Chemical Alternatives to Methyl Bromide

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Abstract—Three soil fumigants were evaluated at a nursery in Georgia and one in South Carolina. Seedbed density and seedling development were compared among plots treated with tarped and not tarped dazomet at 140 and 280 lbs/ac, tarped and not tarped chloropicrin at 125 and 250 lbs/ac, tarped MC33 at 350 lbs/ac and non-fumigated plots. Differences among treatments occurred only in South Carolina where both initial seedbed density and harvested seedlings differed with treatments. Among harvested seedlings, the high rate of dazomet and chloropicrin were not significantly different from MC33 but the low rates and controls were inferior. In a second study at the South Carolina nursery, dazomet (150 and 300 lbs/ac tarped and not tarped), MC33 (350 lbs/ac tarped), 1,3-D (290 lbs/ac tarped), metham-sodium (400 lbs/ac tarped and not tarped), dazomet (150 lbs/ac) plus chloropicrin (115 lbs/ac tarped), and metham-sodium plus chloropicrin (400 and 115 lbs/ac tarped) were evaluated with respect to weed control. MC33 and 1,3-D had the best herbicidal activity.

Keywords: Fumigation, Pinus taeda, seedling quality, weeds control.

INTRODUCTION

Methyl bromide (MBr) fumigation of soils controls a broad spectrum of fungi, nematodes, insects, and weeds (Thompson, 1991). Because all these taxa contain potentially destructive pests of forest tree seedlings, MBr fumigation, with 2% or 33% chloropicrin, has become almost universal in southern nurseries (South, 1992, Carey, 1991). Virtually all southern nurserymen fumigate and very few install control-plots for evaluating pest problems (Carey and Kelley, 1993). Straightforward comparisons between fumigated and non-fumigated productions are rare. Comparisons to the pre-fumigation era are also complicated because the nursery industry itself has shifted most production to sandier soils during the time that fumigation has been extensively practiced (South and Davey, 1983). Handweeding cost provided adequate, reliable estimates for the economic benefits of MBr (South and Gjerstad, 1980) and although alternative herbicides have reduced its importance for pine seedlings (South, 1992) the replacement in hardwood seedling production has been less effective (Stone, 1991). The sporadic occurrence (even in the absence of fumigation) of soil born insects and diseases further complicates estimates for the benefits of fumigation where non-fumigated comparisons are rare. Nevertheless, substantial savings are usually projected (South and Gjerstad, 1980) or

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assumed (Stone, 1991) for MBr fumigation. In fact, forest tree nurseries had the largest projected benefit per acre or per pound of MBr used of all crops that utilized significant quantities (Anonymous, 1993).

In response to rumors of the regulatory disfavor of MBr, during the summer of 1992, the Auburn University Southern Forest Nursery Management Cooperative (AUSFNMC) planned small plot trials to evaluate alternative fumigants. With the first fumigation scheduled for the fall of 1992, the delusion of being ahead of the learning curve lasted only a few days. In November 1992 MBr was listed as a potential ozone depleter. Under the authority of the Clean Air Act, the EPA has now assigned a phase-out schedule with production termination for the year 2001. Before our first trials were finished we began to test additional fumigants and a few nurseries have now initiated production scale trials primarily comparing chloropicrin, dazomet or 1,3-dichloropropene with MBr. Like signs in store windows that count down the days to Christmas it seem only fair to warn nursery managers that there are only six more 1+0 crops before 2001.

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MATERIALS AND METHODS

Fumigation Treatments:
The fumigation treatments utilized these products; MC33 = MBC-33 ® (67% MBr + 33% chloropicrin), Triform ® (70% 1,3 dichloropropenes + 30% chloropicrin), Dazomet is Basamid ® (99% ai), Metham-sodium is Sectagon-42 ® (42% ai), Chloropicrin is HDPic ® (96.5% ai).

Table 1 lists the 11 fumigation treatments used on beds subsiquently sown with pine seed. Each treatment was randomly assigned to positions within each of five blocks. The same relationship of treatments within blocks was used at both nurseries but at Statesboro a double-bed column contained each block and treatment plots were 68 ft long separated by 5 ft buffers. At Summerville blocks were at right angles to beds and each bed contained five 140 ft long treatment plots separated by 5 ft buffers.

At Statesboro, fumigation treatments were applied October 21 and 22, 1992 to nursery beds but not tractor paths (wheel ruts). Post-treatment soil samples were

Table 1. Fumigation treatments applied to loblolly pine production beds in Statesboro, GA and Summerville, SC.

Compound	Rate[1]	Application	Seal[2]
None	None	None	Water
None	None	None	Plastic
Dazomet	140	Rototilled	Water
Dazomet	140	Rototilled	Plastic
Dazomet	280	Rototilled	Water
Dazomet	280	Rototilled	Plastic
Chloropicrin	125	Injected	Water
Chloropicrin	125	Injected	Plastic
Chloropicrin	250	Injected	Water
Chloropicrin	250	Injected	Plastic
MC33	350	Injected	Plastic

[1] Pounds per acre.
[2] Water seals are the irrigation equivalent of 0.25 inches of rain.

collected November 10, 1992 and March 5, 1993 before the treated bed structure was disturbed. The Summerville fumigation was March 18, 1993. Pre-treatment soil samples were collected and fumigation treatments applied after the field was disced but before beds were formed and both the bed and future tractor paths were treated.

Treatments for a second study, installed at Summerville in the fall of 1993, are listed in Table 2. The treatments were arranged at a randomized complete block with four blocks and plots were 12 ft by 110 ft and separated by 5 ft buffers. The area was disced and then fumigated, respectively, on October 24 and 26, 1993. Dazomet was rototilled into the soil in two six-foot- wide strips and the surface of all non-tarped plots was compacted ("power-rolled") using a drum roller. All other chemicals were injected and tarped in single 12-foot-wide strips.

Seedlings:

A single loblolly pine *(Pinus taeda)* half-sib seedlot was sown in each nursery on April 14 (27 days after fumigation) at Summerville and May 14 (201 days after fumigation) at Statesboro. Beds were stabilized with a synthetic resin at Summerville and with pinebark mulch at Statesboro.

Numbers of live seedlings (seedbed density) and dead seedlings (damping-off) were determined 35 days after sowing at both nurseries. Two one-foot-wide sections across nursery beds were delineated near the center of each of replicate plot and these were resampled throughout the study. Seedbed densities were determined again at both nurseries September 8-10, 1993 and January 2-5, 1994.

In January 1994, seedlings from the four center drills of each seedbed-density-plot were carefully removed from the soil and a random subsample of 25 of these seedlings was taken. Rootcollar diameters were used to determine numbers of culls (< 3.25 mm) and number one (> 4.76 mm) and number two (3.26 to 4.75 mm) seedlings per plot. Above and below ground portions of seedlings were separated and each sub-sample was dried to a constant weight. Seedling parameters were calculated both on a mean seedling and a per square foot basis. Mean size and mass values for a 25 seedling replicate were multiplied by plot seedbed density to obtain area values. Seedling height was assessed only for Statesboro seedlings because Summerville seedlings were top-clipped (August 5 and September 16).

Weeds:

The second fumigation trial Summerville was placed in an area with a persistent infestation of nutsedge *(Cyperus* spp.), a weed not adequately controlled by alternative herbicides. Because this area was not put into seedling production, differences in weed control were assessed without the subsequent application of herbicides. Weed data only from this fumigation are

Table 2. Fumigation treatments applied to soil not subsequently used for seedling production (Summerville, SC).

	Chemical	Rate (lb/ac)	Application Method	Soil Seal
1				
2	MC33	350	Injected	Tarped
3	Triform	290	Injected	Tarped
4	Dazomet	300	Rototilled	Tarped
5	Dazomet	300	Rototilled	Power-roll
6	Dazomet	150	Rototilled	Tarped
7	Dazomet	150	Rototilled	Power-roll
8	Metham-sodium	400	Injected	Tarped
9	Metham-sodium	400	Injected	Power-roll
10	Dazomet + Chloropicrin	150 115	Rototilled Injected	Tarped
11	Metham-sodium+ Chloropicrin	400 115	Injected Injected	Tarped
	Control	0	NA	NA

presented here. Percentages of ground covered by weeds for each treatment plot was estimated April 12 and all weeds within a randomly selected four-square- foot area near the center of each plot were counted May 10. 1994. Weeds were categorized as either "spring" or "summer" weeds and nutsedge *(Cyperus* spp.) was enumerated separately.

RESULTS

Seedling quality:

At Summerville, numbers of live seedlings differed significantly between fumigation treatments 35 days after sowing (Table 3). Subsequent mortality was negligible (0.4 seedling per foot) and seedbed densities in May strongly predicted those of September (r=0.95, p=0.0001) and January (r=0.93, p=0.0001). However, the effect of fumigation treatment was not significant in January (p=0.30).

At Statesboro, numbers of damped-off seedlings did not differ among fumigation treatments 35 days after sowing (Table 3). Although the mean seedlings per square foot in June decreased from 23 to 20.6 from June to January. Fumigation treatment effects (in contrast to the trend at Summerville) increased moderately over the same period (p for June = 0.15 and for January =0.08). Correlations for June plot densities (N=55) with those of September (r=0.95, p=0.0001) and January (r=0.93, p=0.0001) were significant.

Among dazomet treatments (N=20), seedling diameters in plots receiving 280 lbs/ac were larger (p=0.03) and there was more shoot (p=0.0001) and root (p=0.009) mass than at the 140 lbs/ac rate. Among chloropicrin treatments (N=20), seedlings in plots treated with 250 lbs/ac produced more root mass per seedling (p=0.05) and per square ft (p=0.02) than those treated with 125 lbs/ac. Tarping did not significantly effect seedling size or mass either in non-fumigated plots or those fumigated with dazomet or chloropicrin. Therefore, tarped and not-tarped treatments were combined for the analysis presented in Table 4. Among the five fumigation treatments (two rates each of chloropicrin and dazomet and one of MC33 and control), plots fumigated with MC33 or the high rates of chloropicrin or dazomet produced larger seedlings than those not fumigated or fumigated with low rates (Table 4).

Among dazomet or chloropicrin fumigations (N=20), no measured seedbed or seedling parameters differed either with rate of fumigant or tarping. Among non-fumigated plots (N=10), seedlings were taller (p=0.02) and had more stem mass (p=0.02) among non-tarped plots. However, seedbed density and seedling root mass was not significantly larger among tarped compared to non-tarped plots. There were no significant differences among Statesboro seedlings in size or mass attributable to the five fumigant by rate treatments (Table 4).

Weeds:

Weed cover by plot and numbers of all weeds and of nutsedge per frame (4ft ^{2}) are presented in Table 5. In May, percentage weed cover differed (p=0.0001) between treatments. MC33 always had the fewest weeds and the 1,3-D and the metham-sodium plus chloropicrin were almost as good. These three treatments and the tarped metham-sodium and the dazomet plus chloropicrin were not significantly different.

In addition to nutsedge, pigweed *(Amaranthus* spp.), dogfennel *(Eupatorium capifillifoliu*m), and horseweed *(Coneza canadensi*s) were common in the May survey and these (exclusive of nutsedge) were analyzed together as "summer-weeds". Other weeds were analyzed together as spring weeds. Summer weeds did not differ between treatments (p=0.58). Spring weeds differed significantly for treatment effects (p=0.0001) with the tarped dazomet treatments and the non-treated control having significantly more weeds than other treatments (Table 5).

Table 3. Seedlings per square foot by nursery, date, and treatment.

Summerville

		May 93		Sept Jan 94					
<u>Chemical</u>	Rate lbs/ac	Tarp	Dead	Live	Live	Live	Ones[1]	Twos[1]	Culls[1]
MC33 350	Yes	3.6	31.7	31.7	29.2	12.9	15.8	0.5	
Chloropicrin	250	No	8.6	27.2	28.3	28.3	9.3	15.5	3.5
Chloropicrin	250	Yes	4.4	30.1	30.2	30.2	9.3	18.8	2.0
Chloropicrin	125	No	3.6	29.1	30.7	30.7	11.3	16.6	2.7
Chloropicrin	125	Yes	2.8	30.1	28.6	28.6	11.4	14.8	2.3
Basamid	280	No	6.8	28.8	29.0	29.0	11.7	16.6	0.7
Basamid	280	Yes	7.2	30.6	27.4	27.4	13.8	12.5	1.1
Basamid	140	No	2.2	30.6	30.7	30.7	9.1	19.8	1.7
Basamid	140	Yes	3.0	30.2	30.5	30.5	8.3	21.3	0.9
None	0	No	11.8	27.8	27.4	28.1	6.4	19.6	2.1
None	0	Yes	5.8	29.2	29.1	28.0	6.9	19.3	1.8
Mean value			5.4	29.6	29.4	29.2	10.0	17.3	1.8
lsd for treatments[2]			5.1	2.6	2.7	3.0	5.2	5.7	2.1
P for treatment effects[2]			0.01	0.04	0.12	0.3	0.12	0.11	0.15

Statesboro

		June 93		Sept Jan 94					
<u>Chemical</u>	Rate lbs/ac	Tarp	Dead	Live	Live	Live	Ones[1]	Twos[1]	Culls[1]
MC33	350	Yes	0.60	23.3	19.7	20.3	7.7	10.8	1.7
Chloropicrin	250	No	0.60	24.1	20.7	22.1	9.1	11.8	1.1
Chloropicrin	250	Yes	0.40	25.1	21.6	22.6	10.2	9.5	2.8
Chloropicrin	125	No	0.20	21.8	18.9	19.9	10.1	8.6	1.1
Chloropicrin	125	Yes	0.40	22.9	19.5	21.0	9.0	9.8	2.1
Basamid	280	No	0.60	23.6	19.7	20.7	7.3	11.7	1.6
Basamid	280	Yes	0.40	21.7	19.5	19.2	8.9	8.2	2.1
Basamid	140	No	0.40	21.5	18.2	18.6	8.1	8.9	1.6
Basamid	140	Yes	0.40	21.4	19.1	19.3	7.3	9.1	2.9
None	0	No	1.20	23.6	20.0	20.8	8.2	10.2	2.3
None	0	Yes	0.00	23.9	20.7	21.5	8.3	10.4	2.7
Mean value			0.47	23.0	19.7	20.6	8.6	9.9	2.0
lsd for treatments[2]			1.02	2.81	2.19	2.59	3.16	3.0	1.88
P for treatment effect[2]			0.70	0.15	0.06	0.08	0.61	0.25	0.49

[1]Seedling rating where ones, two and culls have ground line diameters, respectively of 4.76 mm, 4.75 mm - 3.26 mm, and 3.25 mm.

[2]Statistics from SAS ANOVA.1

DISCUSSION

The herbicidal activities of the fumigants was assessed within seedbeds but standard herbicide applications controlled weeds to the extent that production was not effected. Non-soil associated disease and insect problems were likewise expected to be controlled by standard practices. We expected that any important differences between fumigants would be measured for seed efficiency and seedling quality due to soil-pests other than weeds. The economic aspects of seed efficiency (that is, the number of plantable seedlings culls omitted produced per unit of pure live seed) have been addressed by South (1987) who showed that small changes had significant economic impacts.

Non-significant differences between tarped and not tarped applications of dazomet or chloropicrin were somewhat surprising. Plastic tarps increase effective concentrations of MC2 or MC33 (Munnecke and Van Gundy, 1979). However, MBr boils at 4.6°C and is more physically active than most other fumigants at normal soil temperatures. Dazomet, applied as a granular product evolves its fumigant in contact with soil moisture. Our estimates for soil fungi (data not presented) indicate that much of its activity can occur after tarps would normally

Table 4. Seedbed densities and seedling size and mass by fumigant rate and nursery.

Summerville (271 days after sowing).

Fumigant	Rate (lbs/ac)	Seedlings (/ ft^2)	Diameter (mm)	Shoot (gm OD)	Root (gm OD)
MC33	350	29.2 a [1]	4.70 a	2.45 ab	0.78 a
Chloropicrin	250	29.6 a	4.56 abc	2.38 ab	0.76 ab
Chloropicrin	125	29.2 a	4.40 cd	2.22 bc	0.67 b
Basamid	280	28.2 a	4.68 ab	2.57 a	0.82 a
Basamid	140	30.6 a	4.44 cd	2.00 c	0.69 b
None	0	28.1 a	4.21 d	2.00 c	0.68 b
Mean value		29.1	4.48	2.26	0.73
lsd for treatments [2]		2.3	0.23	0.28	0.08
P for treatment effect		0.19	0.001	0.001	0.001

Statesboro (250 days after sowing).

Fumigant	Rate (lbs/ac)	Seedlings (/ ft^2)	Diameter (mm)	Shoot (gm OD)	Root (gm OD)
MC33	350	20.32 abc	4.52 a	3.31 a	0.93 a
Chlorpicrin	250	22.37 a	4.63 a	3.40 a	1.00 a
Chlorpicrin	125	20.47 abc	4.71 a	3.40 a	1.05 a
Basamid	280	19.95 bc	4.60 a	3.37 a	1.02 a
Basamid	140	18.99 c	4.53 a	3.22 a	0.97 a
None	0	21.16 ab	4.47 a	2.86 a	0.94 a
Mean value		20.6	4.58	3.25	0.99
lsd for treatments		1.93	0.28	0.52	0.15
P for treatment effect		0.012	0.52	0.21	0.61

[1] Means followed by the same letter not significantly different (alpha = .05).
[2] “lsd” and “P” values from SAS GLM.

Table 5. Weeds by fumigant and date on ground not cultivated after a fall fumigation.

Fumigant	Rate lb/ac	Chl. lb/ac	Tarp	Cover %[1] (May)	Numbers [2] (April)	Nutsedge [2] #'s
MBr	235	115	Yes	29 c	8.5 c	0.25 c
1,3-D	290	0	Yes	35 c	14.5 c	2.00 c
Dazomet	300	0	Yes	95 a	101.5 a	36.70 abc
Dazomet	300	0	No	65 b	79.3 ab	63.52 a
Dazomet	150	0	Yes	95 a	82.8 ab	29.75 abc
Dazomet	150	0	No	70 b	81.8 ab	56.75 a
Dazomet	150	115	Yes	46 c	55.0 abc	47.25 abc
Metham-sodium	400	0	Yes	36 c	28.5 c	10.25 bc
Metham-sodium	400	0	No	90 a	35.2 bc	5.75 abc
Metham-sodium	400	115	Yes	38 c	17.3 c	5.50 bc
Control	0	0	No	100 a	91.8 a	31.75 abc
		lsd		16.22	44.21	38.22

[1] Percentage of ground covered by weeds on Apr. 12, 1994.
[2] Number of weeds in four square foot frame on May 10, 1994.

be removed. Chloropicrin is liquid at normal soil temperatures which evaporates slowly (boiling point 112°C) to produce a gas heavier than air. It seems possible that chloropicrin evaporated and subsequently diffused slowly enough without tarping to achieve a large percentage of that effective concentration produced under plastic. Differences between effective concentration of the high and low rates of dazomet or chloropicrin indicate that measured variables (seedling and fungi but not weeds) were sensitive to treatment differences.

Seedling sizes and masses differed between fumigation treatments only at Summerville where all differences followed the same pattern. Seedlings did not differ significantly between the MC33 or the high rate of chloropicrin or dazomet but these were significantly larger than seedlings from plots treated with the low rates which did not differ from non-fumigated controls. Final seedbed densities did not differ among treatments but sizes and masses were negatively correlated with plot densities.

The effects of seedbed density on loblolly pine are well documented (South, et al. 1990). Density differences at the two nurseries result largely from sowing rates and complicate inferences for fumigation treatment effects. At Summerville, the 30 seedlings/ft 2 at the first survey changed negligibly before harvest but at Statesboro, the initial 23/ft 2 , was to 20/ft 2 during that period due to causes not ($p = 0.14$) associated with fumigation treatments. Differences in seedbed densities, between treatments, increased but remained non-significant at Statesboro and decreased at Summerville.

Non-significant differences for seedling growth among treatments at the Statesboro nursery could be attributable either to environmental conditions unfavorable for diseases controlled by fumigation or just the chance "escape" of the study area from a normally sporadic pathogen development.

Not surprisingly, estimates of weed cover in April and numbers of weeds per sample plot in May indicate essentially the same relative herbicidal activities for the fumigant treatments. It seems unfortunate that MC33, which will soon be unavailable, was the best fumigant tested but

1,3-D was almost as good. Although increasing the concentration of chloropicrin usually decrease the herbicidal activity of MBr, it significantly (in April) enhanced the activity of dazomet and insignificantly that of Metham-sodium. Dazomet had the least herbicidal activity of the fumigants.

Nutsedge is currently one of the most difficult weeds to control in southern pine nurseries. Although plants per treatment are presented in Table 3 with a multiple means comparison (Duncan's for SAS ANOVA) it's logical to believe that tuber producing plants will not (as required by these statistics) be normally distributed. Nutsedge plants differed significantly between treatments for non-parametric statistics also (SAS NPAR1WAY) but multiple comparisons are difficult. Anyway, no treatments were significantly different from the control.

As a part of these studies that will be presented later, soil samples were collected each time seedlings were surveyed and subsequently plated on media selective for the development of *Fusarium* (Nash and Snyder, 1961), *Rhizoctonia* (L. J. Herr, 1973) and *Trichoderma* (Elad et al, 1981). Numbers of fungi identified on selective media did not differ significantly among blocks or rows for pretreatment soil samples but all fumigation treatments significantly reduced populations. The assessed fungal "groups" were differentially affected by fumigants and subsequently recovered to prefumigation levels at different rates.

LITERATURE CITED

Anonymous. 1993. The biologic and economic assessment of methyl bromide. USDA NAPIAP. 99 pp.

Carey, W. A. 1991. Insect and disease problems on hardwoods in southern nurseries. In Proceedings. Nursery pest management workshop. Athens, TN July 30-Aug 1.

Carey, W. A. and W. D. Kelley. 1994. Seedling production trends and fusiform rust control practices at southern nurseries, 1981-1991. South. J. Appl. For. 17:207-211.

Elad, Y. I. Chet and Y. Henis. 1981. A selective media for improving quantitative isolation of *Trichoderma* spp. from soil. Phytoparasitica 9:59-67.

Herr, L. J. 1973. Disk-plate method for selective isolation of *Rhizoctonia solani* form soil. Can. J. Microbiol. 19:1269-1273.

Munnecke, D. E. and S. D. Van Gundy. 1979. Movement of fumigants in soil, dosage responses, and differential effects. Ann. Rev. Phytopathol. 17:405-429.

Nash, S. M. and W. C. Snyder. 1961. Quantative estimates in plate counts of propagules of the bean root rot fusarium in field soils. Phytopathology 52:567-572.

South, D. B. and D.H. Gjerstad. 1980. Nursery weed control with herbicides or fumigation: an economic evaluation. SJAF 4:40-45.

South, D. B. and C. B. Davey. 1983. The southern forest nursery soil testing program. Alabama Agricultural Experiment Station Circular 265. 38 pp.

South, D. B., H. S. Larsen, J. N. Boyer and H. M. Williams. 1990. Seed spacing and seedling biomass: Effect on root growth potential of loblolly pine. New Forests 4:179-192.

Stone, J. M. 1991. Hardwood pest problems weeds, grasses & herbicide controls. In Proceedings. Nursery pest management workshop. Athens, TN July 30-Aug 1.

Thompson, W. T. 1991. Agricultural chemicals. Book III – Miscellaneous agricultural chemicals. 1991-1992 revision. Thompson Publications. Fresno, CA.