TEST OF SOIL FUMIGANTS IN LOUISIANA

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This paper summarizes a pilot study with four promising nematocides and multipurpose soil fumigants in a Louisiana Forestry Commission nursery. Objectives were to devise an economical way to control root diseases and weeds that were seriously curtailing nursery production and reducing the size and quality of nursery stock, and to determine the optimum density of slash pine seedlings in the fumigated beds. Each fumigant was evaluated as to its effect on nematode populations, weeds, hand weeding costs, root rots, production of plantable seedlings, and field survival of outplanted stock.

Site

The test was conducted in the Southwest Louisiana Nursery, near Oberlin, in areas infested with root parasites and prostrate button-snakeroot (Eryngium prostratum Nutt.), a weed resistant to mineral spirits and extremely expensive to remove by hand. Hand weeding in these beds had required 600 to 900 man-hours per acre annually.

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Methods

The four fumigants studied were methyl bromide and Vapam (sodium methyl dithiocarbamate dehydrate), which are soil sterilants; and Dowfume W-85 (ethelene dibromide) and Shell D-D (1, 2 dichloropropene-1, a-dichloropropane, 1 to 1 ratio), which are nematocides. Fumigants were applied to previously unfumigated soil and to soil that had been fumigated 1 year earlier with 435 pounds of methyl bromide per acre. Since both areas had been included in a previous fumigation study, valid comparisons were possible between areas as well as between fumigants.

Each chemical was applied to three nursery - beds in each area. Treatments were assigned at random in a block design. Blocks ranged from 0.5 to 0.6 acre and contained nine nursery beds. Alternate beds were fumigated within a block, with the intervening beds serving as buffers.

Prior to treatment, the soil was plowed, disked, and rototilled; it was ready for final shaping of the beds.

Beds were fumigated between March 10 and 20, 1959. The chemicals were applied by production, rather than by research, techniques. Methyl bromide was applied at 435 pounds per acre; special equipment was used to lay thin polyethylene covers and dispense hot gas in a continuous operation (1). Vapam was sprayed from a Hardy sprayer to the surface of shaped beds at 100 gallons per acre; the surface was sealed immediately by watering. Dowfume W-85 and Shell D-D were injected 6 inches below the surface of the soil at 1-foot intervals. These two chemicals were pumped, under low pressure, from a 55-gallon drum through a flow divider into polyethylene tubes attached to the backs of each of seven shanks that were mounted on the implement bar of a Farmall "M" tractor. Rates of application were 7 and 25 gallons per acre for Dowfume W-85 and Shell D-D, respectively. Temperatures and soil moisture at treatment and following treatment were within the limits normally favorable for effective fumigation.

Slash pine (Pinus elliottii Engelm.) seeds were sown for densities of 30, 45, and 60 seedlings per square foot in previously unfumigated beds and for a density of 45 per square foot in the refumigated area. Sowing dates were April 4 to 14; thus, the interval between fumigation and sowing was 2 to 5 weeks. All beds were mulched with pine straw that had been fumigated with methyl bromide to prevent the introduction of weed seeds to treated areas.

After sowing, beds received usual irrigation, fertilization, hand weeding, and spraying to control fusiform rust (Cronartium fusiforme Hedgc. and Hunt ex cumm.), and weeds.

Nematodes were inventoried on April 22, by extraction and enumeration techniques described by Hollis (7) and Hollis and Fielding (8). The field sample consisted of duplicate pints of soil from each plot obtained by compositing randomly selected 3/4- by 6-inch cores in plastic bags.

Weeds emerging before mid-June and persisting despite semiweekly spraying with mineral spirits were counted on permanently located 1- by 4-foot sample plots (5 per bed in refumigated areas and 15 per bed in previously unfumigated areas). Prostrate buttonsnakeroot and nutgrass (Cyperus rotundus L.) were recorded separately because of their high resistance to conventional control. Other weeds were grouped together. Man-hours spent in hand weeding during the entire season were also recorded.

The extent and severity of root rots were sampled in October by examining at least 30 randomly selected seedlings per bed. Seedling roots were also inspected for mycorrhizae.

Total production was measured in November by counting the number of seedlings on the permanent, sample plots established for weed counts. Yield by grade was determined at lifting by classifying samples of seedlings composited from five random locations in each fumigant-density plot. These samples were taken adjacent to the weed-inventory plots.

Morphological grade 1 and 2 seedlings (10) were planted in a Bowie very fine sandy loam in central Louisiana and in a Lakeland loamy fine sand in north Louisiana. The Bowie soil is favorable to survival of planted pines, but the planting was done specifically to test field survival of the stock. The Lakeland soil is droughty.

Results

Nematodes

One month after fumigation, untreated soil from the two . phases of the experiment contained 223 and 250 nematodes per 1/7-pint sample (table 1). About one-fourth of the total was Tylenchorhychus ewingi, which accounted for about 90 percent of the parasitic nematodes in all beds.

Methyl bromide fumigation virtually eliminated both parasitic and nonparasitic nematodes; Vapam reduced their numbers by 80 percent. Shell D-D and Dowfume W-85 were less effective than expected, reducing the population by about 50 percent as against the 80-percent control that is usual in such tests.

Fumigation 1 year earlier with methyl bromide had no apparent lasting effect on nematodes. In fact, previously unfumigated plots usually contained smaller populations than their refumigated counterparts.

Weeds

About 45 weeds per square foot had been pulled from check beds in previously unfumigated areas by mid-June (table 2). Beds treated with methyl bromide or Vapam had about one-tenth as many weeds. The nematocides, Dowfume W-85 and Shell D-D, did not affect weed populations.

Prostrate button-snakeroot made up 37 percent of the total weeds in check beds. It comprised only 26 percent in methyl bromide- and Vapam-treated beds. Thus, these fumigants were at least as effective against this species as against other weeds. Sparsity and patchy distribution precluded any precise determination of the effect of fumigants on nutgrass.

Weeds were only about one-third as numerous in areas fumigated with methyl bromide in 1958 as in previously unfumigated areas, indicating a substantial carryover. This probably resulted from fewer weed seeds maturing in 1958 and from the fumigant killing a substantial number of seeds already in the ground.

In the refumigated area, methyl bromide-treated beds averaged 1.3 weeds per square foot, compared with 19.4 for the check. Vapam fumigation reduced the count to 12.4 per square foot. Close inspection of the data revealed that nutgrass was particularly numerous in one Vapam-treated bed. Its abundance cannot be explained; however, Vapam was ineffective against it. General experience has shown that application of 100 gallons per acre of Vapam

TABLE 1.--Effect of fumigation on number of nematodes per 1/7 pint of soil

Treatment	Tylenchorhychus ewingi	Others[1]
	Number	*Number*
Previously unfumigated soil:		
Methyl bromide	0	3
Vapam	19	40
Dowfume W-85	18	105
Shell D-D	15	31
Check	43	180
Refumigated soil:[2]		
Methyl bromide	1	4
Vapam	3	22
Dowfume W-85	19	104
Shell D-D	102	73
Check	84	166

[1] Includes nonparasitic and parasitic species except T. ewingi.
[2] Fumigated 1 year earlier with methyl bromide.

TABLE 2.--Effect of fumigation on number of weeds per square foot in mid-June and on labor per acre needed for hand weeding

Treatment	Nutgrass	Prostrate button-snakeroot	All others	Total	Labor to weed
Previously unfumigated soil:	*Number*	*Number*	*Number*	*Number*	*Man-hours*
Methyl bromide	0.3	1.3	3.6	5.2	339
Vapam	.6	1.2	2.9	4.7	262
Dowfume W-85	7.1	10.5	23.6	41.2	724
Shell D-D	5.5	13.7	25.6	44.8	1,024
Check	2.4	16.5	25.7	44.6	758
Refumigated soil:[1]					
Methyl bromide	.1	.8	.4	1.3	122
Vapam	11.6	.4	.4	12.4	290
Dowfume W-85	.6	2.6	6.0	9.2	205
Shell D-D	3.7	5.7	6.2	15.6	349
Check	3.1	7.5	8.8	19.4	355

[1] Fumigated 1 year earlier with methyl bromide.

under a water seal does not control nutgrass satisfactorily. Hodges (6) found that Vapam should be sealed with airtight covers, such as polyethylene.

The results permit no conclusions concerning the effectiveness of methyl bromide against nutgrass; however, its utility in this respect has been amply demonstrated elsewhere (J 5).

The amount of labor required to hand weed confirmed the value of methyl bromide and Vapam as herbicides. When contrasted with the average for check, Dowfume W-85, and Shell D-D, fumigation with methyl bromide reduced hand-weeding labor by 496 man-hours per acre in the previously unfumigated area and by 181 man-hours in the refumigated area (table 2). Comparable values for Vapam are 573 and 13 man-hours. As already noted, the poor performance of Vapam in the refumigated area was because of its ineffectiveness against nutgrass.

Except for Vapam, hand-weeding costs were one-third as great on refumigated plots as on previously unfumigated plots. This relationship is similar to that found for number of weeds.

Fungi

Serious root-rot infections developed in the check area which was one block of the previously unfumigated area. Here, 44 percent of the check seedlings showed some root rot by mid-October, and 7 percent were seriously infected. By lifting time, the damage had intensified until thee untreated bed produced only 5.9, 5.7, and 6.1 plantable seedlings per square foot from densities of 30, 45, and 60, respectively. An additional 2.2 to 4.7 plantables were discarded because most of their lateral roots had been destroyed. The remaining seedlings failed to reach plantable size. In contrast, fumigated beds in this block yielded 19.8 to 29.0 plantables per square foot, with the four fumigants controlling the disease equally well. They increased plantable yield per acre by 468,000 seedlings in the 30 density, 560,000 in the 45, and 540,000 in the 60 if a conversion factor of 28,000 square feet of nursery bed per gross acre is assumed. No serious root rot infections were encountered in the other study beds.

Adequate mycorrhizae developed on all seedlings except those in the check bed that was heavily infected with root rot.

The Seedling Crop

Total production.--In the fall inventory actual densities in previously unfumigated beds agreed reasonably well with prescribed densities. They averaged 35.1, 45.7, and 56.4 per square foot for the 30, 45, and 60 densities, respectively (table 3). Total production was not affected by fumigation, nor was there a demonstrable interaction between densities and fumigants. These results are important because they permit evaluation of the effects of density and fumigation on size of stock, yield of plantable seedlings, and field survival.

Beds in the refumigated area contained 45.8 seedlings per square foot (table 3). This yield agreed almost exactly with the average yield of the middle density in the other phase of the experiment, facilitating comparisons of seedling crops between the two phases. As before, fumigation did not affect the total seedling stand.

Plantable production.--In the area of severe root rot discussed earlier, fumigation increased nursery production by more than one half million plantable seedlings per acre. Where root disease was inconspicuous, however, fumigated and unfumigated beds produced similar numbers of plantable seedlings.

Actual yields depended on stocking, being greater with a density of approximately 45 living seedlings per square foot than with densities in the midthirties or high fifties. Except in the rot-infested check bed, yields averaged 610,000, 658,000, and 627,000 plantable seedlings per acre for the 30, 45, and 60 densities, respectively. These data substantiate published recommendations (2) to sow for 40 or slightly more slash seedlings per square foot. They also help define the effect of density on yield of plantable seedlings from fumigated beds. Hansbrough and Hollis (4) concluded that 60 seedlings per square foot is superior to 30 for loblolly pine (*Pinus taeda* L.), but they did not test an intermediate density or exclude oversized stock from plantable grades.

Plantable seedlings from fumigated beds averaged 1 to 3 inches taller than check plot seedlings from the same density. Average heights ranged from 9.8 inches for grade 1 and 2 seedlings from Vapam-treated soil to 11.4 inches for similar stock from beds fumigated with Dowfume W-85.

Thirty-seven percent of seedlings from the 60 density, 50 percent of those from the 45, and 59 percent of those from the 30 were plantable. These seemingly low proportions of plantable seedlings resulted from rigid adherence to Wakeley's morphological grades. Many seedlings--perhaps 15 to 25 percent of the total--having stiff, woody stems and fascicled needles were discarded because they were slightly less than 1/8-inch in root-collar diameter. Two percent was considered too large to plant.

TABLE 3.--Seedling production per square foot of nursery bed, by density and fumigant

Fumigant	Previously unfumigated soil						Refumigated soil	
	30 square feet		45 square feet		60 square feet		45 square feet	
	Total	Plantable	Total	Plantable	Total	Plantable	Total	Plantable
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Methyl bromide.	35.4	23.2	48.4	27.0	59.5	26.5	46.4	25.2
Vapam..........	35.3	20.5	48.2	25.8	57.3	22.0	44.2	21.6
Dowfume W-85...	35.1	21.6	45.3	24.5	55.4	20.8	47.2	23.1
Shell D-D......	35.5	21.1	43.6	22.2	52.8	21.3	46.2	21.5
Check..........	34.1	16.9	43.0	15.1	57.2	16.4	44.8	21.9
Average..	35.1	20.7	45.7	22.9	56.4	21.2	45.8	22.7

Results for the refumigated area agreed remarkably well with those for the middle density of the previously unfumigated area. The seedlings showed no pronounced root-rot infection, and plantable production was unaffected by fumigation. As before, about onehalf of the total production was plantable.

Survival

In plantings on the Lakeland loamy fine sand, Vapam fumigation of nursery beds lowered survival 20 percent for seedlings from refumigated soil and 6 percent for stock from previously unfumigated soil (table 4).

TABLE 4.--Effect of nursery soil fumigation and bed density on outplanting survival of slash pine on two sites

Treatment	Bed density per square foot	Outplanting survival	
		Bowie sandy loam	Lakeland loamy fine sand
	Number	*Percent*	*Percent*
Previously unfumigated soil:			
Methyl bromide	30	99	86
	45	99	84
	60	95	80
	Av.	98	83
Vapam	30	89	83
	45	96	81
	60	97	81
	Av.	94	82
Dowfume W-85	30	95	74
	45	95	70
	60	94	79
	Av.	95	74
Shell D-D	30	97	84
	45	96	86
	60	95	82
	Av.	96	84
Check	30	98	89
	45	97	89
	60	97	87
	Av.	97	88
Refumigated soil:			
Methyl bromide	45	94	84
Vapam	45	97	67
Dowfume W-85	45	90	78
Shell D-D	45	93	84
Check	45	99	87

Corresponding depressions for Dowfume W-85 were 9 and 14 percent. Survival of other seedlings was not markedly different from that of the checks, which averaged 88 percent on this site. The poorer survivals with Dowfume W-85 and Vapam are not readily explained. Nevertheless, caution is recommended against the use of these fumigants if seedlings are to be planted on droughty sites.

Seedling survival on the Bowie very fine sandy loam was excellent--90 percent or above--and was not affected by nursery fumigation.

Nursery bed density had no prominent effect on field survival of seedlings from any of the fumigation treatments.

Conclusions

The test demonstrated that large-scale fumigation of nursery soil is practical and feasible. All fumigants controlled root diseases in an area seriously infected with root rot, thus increasing yields of plantable seedlings. Their effects on field survival and on weeds varied. When all factors are considered, methyl bromide was the best multipurpose fumigant and Shell D-D was the best nematocide. The others were inferior because they depressed field survival on the droughty site. Vapam was also less dependable than methyl bromide as a herbicide.

The results suggest that a nurseryman should isolate problem areas before fumigating and should choose a fumigant for his particular needs. Of the four included in the test, Shell D-D should be used if only nematodes and root rots are present. Methyl bromide should be selected if annual handweeding costs are about equal to the cost of fumigation less the cost of controlling nematodes and root rots by cheaper methods. The latter conclusion is predicated on growing two crops of seedlings following fumigation and assumes a substantial carryover value. Both assumptions are logical. Successive crops of quality seedlings were produced in the area fumigated with methyl bromide in 1958. Moreover, beds that were fumigated with methyl bromide in 1958 and received no additional herbicidal treatment required only 36 to 40 percent as much hand weeding in 1959 as areas that were unfumigated in both years.

Costs of fumigation with methyl bromide vary. They amounted to $800 per acre in this study. However, Foster (3) reported costs of $300 to $350 per acre in Georgia when larger areas were treated and less gas was used. This amounts to about $400 per acre for the 435-pound rate. Fumigation with Shell D-D cost about $60 per acre in this test. Thus, a savings in weeding of at least $340 per acre may be expected if methyl bromide is to be used.

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