The Use of Chemical Fumigants and Potential Alternatives at Weyerhaeuser Mima Nursery

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Abstract - Potential loss of methyl bromide as a soil fumigant by year 2000, due to its ozone depletion potential, has resulted in extensive exploration of both chemical and non-chemical alternatives at the Weyerhaeuser Mima Nursery. Although not as effective as methyl bromide/chloropicrin (MB/CHL), both Basamid granular (Dazomet) incorporated, rolled and water sealed and chloropicrin, injected and tarped, provided control of targeted soil pathogens. However, neither fumigant controlled weeds as well as MB/CHL. Bare fallowing fields between Douglas-fir seedling crops significantly reduced soil pathogens in contrast to oat and pea green manure cover crops. Brassica spp., used as green manure crops, were not effective in reducing soil pathogens, as compared to bare fallow or MB/CHL fumigation treatments. In addition to MB/CHL fumigation, application of yardwaste compost and fungicides had a positive effect on Douglas-fir seedling growth. Unfortunately, seedling mortality was greater in compost amended treatments.

INTRODUCTION

The Weyerhaeuser Mima Nursery, located 12 miles southwest of Olympia, Washington produces over 20 million bare-root seedlings annually for outplanting. Two year old seedlings and numerous transplant stock types are grown in a predominately loamy sand soil type. Since the mid-1970's, methyl bromide/chloropicrin fumigation has been utilized at the nursery to help control weeds, insects and soil-borne pathogens during the early stages of crop development. Beginning in the mid -1980's, a series of experiments was begun, which explored chemical and non-chemical alternatives to MB/CHL.

BASAMID

In September of 1984, an experiment was installed at Mima, which tested the efficacy of Basamid, in comparison to methyl bromide/chloropicrin (MB/CHL) fumigation. The treatments tested were:

Treatment 1: Methyl bromide/chloropicrin (67/33) at 360 #/ac (1x) with tarp.

Treatment 2: Methyl bromide/chloropicrin (67/33) at 720 #/ac (2x) with tarp.

Treatment 3: Basamid 350 #/ac with no tarp.

Treatment 4: Control - no fumigation, no tarp.

In early May of 1985, Douglas-fir seed was sown and a 2+0 crop was grown the same across all treatments.

The methyl bromide/chloropicrin at 360 #/ac and Basamid treatments significantly increased fall 1+0 seedling counts over the non-fumigated treatment (Table 1). Seedlings from the fumigated treatments were generally larger than control seedlings when measured in the fall of 1985 (Table 2). In particular, seedlings from the MB/CHL 360 #/ac treatment had significantly larger stem diameter and higher root and shoot dry weights compared to seedlings from the non-fumigated treatment (Tanaka et al. 1986).

Table 1. Effects of soil fumigants on Douglas-fir seedling emergence and 1+0 stand count. Treatments followed by the same letter are not significantly ($p<0.05$) different within each assessment time.

	Seedlings (#/6 sq. ft.)	
Treatment	6/85 (Emergence)	10/85 (1+0)
MBC/CHL (1x)	187 a	177 a
MBC/CHL (2x)	176 a	167 ab
Basamid	187 a	177 a
Control	168 a	158 b

Table 2. Effects of soil fumigants on Douglas-fir seedling growth assessed in October 1985. Treatments followed by the same letter are not significantly ($p<0.05$) different in each variable.

	Seedlings (#/6 sq. ft.)		
Treatment	Shoot wt. (mg)	Root wt. (mg)	Stem diameter (mm)
MBC/CHL (1x)	800 a	185 a	2.0 a
MBC/CHL (2x)	595 ab	138 b	1.6 b
Basamid	496 b	134 b	1.5 b
Control	415 b	105 b	1.4 b

Seedlings were assessed for mycorrhizal infection October 1985 and May 1986. There was no significant treatment affects at either assessment date. Essentially all seedlings had become mycorrhizal by May 1986 (Tanaka et al. 1986).

All fumigation treatments significantly suppressed and preserved low levels of soilborne pathogens (Fusarium spp. and Pythium spp.) during the first growing season.

MB/CHL fumigation was slightly more effective in reducing pathogen counts compared to Basamid. Both MB/CHL treatments suppressed root infection by Fusarium spp., but not Pythium spp. (Table 3). Basamid was not as effective as MB/CHL in reducing Fusarium root infection (Tanaka et al. 1986).

Table 3. Effects of soil fumigants on the incidence of infections of Douglas-fir roots by species of *Pythium* and *Fusarium*. Treatments followed by the same letter are not significantly (p<0.05) different in each fungus.

	Infected Root Segments (%)	
Treatment	Pythium	Fusarium
MBC/CHL (1x)	71 a	16 b
MBC/CHL (2x)	49 a	15 b
Basamid	71 a	51 ab
Control	88 a	74 a

COVER CROPS

Prior to 1990, production blocks at Mima Nursery had been used to grow a combination of 2+0 seedlings non-fumigated and transplants for three consecutive seasons, followed by a fallow season. During the fallow season, an oat and pea cover crop was grown and incorporated before fall fumigation. The role of the cover crop on soil pathogen levels and the growth of subsequent conifer seedling crops was generally unknown.

In June of 1985, a split-plot designed experiment was installed at Mima Nursery to test the effects of soil fumigation and cover crops. Oat and pea cover crop treatments were assigned to whole plots in a randomized complete block design and fumigation treatments were assigned to subplots. The cover crop treatments included: oats, peas, an oat/pea mix and bare fallow. The fumigation treatments included: tarped methyl bromide/chloropicrin (67/33) at 350 #/ac and nonfumigated. The fumigation treatment was applied in September of 1985 and Douglas-fir seed was sown in May of 1986. Seedlings were harvested in February of 1988 as a 2+0 crop (Hansen et al. 1990).

Prior to fumigation, all three oat and pea cover crop treatments resulted in higher soil Fusarium spp. and *Pythium* spp. colony counts compared to the bare fallow treatment. Fumigation significantly lowered populations of *Fusarium* and *Pythium* in all cover crop treatments. This trend continued across the ten soil sampling dates. Although, levels of *Fusarium* in the unfumigated bare fallow treatment were higher than those in fumigated plots, the difference was not significant. In fact, the non-fumigated bare fallow treatment continued to be comparable to the fumigated treatments at all but one soil sample date (Hansen et al. 1990).

Cover crop treatments did not significantly affect the number of packable 2+0 seedlings harvested. In contrast, fumigation resulted in higher amounts of live and packable seedlings at harvest. Seedlings from the non-fumigated plots were smaller and more variable in size than those from fumigated plots (Hansen et al. 1990).

BRASSICA COVER CROPS

Brassica species contain secondary metabolites, glucosinalates, which yield volatile and soluble isothiocyanates. These isothiocyanates, have similar activity to many commercial fumigants, and may suppress soil pathogens when *Brassica* cover crops are incorporated into soil (Stone and Hansen 1993).

In 1990 and 1991, studies were installed at Mima Nursery comparing the effects of *Brassica* cover crops, bare fallow, and methyl bromide/chloropicrin (67/33) fumigation on soil populations of *Fusarium* and *Pythium* spp. and performance of subsequent Douglas-fir 2+0 crops.

Treatments in the 1990 study included: bare fallow with sawdust, *Brassica* (yellow mustard) with and without sawdust, and an oat cover crop with methyl bromide/chloropicrin (67/33) fumigation. These treatments were installed in a randomized complete block design. Propagule counts from soil samples were taken directly before, 8 weeks after fumigation, and once more immediately prior to sowing Douglas-fir seed. *Fusarium* and *Pythium* propagule counts were higher in the *Brassica* plots compared to the bare fallow and fumigated plots 8 weeks after fumigation (Table 4). Propagule counts did not significantly differ between *Brassica* plots with and without sawdust. MB/ CHL fumigation significantly reduced soil pathogen levels. Douglas-fir seedling densities at the end of first growing season did not significantly vary among treatments. Thus, first year survival was not higher ill treatments that contained the lowest *Fusarium* and *Pythium* propagule counts (Stone and Hansen 1993).

Table 4. Average numbers of *Fusarium* and *Pythium* propagules recovered from soil samples in the 1990 study.

Treatment	Pre-fum. Fusarium	Pre-fum Pythium	Post-fum. Fusarium	Post-fum. Pythium	Pre-sow Fusarium	Pre-sow Pythium
Fallow	3534	59	1534	40	3870	180
Brassica + sawdust	2735	60	4743	1303	3174	1009
Oats + MB/CHL	4701	74	37	0	533	0
Brassica + no sawdust	5650	42	5402	1054	5736	1373

Treatments in the 1991 study included: bare fallow with and without sawdust; oats with fumigation (MB/ CHL); dwarf Essex winter rape, Tilney white mustard, and brown mustard at 10#/ac and 20#/ac; and Gisilba white mustard at 20#/ac. The study was installed as a randomized complete block design with four blocks. Douglas-fir seed was sown in spring of 1992 for a 2+0 crop. During the first growing season, soilborne *Fusarium* population levels increased significantly in all *Brassica* cover crop plots. Population levels were proportional to the amount of green biomass incorporated. Soil propagule counts remained low in the fumigated and bare fallow plots throughout the first growing season. Seedling pre-emerge and post-emerge mortality was poorly correlated to soilborne *Fusarium* levels, although, the highest seedling mortality caused by *Fusarium* did occur in winter rape plots. Sawdust addition decreased seed germination and growth. Growth loss was probably related to nitrogen deficiency caused by biological fixation during sawdust decomposition.

CHLOROPICRIN

As a potential chemical alternative to methyl bromide/chloropicrin (67/33), chloropicrin (99%) was tested at Mima Nursery in 1993. Beds were fumigated on July 30th with chloropicrin at 200 #/ac and methyl bromide/chloropicrin at 350 #/ac. Both materials were covered with I mil high barrier film. On May 3, 1994 these beds were sown with Douglas-fir seed and a 2+0 crop was grown.

Final seedbed density was significantly greater for the methyl bromide/chloropicrin treatment than the chloropicrin treatment (Table 5). However, seedlings in the chloropicrin treatment were significantly larger in diameter and height. It may be possible that this was related to the lower seedling density of the chloropicrin treatment plots. Weed control was poorer in the chloropicrin treated plot.

Table 5. Comparison of methyl bromide/chloropicrin and chloropicrin fumigants on Douglas-fir seedlings. Treatments followed by the same letter are not significantly ($p<0.05$) different.

Treatment	Height (cm)	Caliper (cm)	Density
MB/CHL	35.7 b	4.32 b	121.0 a
Chloropicrin	38.6 a	4.92 a	104.9 b

In order to further test the efficacy of chloropicrin and repeat earlier work with Basamid, a chemical fumigant comparison study was installed in the fall of 1995. Treatments included: (1) tarped methyl bromide/ chloropicrin (67/33) at 350 #/ac, (2) tarped chloropicrin at 250 #/ac, and (3) incorporated, rolled, and water sealed Basamid at 250 4/ac. In May of 1996, all treatments were sown with Douglas-fir seed. As of July 1996, seedling counts were not significantly different between fumigation treatments (Table 6).

Table 6. Comparison of methyl bromide/ chloropicrin, chloropicrin, and Basamid fumigants on Douglas-fir seedbed densities. Treatments followed by the same letter are not significantly (p<0.05) different.

Treatment	Density
MB/CHL	260.8 a
Chloropicrin	259.2 a
Basamid	264.0 a

FUMIGATION, COMPOST AND FUNGICIDES

Soil incorporated compost may be antagonistic towards seedling soil pathogens and result in increased crop growth. In addition, fungicides may also provide viable alternatives to chemical fumigants. Consequently, a split-split plot designed experiment was installed at Mima in 1994 to test their effectiveness in comparison to MB/CHL fumigation. One half of the study area was fumigated with 350 #/ac MB/CHL in August 1994, the other half was not fumigated. Compost (2% N) from the Purdy yardwaste facility was spread 1/2" deep and incorporated into four sub-plots in fumigated and non-fumigated beds in April 1995. Across these treatments fungicide and non-fungicide plots were superimposed. A Douglas-fir seedlot was sown on the experimental beds in May of 1995 and a 2+0 crop of seedlings was grown.

In November of 1995 dramatic differences in seedling density were observed in the experimental plots (Table 7). Compost treated plots had significantly lower seedling densities (Table 8). During the summer of 1995 seedling mortality had been evident in the compost treated plots, the high nitrogen content (2%) of the compost may have led to the lower seedling densities. In a previous study at Mima, summer seedling mortality due to *Fusarium oxysporum* had been correlated to increased nitrogen fertilization (Sinclair et al. 1975). Fumigation and fungicide treatments did not significantly affect seedling density.

Table 7. Effects of fumigation, compost, and fungicides on density of Douglas-fir seedlings during their first season. Density measurements were taken during November of 1995.

Treatment	Density (seedlings/LBF)
Control	95.6
Compost	89.8
MB/CHL	93.8
Fungicides	106.4
Compost + MB/CHL	87.0
Compost + Fungicides	79.0
MB/CHL + Fungicides	99.0
Compost + MB/CHL + Fungicides	76.2

Table 8. Analysis of variation for seedling density as affected by fumigation, compost and fungicides. Based on density measurements taken during November of 1995.

Source of Variation	F-Ratio	Significance Level
Main Effects		
Compost	7.115	0.0135
MB/CHL	0.395	0.5422
Fungicides	0.057	0.8165
Interactions		
Compost x MB/CHL	0.023	0.8814
Compost x Fungicides	2.550	0.1233
MB/CHL x Fungicides	0.057	0.8165
Compost x MB/CHL x Fungicides	0.057	0.8165

As of August 1996 large differences in seedling size were evident among treatments (Table 9). Fumigation, compost and fungicides all significantly increased seedling height and caliper growth (Table 10). The compost treatment could have increased seedling growth because of its nutritional properties and also the lower seedling densities in these plots. The stimulatory affect of fumigation on Douglas-fir seedling growth duplicates the results of earlier studies at Mima Nursery (Hansen et al. 1990; Tanaka et al. 1986). In the spring of 1996 upper and lower stem canker, caused by *Fusarium roseum* and *Phoma eupyrena*, was much more prevalent in plots that had not received the fungicide treatment. Since stem canker often kills only the seedling top and not the whole seedling, nonfungicide treated seedlings would be expected to be smaller in size.

Table 9. Effects of fumigation, compost, and fungicides on growth of Douglas-fir 2+0 seedlings. Size measurements were taken during August of 1996.

Treatments	Height (cm)	Caliper (mm)
Control	29.8	3.38
Compost	37.3	4.00
MB/CHL	36.3	3.88
Fungicides	32.2	3.67
Compost + MB/CHL	38.8	4.10
Compost + Fungicides	42.4	4.48
MB/CHL + Fungicides	40.7	4.57
Compost + MB/CHL + Fungicides	50.0	5.18

Table 10. Analysis of variation for seedling height and caliper as affected by fumigation, compost and fungicides. Based on size measurements taken during August of 1996.

	Height		Caliper	
Source of Variation	F-ratio	Significance Level	F-ratio	Significance Level
Main Effects				
Compost	58.124	<0.0001	18.161	0.0003
MB/CHL	38.627	<0.0001	17.204	0.0004
Fungicides	35.480	<0.0001	22.968	0.0001
Interactions				
Compost x MB/CHL	2.412	0.1335	1.349	0.2569
Compost x Fungicides	6.021	0.0218	1.199	0.2844
MB/CHL x Fungicides	4.215	0.0511	3.577	0.0707
Compost x MB/CHL x Fungicides	1.119	0.3006	0.140	0.7153

SUMMARY

Due to the negative results of cover crops in the Brassica studies and the earlier pea/oat study, we no longer use cover crops at Mima Nursery. Fields are left bare during the fallow season and then fumigated in the fall with methyl bromide/chloropicrin. Chloropicrin and Basamid will continue to be tested as alternatives to methyl bromide/chloropicrin. Both of these products have the potential to reduce soil pathogens and increase growth of Douglas-fir seedlings as compared with nontreated controls. Composts may significantly increase seedling growth; however, questions remain as to their effectiveness in reducing disease and their potential negative affect on seedling density.

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