USE OF CHROLORPICRIN AS A SOIL FUMIGANT IN PINE NURSERIES[1]

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ABSTRACT

Since 1985, chloropicrin has been tested as a soil fumigant in forest nurseries in Georgia, Mississippi, South Carolina, Texas, Virginia and Wisconsin. The Wisconsin test indicated that when used for reducing soilborne pathogens, chloropicrin (applied at 196 kg/ha with a polyethylene tarp) may be as effective as applying twice as much methyl bromide. Advantages of using chloropicrin as a soil fumigant in southern pine nurseries might include: no plastic tarp required, efficacy similar to methyl bromide with regards to reduction in fungi, nematodes and insects. and it is not a Class 1 ozone depleting substance.

INTRODUCTION

Under authority of the Clean Air Act, the Environmental Protection Agency has assigned a phase-out schedule for methyl bromide with a production termination set for the year 2001. As a result, several organizations are examining alternatives to methyl bromide as a soil fumigant. Some trials involve chemical treatments while others involve non-chemical alternatives. A few of the chemical trials are comparing chloropicrin, dazomet, or 1,3-dichloropropene with methyl bromide. This paper highlights trials with chloropicrin.

On a weight basis, chloropicrin is the second most commonly used fumigant in forest nurseries in the southern United States. In 1994, more than 20,000 kg of chloropicrin were used to produce one billion pine seedlings (South and Zwolinski 1996). Currently, chloropicrin is used in combination with methyl bromide either as a warning agent to enhance safety (2% chloropicrin) or to enhance fungicidal efficacy (33% chloropicrin).

METHODS

Since 1992, the Auburn University Southern Forest Nursery Management Cooperative has conducted soil fumigation trials in Georgia, Mississippi, South Carolina, Texas, and Virginia. Several of the studies included chloropicrin at rates from 140-336 kg/ha. Most of the chloropicrin treatments were applied without using a polyethylene tarp to contain the fumigant. However, a tarp was tested at two nurseries (Statesboro Nursery - Georgia; Summerville Nursery - South Carolina) in 1993 (Table 1).

Basically, studies involved fumigating soil with different chemicals at varying rates and comparing seedling production among the treatments. In 1993 at the Statesboro and Summerville Nurseries, loblolly pine seed were sown in April and May, respectively. At lifting (January, 1994), seedling diameters were measured with a digital caliper. Root-collar diameter (RCD) was used to determine number of cull seedlings (RCD<3.25mm), and the number of grade 2 (RCD 3.25-4.75mm) and grade one (RCD>4.75mm) seedlings. At each nursery, the study involved a randomized complete block design with five replications. Soils at both nurseries were loamy sands. Details of the studies were reported by Carey (1995).

RESULTS AND DISCUSSION

In both the Statesboro or Summerville studies, chloropicrin treatments did not result in significant increases in either total number or in the number of large diameter seedlings produced. For statistical differences to occur, the number of seedlings produced would need to be increased by about 12-14% over other treatments. When compared to not-recently-fumigated soil, chloropicrin (280kg/ha) only increased seedling production by an average of 9% (about 28 seedlings m^2) at the Statesboro Nursery. At the Summerville Nursery, the increase was only 1.5% (about 4 seedlings/m^2). Neither increase was statistically significant at $P=0.05$. However, with a value of $0.04 per seedling, an increase in seedling production of 18/m^2 would be worth about $4,800/ha and a 4/$m^2$ increase would be worth $1,066/ha.

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Table 1. Effects of soil fumigation on 1993 loblolly pine seedlling production at the Statesboro Nursery in Georgia and the Summerville Nursery in South Carolina.

Fumigant	Rate kg/ha	Tarp Used	Number of Seedlings Produced[1] per $0.929m^2$							
			Statesboro Nursery				Summerville Nursery			
			Total	Ones	Twos	Culls	Total	Ones	Twos	Culls
MC33	392	yes	20.3	7.7	10.8	1.7	29.2	12.9	15.8	0.5
Chloropicrin	280	no	22.1	9.1	11.8	1.1	28.3	9.3	15.5	3.5
Chloropicrin	280	yes	22.6	10.2	9.5	2.8	30.2	9.3	18.8	2.0
Chloropicrin	140	no	19.9	10.1	8.6	1.1	30.7	11.3	16.6	2.7
Chloropicrin	140	yes	21.0	9.0	9.8	2.1	28.6	11.4	14.8	2.3
Dazomet	314	no	20.7	7.3	11.7	1.6	29.0	11.7	16.6	0.7
Dazomet	314	yes	19.2	8.9	8.2	2.1	27.4	13.8	12.5	1.1
Dazomet	157	no	18.6	8.1	8.9	1.6	30.7	9.1	19.8	1.7
Dazomet	157	yes	19.3	7.3	9.1	2.9	30.5	8.3	21.3	0.9
None	0	no	20.8	8.2	10.2	2.3	28.1	6.4	19.6	2.1
None	0	yes	21.5	8.3	10.4	2.7	28.0	6.9	19.3	1.8
Mean - All Treatments			20.6	8.6	9.9	2.0	29.2	10.0	17.3	1.8
LSD			2.59	3.16	3.0	1.88	3.00	5.2	5.7	2.1
P For Treatment Effect			0.08	0.61	0.25	0.49	0.30	0.12	0.11	0.15

[1] Seedlings rated as Ones, Twos and Culls have ground line diameters of greater than 4.76mm, 3.26-4.75mm, less than 3.25mm, respectively.

At a Wisconsin nursery (Table 2), large increases in seedling production resulted from effective soil fumigation with either methyl bromide or chloropicrin (Enebak et al. 1990). Similar increases have also been reported at other nurseries (Sutherland and Adams 1965). It is possible that the absence of large increases in seedling production at southern nurseries might be due to past fumigation practices. For example, low levels of disease currently occurring may be due to improved soil management practices and periodic fumigation in the past which keeps pathogen levels low.

Overall, chloropicrin is a better fungicide than methyl bromide. In some cases, half the amount of chloropicrin was as effective as methyl bromide (Enebak et al. 1990 - Table 2). Chloropicrin is very effective in reducing populations of soil-borne *Fusarium*, *Rhizoctonia* and *Pythium* spp. (Enebak et al. 1990).

Unfortunately, chloropicrin is not as effective as methyl bromide in reducing weed populations. For weed control, it might require 2-1/2 times as much chloropicrin to equal the effectiveness of methyl bromide (Goring 1962). Although chloropicrin does have some herbicidal activity, its use as a fumigant will have to be supplemented with standard herbicides that are effecive in conifer nurseries. If applied appropriately, herbicides are more cost effective for weed control than soil fumigation (South and Gjerstad 1980). However, for control of yellow (*Cyperus esculentus* L.) and purple (*C. rotundus* L.) nutsedge, methyl bromide is still the most effective chemical.

Some nursery managers use economic thresholds (ET) to determine when pesticides should be applied. The ET is the point at which the cost of an option equals the economic impact of the pest controlled (National Research Council 1969). The ET value is determined by the cost of fumigation. Determining if crop loss exceeds the ET value will depend on crop value (Table 3); soil fumigation will be easier to justify when crop value is high. For example, if seed costs $0.06 each and if the manager sows 250 seeds/m^2, then about $10,000 worth of seed are sown per hectare. The ET of $2,500/ha fumigation would be a 25% reduction in seed loss. It may be surprising to know that the average seed efficiency gain from methyl bromide fumigation (where fumigation had not be done previously) can exceed

Table 2. Effects of soil fumigation on 1986 white pine seedling production at the F.G. Wilson State Nursery in Wisconsin (from Enebak et al. 1990).

Fumigant	Rate kg/ha	Tarp Used	Seedlings Produced Per m^2
Methyl Bromide	392	yes	484
Chloropicrin	196	yes	456
Dazomet	280	no	250
None	0	no	108

25% (Sutherland and Adams 1965). However, today many nurseries sell seedlings that may be 10 times more valuable than seed. At $40/thousand seedlings. the ET for fumigation is reduced to a loss of only 62.5 thousand seedlings. Assuming a production level of 2 million seedlings/ha, this amounts to only a 3% reduction in production. However, the net present value (NPV) of seedlings can be higher than production costs. For some organizations, seedlings that are genetically or morphologically improved have a much higher value than the costs to produce them. For example, the superior performance of large-diameter seedlings, which have a larger root mass, after outplanting compared to small-diameter seedlings is clear. South and Mexal (1984) concluded from numerous published reports that grade 1 seedlings outperformed grade 2 seedlings in both survival and growth. South (1993) concluded that outplanting morphologically improved seedlings (those with 6.5mm diameter instead of 4.5mm) can increase volume production at age 10-20 years by as much as 55 m^3/ha. Using conservative prices, the NPV of grade 1 seedlings can be worth $80/thousand more than grade 2 seedlings. If a nursery produces 100% grade 1 instead of grade 2 seedlings, the ET would be exceeded if production of grade 1 seedlings decreased by 32 thousand (about 1.6%). Therefore, when nursery managers value grade 1 more than grade 2 seedlings, soil fumigation might be relatively easy to justify, even with no increase in number of plantable seedlings.

Table 3. The increase in plantable seedlings required to equal the economic threshold for fumigation ($3000/ha).

Seedling Value	Additional Seedlings Needed per m^2	Additional Seedlings Needed per ha	% Increase in Conifer Stand (2 Million Base)	% Increase in Hardwood Stand (0.5 Million Base)
$0.03	15	100,000	5	20
$0.06	7.5	50,000	2.5	10
$0.12	3.8	25,000	1.25	5
$0.20	2.3	15,000	0.75	3
$0.30	1.5	10,000	0.5	2

When 1+0 seedlings are grown at densities of 200/m^2 in the nursery and are outplanted at 1,000/ha, fumigation of nursery soil with untarped chloropicrin might add $1.12/ha to overall reforestation costs, assuming soil fumigation once every two seedling crops ($2.24/ha assuming soil fumigation once for every seedling crop). We believe this small investment would be good insurance against soilborne pathogens. In some situations, increases in seedling size alone might justify the investment. At a few nurseries, reduction in number of asymptomatic diseased seedlings would justify the cost. For example, the cost of fumigation could be justified if only 7 seedlings/ha died after outplanting due to infection by soilborne nursery pathogens. This mortality amounts to less than 1%. The cost of planting 7 seedlings and treating them with herbicides could exceed $1.12, assuming it costs $0.03/seedling, $0.06 to plant a seedling, and $0.08 to treat with herbicides.

CONCLUSIONS

When production of methyl bromide ceases in the United States, many managers of bare-root nurseries may discover they need to adjust their pest management programs. Some nursery managers in the southern United States may choose to adopt the practice of fumigating with chloropicrin since suppression of pathogens and nematodes with this fumigant is similar to that obtained with methyl bromide. However, some managers may find a need to increase use of selective herbicides, since chloropicrin is not a very effective herbicide.

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