to seedling lifting in November. Half of each soil sample was plated onto *Trichoderma*-selective media (TSM) (Elad, Chet and Henis 1981) and the remaining half was sent to the Soils Laboratory at Auburn University for a quantitative assessment of nematode populations. Seedling densities and growth characteristics were assessed in four subplots (4' x 1') per treatment plot at 7 wks post sowing, mid-summer (15 wks post sowing) and just prior to lifting in the fall (26 wks post sowing) in both production years. To determine seedling quality and characteristics, twenty-five seedlings per subplot were collected in mid-summer and fall of the first year (2007) and only in the fall of the second year (2008) and measured. Seedling root collar diameter (RCD), shoot height and seedling dry weight (biomass) was determined for each soil fumigant tested. To determine the effect of soil fumigants on root morphology (root length, root surface area, average root diameter and the number of root tips) ten seedlings per subplot were examined using WinRhizo® software by Regents Instruments Inc. Quebec, Canada.

RESULTS AND DISCUSSION

At the time of lifting in 2007, seedling densities for the chloropicrin treatment were significantly greater than the MBr treatments. The true test of a MBr alternative is its' performance during the second growing season where treatment differences usually begin to appear. However, by the end of the second growing season in 2008, there were no significant differences for seedling density for any of the soil fumigants tested, as all gave similar seedling densities as the standard MBr (Table 4).

In the 2007 growing season differences in seedling root collar diameters (RCD) among the soil fumigants tested were observed (Table 5). Some of the newer chemistries, Pic+, New Pic+ and DMDS+Chlor had seedlings with significantly larger RCD than seedlings sown to 100% Chloropicrin. In 2008, soils fumigated with chloropicrin had significantly larger RCD's than New Pic+ (Table 5). Seedlings grown in soils fumigated with Chloropicrin had the smallest RCD (4.6 mm) for 2007 and the largest RCD (4.7 mm) in 2008. The small RCD for 2007 can be attributed to the high seedling density that season (Table 4) as seedlings sown at higher densities tend to have smaller RCD's. When considering seedling grades (Grade 1 = seedlings > 4.69 mm, Grade 2 = seedlings 3.2 - 4.69 mm and Cull = seedlings < 3.2 mm), the proportion of seedlings for each grade was similar across all soil fumigants in 2007 except Chloropicrin. In that growing season, Chloropicrin was the only soil fumigant tested at this nursery that had more Grade 2 seedlings than Grade 1 seedlings. In 2008 the proportion of Grade 1 seedlings were fewer than in 2007 for all soil fumigants except for Chloropicrin (Figures 1 & 2). Higher seedling densities typically result in a lower mean RCD yielding fewer Grade 1 seedlings per sq ft. Chloropicrin fumigated soils had higher seedling density than other fumigants in 2007, producing a lower percentage of Grade 1 (42%) than Grade 2 (58%) seedlings, yet with a lower seedling density in 2008 more Grade 1 (50%) than Grade 2 (45%) seedlings were produced.

Overall, and not surprisingly, seedling root architecture and root morphology indicated smaller seedlings in 2008 when compared to seedlings grown in 2007 (Table 6). First year soil fumigation with MBr typically results in larger seedlings and these soil fumigants are behaving similarly. In 2007, as far as an MBr alternative, New Pic+ performed the best across all the root morphology measurements at this nursery. In 2008, there were no significant differences in seedling quality and quantity among any of the soil fumigants that did not contain MBr in its formulation. One of the primary reasons for determining the effects of these soil fumigants on root architecture is that a more fibrous root system increases the chance of seedling survival in the field (Hatchell & Muse 1990, Frampton, Isik & Goldfard 2002, Davis & Jacobs 2005). An interesting point to take home from these seedling roots is that total seedling root length in these trials ranged from 212 cm to 317 cm, or about 7 - 10 feet of total fine roots per seedling.

At the end of the first growing season in 2007, nursery soils at Jesup GA fumigated with MBr had significantly lower levels of *Trichoderma* than soil fumigants mixed with telone (Chlor 60) (Table 7). This is unusual as previous Nursery Cooperative research has shown that *Trichoderma* is not as sensitive to MBr as other soil fumigants (dazoment, iodomethane) (Cary, McCraw & Enebak 2005, Starkey, Enebak & McGraw 2006, Starkey & Enebak 2008). The other soil fumigants tested did not affect *Trichoderma* levels like that of MBr, and by the end of the second growing season (2008) the *Trichoderma* levels within the various soil fumigants tested were all similar to MBr.

Over the course of the 2-yr study, each soil fumigant treatment was examined five times for both the number and species of nematodes within the soil/seedling interface. Nematode populations within the soil are never uniformly distributed and these studies had a wide range in numbers and species for all soil fumigants used (Table 8). One of the more troublesome species on seedling production is the Stunt nematode which appeared during the second cropping season in all soil fumigants tested. Of the soil fumigants tested Pic + had the lowest number of nematodes recovered in soil samples over the course of the study.

MANAGEMENT IMPLICATIONS

The primary objective of the USDA Areawide MBr Alternative program is to identify possible alternatives to MBr using large-scale, multi-year trials in soils and conditions throughout the southern US. One of the unique aspects of MBr as a soil fumigant is its ability to consistently control weeds, insects, nematodes and fungi across many different growing conditions. We have yet to find a MBr alternative (Magic Bullet) that fits those characteristics and these studies bear that out. When MBr is no longer available (either by CUE or QPS), those soil fumigants with chloropicrin appear to be the most useful in controlling pests in Jesup, GA and producing high quality seedlings. DMDS+Chloropicrin was comparable to MBr in RCD and root morphology characteristics and soilborne *Trichoderma* levels, but had a significant odor problem that lasted into summer growing season. The lingering odor when this particular soil fumigant is used could limit its acceptance as an alternative to MBr. By far the best MBr alternative tested was Pic+ and New Pic+, with both soil fumigants controlling weeds, nematodes and producing high quality seedlings. Chloropicrin controlled weeds and produced high quality seedlings, but had a high incident of nematodes the second growing season. One of the potential pitfalls with using 100% Chloropicrin at 300 lbs/acre is the buffer zone restrictions under current nursery fumigation practices. If these restrictions limit the use of 100% Chloropicrin, then Pic+ or New Pic+, with 85% Chloropicrin would be the best alternative at Jesup. The final decision when selecting a MBr alternative needs to take into consideration the ability of the soil fumigant to work under individual nursery soil conditions and the impact of the new EPA Reregistration Eligibility Decision (REDs) on each individual nursery. While it would be wonderful for nursery managers and researchers to continue to use MBr in perpetuity to grow forest tree seedlings, MBr is going to go away and each nursery manager will need to identify the best alternative for their nursery.

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Table 1. Fumigants and rates used in the 2007 Area-wide demonstration plots – Jesup, GA.

Fumigant	Rate	Components
MBr	350 lbs/a	67% MBr & 33% Chloropicrin
DMDS + Chlor	74 gal/a (731 lb/a)	79% DMDS & 21% Chloropicrin
MBrC 70/30	400 lbs/a	70% MBr (98/2) & 30% Solvent A
New Pic+	300 lbs/a	85% Chloropicrin + 15% Solvent B
Pic+	300 lbs/a	85% Chloropicrin + 15% Solvent A
Chloropicrin	300 lbs/a	100% Chloropicrin
Chlor 60	400 lbs/a	60% Chloropicrin & 40% 1,3-D (Telone)

Table 2. Site information for Plum Creek nursery fumigation.

	Jesup, GA
Fumigation	3-Apr-07
Fumigation type	Broadcast/flat tarp
Area in trial	4 acres
Air temperature range	67° to 88°F
Wind speed	3 – 6 mph
Soil moisture	8.5%
Soil series	Norfolk loamy sand
Plastic in place	7 days

Table 3. Soil particle size analysis for Jesup, GA trial.

Nursery	% clay	% silt	% sand	Texture class
Jesup, GA	8.8	11.3	80	Loamy sand

Table 4. Seedling density (seedlings/ft²), Jesup, GA

Treatment	Nov 2007	Nov 2008
MBr	19 b	20 a
Chloropicrin	24 a	21 a
Chlor 60	22 ab	22 a
MBrC 70/30	19 b	21 a
DMDS+Chlor	19 b	21 a
Pic+	19 b	21 a
New Pic+	19 b	22 a
$lsd_{(0.05)}$	4	4

Within column means followed by the same letter do not differ at 0.05 level using Duncan's Multiple Range Test
Target seedling density is 24 seedlings/ft²

Table 5. Loblolly seedling root collar diameter (RCD in mm), Jesup, GA

Treatment	Nov 2007	Nov 2008
MBr	4.83 ab	4.43 ab
Chloropicrin	4.65 b	4.70 a
Chlor 60	4.91 ab	4.16 ab
MBrC 70/30	4.99 ab	4.27 ab
DMDS+Chlor	5.19 a	4.04 ab
Pic+	5.13 a	4.46 ab
New Pic+	5.13 a	3.97 b
$lsd_{(0.05)}$	0.37	0.70

Within column means followed by the same letter do not differ at 0.05 level using Duncan's Multiple Range Test

Table 6. Loblolly pine seedling root morphology, Jesup, GA

Treatment	Root Length (cm)		Root Surface Area (cm²)		Avg Root Dia (mm)		No. Root tips	
	2007	2008	2007	2008	2007	2008	2007	2008
MBr	315 a	243 a	91 a	54 a	0.92 ab	0.72 a	910 a	568 a
Chloropicrin	254 b	249 a	69 b	55 a	0.87 b	0.72 a	730 b	584 a
Chlor 60	274 ab	212 a	78 ab	46 a	0.91 ab	0.72 a	806 ab	532 a
MBrC 70/30	317 a	227 a	91 a	50 a	0.91 ab	0.72 a	943 a	560 a
DMDS + Chlor	299 ab	231 a	87 a	51 a	0.93 a	0.71 a	925 a	579 a
Pic+	277 ab	218 a	84 a	51 a	0.96 a	0.77 a	834 ab	545 a
New Pic+	313 a	232 a	91 a	49 a	0.92 ab	0.70 a	941 a	636 a
$lsd_{(0.05)}$	51	54	15	9	0.06	0.10	155	176

Within column means followed by the same letter do not differ at 0.05 level using Duncan's Multiple Range Test

Table 7. Post-sowing recovery of *Trichoderma* from soil samples (colony fungal units/mg soil)

	2007			2008		
Treatment	**7 wks**	**15 wks**	**26 wks**	**7 wks**	**15 wks**	**26 wks**
MBr	86 a	117 a	18 bc	86 a	84 a	93 a
Chloropicrin	42 ab	71 ab	18 bc	108 a	69 a	86 a
Chlor 60	53 ab	90 ab	64 a	91 a	60 a	96 a
MBrC 70/30	27 b	42 b	6 c	74 a	85 a	69 a
DMDS+Chlor	63 ab	84 ab	30 abc	95 a	72 a	73 a
Pic+	34 ab	61 ab	20 bc	68 a	84 a	85 a
New Pic+	48 ab	93 ab	57 ab	96 a	57 a	77 a
$lsd_{(0.05)}$	55	71	44	79	46	40

Within column means followed by the same letter do not differ at 0.05 level using Duncan's Multiple Range Test

Table 8. Jesup, GA nematode levels at time of lifting in the fall.

		2007 nematodes/100cc				2008 nematodes/100cc			
Trt	**Nematode**	**R1**	**R2**	**R3**	**R4**	**R1**	**R2**	**R3**	**R4**
MBr	Stunt	6	26	0	0	342	20	26	174
	Stubby root	14	58	0	86	0	0	0	0
	Ring	0	0	0	0	0	0	0	0
Chloropicrin	Stunt	0	70	0	10	38	416	6	74
	Stubby root	24	38	10	44	0	0	2	0
	Ring	0	0	0	0	10	0	0	0
Chlor 60	Stunt	0	12	0	0	242	66	0	186
	Stubby root	46	40	50	0	0	0	0	0
	Ring	0	0	0	0	0	0	0	0
MBrC 70/30	Stunt	2	0	4	46	286	96	22	178
	Stubby root	22	16	14	28	0	0	0	0
	Ring	0	0	0	0	2	0	0	0
DMDS+Chlor	Stunt	48	62	0	22	18	48	116	78
	Stubby root	0	46	64	28	0	0	0	0
	Ring	0	0	0	0	2	0	0	0
Pic+	Stunt	54	82	30	18	48	74	54	14
	Stubby root	22	14	26	16	0	0	0	0
	Ring	0	0	0	0	2	0	0	0
New Pic+	Stunt	44	8	0	6	72	64	16	36
	Stubby root	6	42	0	98	0	0	0	0
	Ring	0	0	0	0	0	0	0	0

Figure 1. Seedling grade by soil fumigant tested at Jesup, GA – 2007.

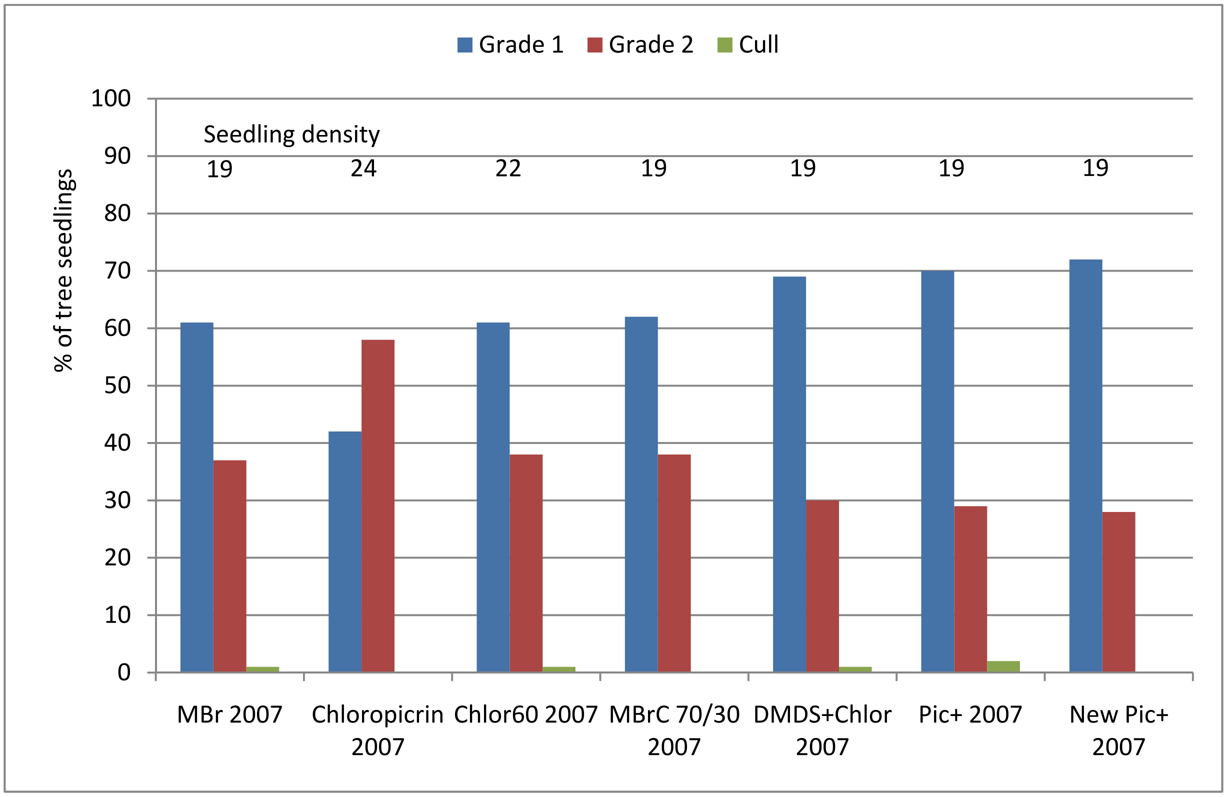
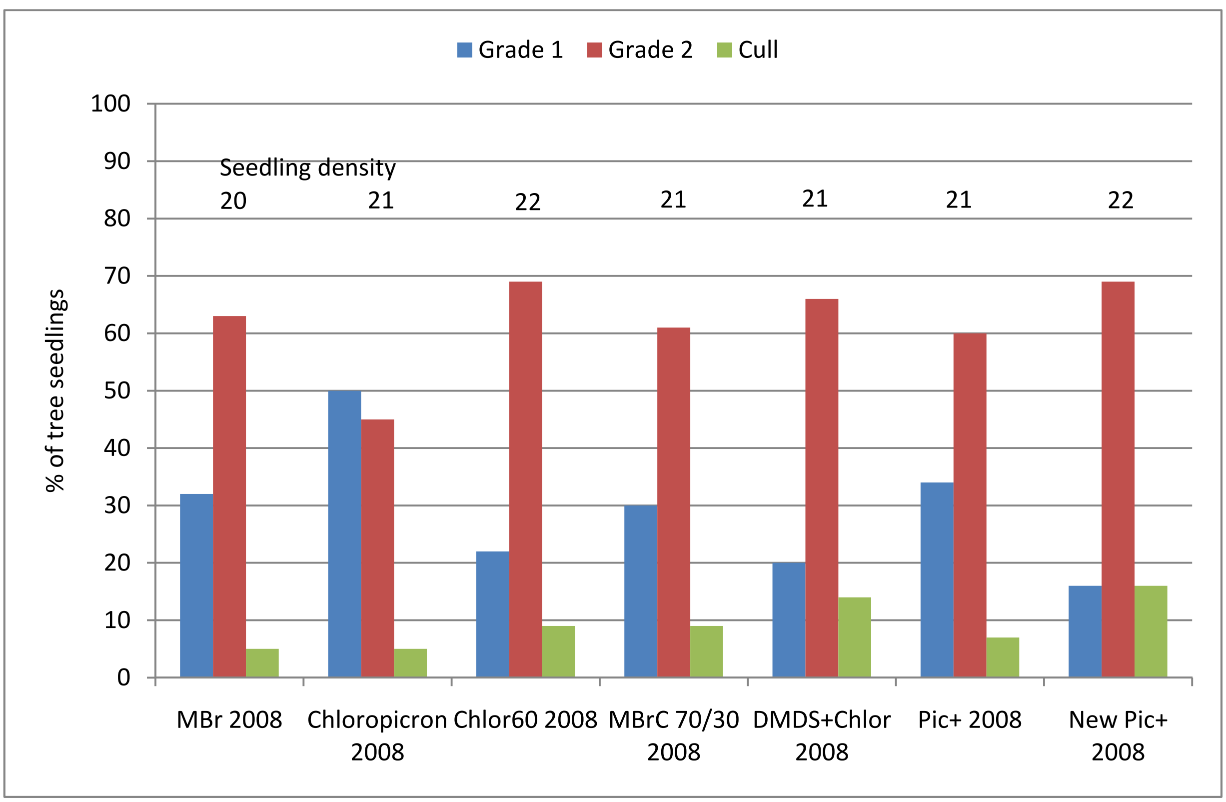


Figure 2. Seedling grade by soil fumigant tested at Jesup, GA – 2008.



EFFECT OF METHYL BROMIDE ALTERNATIVES ON SEEDLING QUALITY AND PATHOGENIC SOIL FUNGI AT THE PLUM CREEK JESUP NURSERY

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STUDY 2: SOIL PATHOGENIC FUNGI

INTRODUCTION

Forest nurseries in the United States have relied for many years on MBr soil fumigation to control weeds, pathogenic fungi, insects and nematodes. In the southern United States, there are three fungal genera that are of primary concern in the production of pine seedlings. These genera are: *Fusarium*, *Pythium* and *Rhizoctonia* which are associated with seedling root and foliage diseases.

For many years, nursery managers have recognized the importance of MBr to control these soil borne pathogens in the production of forest tree seedlings (Henry 1953). However, due to the concern over ozone depletion in the stratosphere, the use of MBr has begun a phase-out program as dictated by the 1987 Montreal Protocol. Finding alternatives for MBr has been a priority for the forest nursery industry and the Southern Forest Nursery Management Cooperative since 1991. Although it will be difficult to find a soil fumigant alternative that is as broad-spectrum as MBr, the nursery industry realizes the importance of testing new compounds, rates and application techniques.

The purpose of this study is to look at the efficacy of MBr and a number of fumigant alternatives against the soil borne fungi *Fusarium*, *Pythium* and *Rhizoctonia* that cause root and foliage diseases on forest tree seedlings in the southern United States.

METHODOLGY

A five section (9 bed rows each) soil fumigation trial was established at the forest tree nursery at the Plum Creek nursery in Jesup, GA, to look at alternative fumigants for the production of forest tree seedlings over a typical two-year rotation. The soil fumigants included in this study were determined from previous results of small plot studies conducted by the Nursery Cooperative. Methyl bromide and alternatives were applied during the spring 2007 fumigation (Table 9) and covered with 1 mm High Density Polyethylene Tarp (Cadillac Tarps Inc.) as broadcast/flat tarp. A single family of loblolly pine (*Pinus taeda*) was sown to the area containing the alternative soil fumigant treatments.

The experimental design used a randomized complete block design replicated four times with each treatment 305 linear bed feet. The 305 linear bed feet of chloropicrin treatment in each replication was further subdivided as described in Table 10 to include two rates of chloropicrin and under tarp or no tarp. The same sequence of chloropicrin treatments and tarp were repeated in each replication:

In 2007 *Pythium, Rhizoctonia and Fusarium,* all known pathogenic soil borne fungi, were cultured in the laboratory on Potato Dextrose Agar. Approximately eight weeks prior to soil fumigation, agar plates of each fungi was used to inoculate bags containing moistened, sterilized oatmeal. The oatmeal bags were mixed on a regular basis to encourage fungal growth throughout the oatmeal. Two days prior to soil fumigation in Jesup, a 300 ml beaker of the oatmeal/fungus mixture was placed into a Hubco® Soil Sample Bags (5” x 7”) whose top was folded over, stapled shut, and labeled as to the fungus.

As the soil fumigation was occurring, three Hubco bags, containing one species of each soilborne fungus were placed into each treatment listed in Table 9. For the soil fumigants placed under tarp, an 18" slit was cut and the three bags (one of each soilborne pathogenic fungus) were buried approximately 4 inches deep and 18" from the tarp edge. The slit was then sealed with fumigation tape. The bags in the sections without tarp were buried at the same depth in the fumigated area.

Six days after soil fumigation, the Hubco soil bags containing fungal inoculated oatmeal were removed from each of the soil fumigation plots, placed in a cooler and returned to the laboratory at Auburn University. In the laboratory, each Hubco soil bag was thoroughly mixed and then opened. From each fungal species, nine oatmeal pieces were placed in groups of three on the following selective media: 1) PARP media for *Pythium, 2)* Komada's media for *Fusarium* and 3) Ko and Hora's media for *Rhizoctonia* There were three agar plates for each replication and for each treatment.

One week after plating the inoculated, then fumigated oatmeal onto selective agar media, each plate was examined for fungal growth that would indicate the target soilborne pathogens. Of the three fungi tested, *Pythium* plates grew slower than the other two fungi. In addition to the soilborne pathogens, the numbers of oatmeal groups with non-target fungi were also counted. As a control, bags of each soilborne pathogenic fungus not fumigated were also plated out on selective media as described above.

RESULTS AND DISCUSSION

The number of pathogenic (target) and nonpathogenic fungi (non-target) recovered from bags fumigated is shown in Table 10. When non-fumigated control bags were plated onto their selective media, the individual soilborne fungus was recovered from 100% of all oatmeal groups on each plate. The following observations were made:

1. In general, fewer soilborne pathogenic fungi inoculated onto oatmeal were recovered than non-target fungi. The non-target fungi were primarily saprophytic fungi either *Penicillium* or *Aspergillus*.
2. Soil fumigation with either MBr or the other soil fumigant alternatives does not completely eliminate all soilborne fungi. This is important since growth of pine seedlings has been correlated with the occurrence of the beneficial genus of *Trichoderma* (Bailey and Lumsden 1998; Dong, et. al. 1987; Papavizas 1985; Mousseaux et.al. 1998; Samuels 1996).
3. All soil fumigants and rates tested at the Jesup nursery were effective in eliminating target *Pythium, Fusarium* or *Rhizoctonia*.
4. When comparing Chloropicrin at 150 lbs/a under tarp with Chloropicrin at 150 lbs/a with no tarp the amount of non-target fungi recovered was not significantly different for *Pythium, Fusarium* or *Rhizoctonia*.
5. When comparing Chloropicrin at 300 lbs/a under tarp with Chloropicrin at 300 lbs/a with no tarp the amount of non-target or target fungi recovered was not significantly different for *Pythium, Fusarium or Rhizoctonia*.
6. Both Chloropicrin at 300 lbs/a under tarp and Chloropicrin at 150 lbs/a under tarp were equally effective at reducing populations of *Pythium, Fusarium or Rhizoctonia* target fungi. This indicates that control of these pathogenic fungi may be obtained at lower fumigant rates than are normally used. However, that long-term effect of lower rates was not examined in this study.
7. DMDS plus chloropicrin had the lowest recovery of non-target *Rhizoctonia* compared to the other soil fumigants used. The difference in fungal recovery on all the DMDS agar plates for all fungi was apparent even after seven days, many agar plates were void of any fungal growth.

8. New Pic+ had significantly less non-target *Pythium* and *Rhizoctonia* than Chloropicrin at both 300 and 150 lbs/a with no tarp. The numerical trend was present with *Fusarium* also, although not statistically significant. Pic + also had significantly less non-target *Rhizoctonia* than Chloropicrin at both 300 and 150 lbs/a with no tarp. The numerical trend was also present with *Fusarium* also, although not statistically significant. These differences may be explained by the fact that both New Pic+ and Pic+ contain a solvent that enables the fumigant to stay active in the soil for a longer period of time.

MANAGEMENT IMPLICATIONS

Soil fumigation is an effective way to reduce pathogenic soilborne fungi that infect forest tree seedlings. All soil fumigants tested at the Plum Creek Jesup nursery were found to be effective in controlling *Pythium*, *Rhizoctonia* and, *Fusarium* when inoculated onto oatmeal. The wide spread use of MBr has minimized widespread seedling losses due to soilborne pathogenic fungi. Of the fungi tested, *Pythium* still can cause damping-off problems in the early spring and are often limited to areas of poor drainage and standing water. *Rhizoctonia* can appear in nurseries both as root decay and as foliage blight. Typically, the foliage blight is more severe in second year crops as the fungus increases in numbers over the first growing season.

The soil fumigants currently being tested in southern forest nurseries do not completely eliminate beneficial fungi which are needed for seedling growth. In these trials, the population levels of non-target soilborne fungi rebounded quickly. In contrast, dazomet, a soil fumigant tested by the Nursery Cooperative for several years significantly reduced the levels of beneficial fungi which remained after two growing seasons (Starkey et. al. 2006).

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Table 9. Fumigants and rates used in 2007 Area-wide demonstration plots.

Fumigant	Rate	Components
MBr	350 lbs/a	67% MBr & 33% Chloropicrin
DMDS+Chlor	731 lbs/a	79% DMDS & 21% Chloropicrin
MBrC 70/30	400 lbs/a	70% MBr (98/2) & 30% Solvent A
Pic+	300 lbs/a	85% Chloropicrin + 15% Solvent A
New Pic+	300 lbs/a	85% Chloropicrin + 15% Solvent B
Chloropicrin	300 lbs/a Under Tarp	100% Chloropicrin
Chloropicrin	300 lbs/a No Tarp	100% Chloropicrin
Chloropicrin	150 lbs/a Under Tarp	100% Chloropicrin
Chloropicrin	150 lbs/a No Tarp	100% Chloropicrin
Chlor 60	400 lbs/a	60% Chloropicrin & 40% 1,3-D

Table 10. Rate of chloropicrin, tarp and linear bed feet used for each chloropicrin treatment.

Chloropicrin Rate	Tarp/None	Linear Bed Feet
300 lbs/a	Under tarp	150’
300 lbs/a	No tarp	50’
150 lbs/a	No tarp	50’
150 lbs/a	Under tarp	50’

Table 11. Proportion of pathogenic soilborne (target) and nonpathogenic fungi (non-target) recovered from sample plates at Jesup, GA.

Jesup, GA		**Pythium**		**Fusarium**		**Rhizoctonia**	
Fumigant	**Rate**	**Target**	**Non-Target**	**Target**	**Non-Target**	**Target**	**Non-Target**
MBr	350 lbs/a	0.00 a	0.77 ab	0.00 a	0.03 a	0.00 a	0.78 ab
DMDS + Chlor	74 gal/a (731 lbs/a)	0.00 a	0.69 ab	0.00 a	0.00 a	0.00 a	0.00 c
MBrC 70/30	400 lbs/a	0.00 a	0.86 a	0.25 a	0.28 a	0.00 a	0.86 ab
New Pic+	300 lbs/a	0.00 a	0.39 b	0.03 a	0.00 a	0.00 a	0.61 b
Pic+	300 lbs/a	0.00 a	0.77 ab	0.04 a	0.07 a	0.00 a	0.63 b
Chloropicrin	300 lbs/a tarp	0.00 a	0.77 ab	0.00 a	0.11 a	0.00 a	0.81 ab
Chloropicrin	300 lbs/a no tarp	0.00 a	0.83 a	0.21 a	0.19 a	0.00 a	1.00 a
Chloropicrin	150 lbs/a tarp	0.03 a	0.77 ab	0.00 a	0.33 a	0.00 a	0.83 ab
Chloropicrin	150 lbs/a no tarp	0.11 a	0.83 a	0.28 a	0.19 a	0.00 a	1.00 a
Chlor 60	400 lbs/a	0.00 a	0.76 ab	0.01 a	0.06 a	0.00 a	0.97 a
	lsd	*0.12*	*0.41*	*0.31*	*0.38*	*0.00*	*0.31*

Within column means followed by the same letter do not differ at 0.05 level using Duncan's Multiple Range Test