Improving Seedling Growth in Longleaf Pine Plantations with Nematicidal Soil Fumigants

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Abstract: In-row, preplanting fumigation with DD and DBCP in a longleaf pine plantation was evaluated for nematode control, improved seedling survival, and early and uniform release of seedlings from the grass stage. Only DD significantly lowered the nematode population during the first growing season. DBCP not only failed to control nematodes, but was phytotoxic. Fumigation had little effect on seedling survival. Seedlings in rows fumigated with DD started height growth earlier and produced taller trees after 5 years than those in nonfumigated rows.

Longleaf pine (*Pinus palustris* Mill.) is native to many dry, sandy areas in the southeastern United States. Yet because of its failure to grow rapidly in the early seedling stage and the difficulties in planting seedlings with long and well-developed root systems, many of these sites have been regenerated with slash (*P. elliottii* var. *elliottii* Engelm.) and loblolly (*P. taeda* L.) pine. Longleaf, however, remains an important pine species in southern woodlands because its yield potential is greater than that of either slash or loblolly (5). It is also rarely infected by southern fusiform rust and is especially resistant to fire (3, 7). Throughout the South, many areas are especially suitable for the growth of this pine species; and, if regeneration problems can be solved, longleaf may return to popularity.

The machine planting of longleaf seedlings in special containers, a technique which may overcome the difficulties of planting seedlings with long roots, is now being tested (1). Research is also underway into the causes for lack of early height growth in longleaf seedlings, some of which remain in the grass stage from 3 to 5 years. Brown spot disease, caused by the fungus *Scirrhia acicola* (Dearness) Siggers, is prevalent in natural longleaf areas, particularly in the Gulf states. When this disease is severe, seedlings may stay in the grass stage more than 10 years (6). First-year mortality of longleaf is usually higher than that of slash or loblolly pine; and, in areas where height growth is delayed, annual mortality continues to be high (7).

Nematodes may also be responsible for the delay in height growth in planted longleaf seedlings. Ruehle and Sasser (4) reported that longleaf grew better when DD (dichloropropane-dichloropropene), a standard agricultural nematicide, was applied in the plantation row prior to planting. The percentage of longleaf seedlings which exhibited early vigor and rapid height growth by the third growing season was higher in the fumigated than in the unfumigated rows.

This report deals with the effect of soil fumigation with nematicides on the survival and early release of longleaf seedlings from the grass stage. Two nematicides were tested: DD and DBCP (1,2-dibromo-3-chloropropane). The work was based on the assumption that the first growing season is the most critical for seedling establishment and survival of longleaf pine, as is the case for loblolly pine (8). The assumption was also made that nematodes damage the fine feeder roots of pine seedlings and that, consequently, nematicidal soil treatment should reduce root losses. In soils infested with parasitic nematodes, longleaf seedlings

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FIG. 1. Planting machine adapted for row fumigation with liquid nematicides. A.—Planter attached to crawler tractor. Note regulated flow tank on top of planter cab. B.—Inside view of planter. Note placement of flow tube from fumigant tank behind planting blade.

planted in fumigated rows should develop larger and healthier root systems than those in unfumigated rows during the critical first year.

The objectives of this study were to determine: (i) if nematicidal fumigants improve seedling vigor and stimulate earlier release from the grass stage, (ii) if these

treatments increase seedling survival, and (iii) how well these fumigants control nematode populations in forest plantation sites.

Materials and Methods

A one-hectare planting site with deep sandy soil and natural woodland growth was selected in a typical longleaf area in south Georgia. This site was cleared and burned in November 1962, one month prior to soil treatment.

The plots were arranged in a random block design. Six blocks of five rows 3 m apart and 46 m long were marked out in a paired linear arrangement, each block having border rows on both sides. On each block, five treatments, one to each of the five rows, were applied as follows: (i) DD at the rate of 37.3 liters per hectare (4 gal/acre) (DD low); (ii) DD at the rate of 65.4 liters per hectare (7 gal/acre) (DD high); (iii) DBCP 50-percent EC at the rate of 3.7 liters per hectare (0.4 gal/acre) (DBCP low); (iv) DBCP 50-percent EC at the rate of 6.5 liters per hectare (0.7 gal/acre) (DBCP high); and (v) no fumigant applied (check). The fumigants were applied in December 1962, 3 weeks prior to planting.

A regulated flow applicator was mounted on a tree planter with the output hose placed behind the planting blade (Fig. 1). The blade was adjusted to place the liquid fumigant in a continuous strip at a depth of 25 to 30 cm. The check rows were identically plowed, but fumigants were not applied.

A total of 1,500 seedlings, each larger than Wakeley's morphological grade one (7), were obtained from nursery stock grown at the Morgan Nursery, Byron, Georgia, in beds fumigated with methyl bromide. The seedlings had been root pruned three times in the summer and fall of 1962, and lifted and root pruned once more in January 1963.

Two days after lifting, the seedlings were hand planted on the test plots; 50 seedlings, spaced one meter apart, were planted in each row.

At the time of planting and at yearly intervals for the next 2 years, the stem diameter of each seedling was measured with calipers at a point just below the needle bundles. Following the second-year measurements, every other seedling was removed so that the trees on each block were spaced 1.8 by 3 m. Tree height, stem diameter and percentage of trees released from the grass stage were used to compare treatments each year thereafter through the fifth growing season.

Composite soil samples were taken in each row with a sampling tube before fumigation, at planting time, and 6 months, 1 year and 5 years after planting. The soil samples, each approximately 0.5 liter in volume, were assayed for nematodes using Jenkins' centrifugal-flotation procedure (2).

During the spring of the first two growing seasons, the seedlings were sprayed with ferbam (ferric dimethyl dithiocarbamate) to control brown spot. The ferbam was mixed at the rate of 2.4 g/liter (2 lb/100 gal) of water; and the suspension, which contained a spreader-sticker, was applied with portable hand sprayers at 6-week intervals three times each year during the first three years.

Results

Two years after planting, 10% more seedlings had started height growth in the rows fumigated with DD than in the check rows (Table 1). During this period DBCP at the high rate was detrimental: only 13.8% of the seedlings had started height growth, 10% less than the number in the check rows. After the third year, the number of seedlings starting height growth had increased in each of the fumigated and unfumigated rows, the means ranging from approximately 71 to 82%. The difference between the number

TABLE 1. Effect of fumigation on release of longleaf pine seedlings from the grass stage.

Years after planting	Percentage[a] of seedlings released after treatment with—				
	DD high	DD low	Check	DBCP high	DBCP low
2	33.5	33.7	23.5	13.8	20.0
3	82.3	82.1	75.8	71.8	75.0
5	86.6	82.0	82.9	81.7	77.0

[a] Based on surviving seedlings. Tally made after seedlings have been thinned to 25 per row.

of seedlings starting height growth in the check rows and those in the rows treated with high dosages of DD was only 6% after the third year and 4% after the fifth year. The detrimental effect of DBCP on initial height growth was no longer evident after the third year.

There was little or no difference between survival of seedlings in the rows fumigated with DD and that of seedlings in the check rows after the second year (Table 2). After the fifth year, survival of seedlings was 9 to 12% higher in rows fumigated with DD at the low rate or with DBCP at the low rate than in the check rows.

The seedlings in the rows treated with DD had a significantly greater ($P < .05$) increase in stem diameter after 2 years than did those in the check rows (Table 3). At that time, the increase in stem diameter of the seedlings treated with DBCP was not significantly different from that of the check seedlings. After 5 years, the seedlings treated with DD

TABLE 2. Effect of fumigation on survival of longleaf pine seedlings.

Years after planting	Percentage of seedlings which survived after treatment with—				
	DD high	DD low	Check	DBCP high	DBCP low
2[a]	77.7	85.3	82.0	18.0	73.7
5[b]	89.6	99.8	88.0	90.6	97.4

[a] Tally made before seedlings had been thinned (50 per row).
[b] Tally made after seedlings had been thinned (25 per row).

TABLE 3. Effect of soil fumigants on stem diameter and height growth of longleaf pine seedlings.

Treatment	Increase in *stem diameter* after 2 yr.	Height growth after 5 yr.
	(cm)	(m)
DD high	1.23^{ab}	1.82^{ab}
DD low	1.25^{a}	1.91^{a}
DBCP high	1.14^{bc}	1.57^{c}
DBCP low	1.10^{c}	1.71^{abc}
Check	1.05^{c}	1.67^{bc}

Means not followed by the same letter are significantly *different* ($P < .05$).

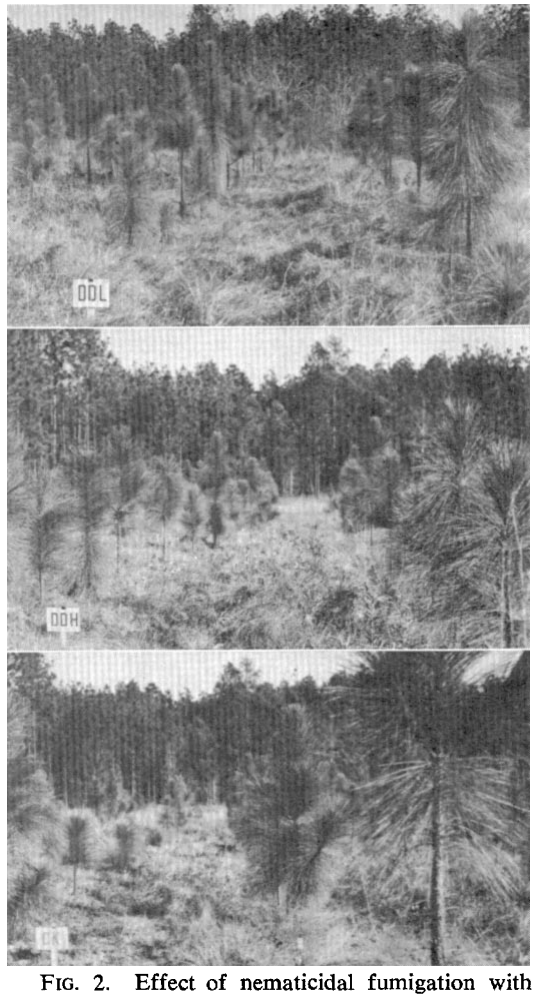

FIG. 2. Effect of nematicidal fumigation with high (DDH) and low (DDL) dosages of DD on the growth of longleaf pine seedlings after the fifth growing season.

were more uniform and generally exhibited better growth than those in the check rows (Fig. 2). However, measurements of height growth at that time showed that only the seedlings treated with DD at the low rate were significantly taller ($P < .05$) than the check seedlings (mean height difference, .24 m or .75 ft) (Table 3).

The most prevalent plant-parasitic nematodes collected from this area before fumigation were *Helicotylenchus* spp., *Criconemoides* spp., and *Xiphinema americanum* Cobb. Lower numbers of *Hoplolaimus galeatus* (Cobb) Thorne, *Trichodorus christiei* Allen, and *Hemicycliophora* sp., and trace amounts of *Scutellonema* sp., *Longidorus* sp., *Meloidodera* sp., *Pratylenchus* sp., and *Tylenchorhynchus claytoni* Steiner were also found.

Fumigation with DD gave the best nematode control (Fig. 3). Total counts of plant-parasites were significantly less ($P < .05$) at

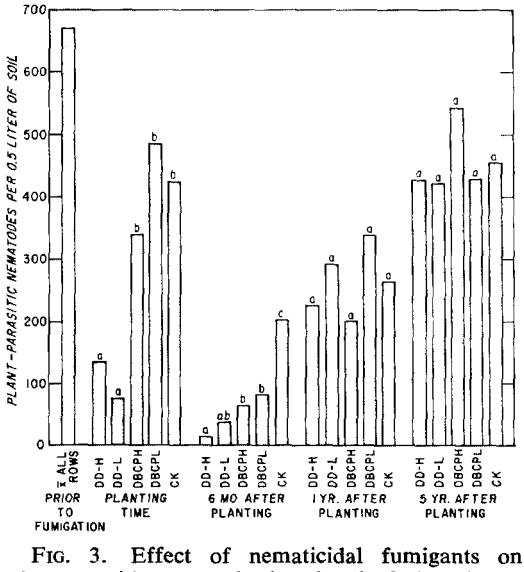

FIG. 3. Effect of nematicidal fumigants on plant-parasitic nematodes in a longleaf pine plantation. (Duncan's multiple range test was performed on $\sqrt{+.05}$ transformation of data, then the results were reconverted to actual means.) Within each group, bars not under the same letter are significantly different ($P < .05$).

planting time (3 weeks after fumigation) in rows treated with DD than in check rows or those treated with DBCP. Counts of nematodes after 6 months were significantly lower ($P < .05$) in fumigated rows (both DD and DBCP) than in check rows. There were no significant differences between treatments and checks after 1 and 5 years. Total numbers of plant-parasitic nematodes after 5 years had not yet reached the levels found prior to fumigation.

DISCUSSION AND CONCLUSIONS

Row fumigation with DD prior to planting stimulates the growth of longleaf seedlings and their early release from the grass stage. DBCP is unsuitable for use with pines because of its phytotoxicity. Seedling growth lacked uniformity in fumigated rows during the first 4 years because of brown spot infections. Foliar sprays with ferbam failed to control the disease.

Fumigation had little effect on survival. After 2 years, survival was only slightly less in the rows treated with either level of DBCP or with the high level of DD than it was in the rows treated with the low level of DD and in the check rows (4 to 11%). Residual fumigants at planting time may have affected survival.

Row fumigation with DD gave good nematode control during the first growing season. The general decline in nematode counts in all treated rows 6 months after planting was probably caused by hot, dry weather during July. Other sampling periods were in December and January when soil conditions were more favorable for nematode reproduction.

Although the improvement in seedling growth was not of sufficient magnitude to warrant a recommendation for the use of a nematicide like DD, it does suggest that continued research on the use of fumigants in longleaf plantations is desirable. Hope-

fully, a nonphytotoxic nematicide can be found or developed that will not require a delay between application and planting. To minimize costs, treatment should be applied at the time of planting.

LITERATURE CITED

1. BROWN, C. L. 1964. The place of longleaf pine in southern forest management. Forest Farmer 24:6–8, 16, 18–19. (December 1964)
2. JENKINS, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Pl. Dis. Rep. 48:692.
3. MUNTZ, H. H. 1954. How to grow longleaf pine. U. S. Dep. Agr. Farmers Bull. 2061, 25 p.
4. RUEHLE, J. L., and J. N. SASSER. 1962. The role of plant-parasitic nematodes in stunting of pines in southern plantations. Phytopathology 52(1):56–68.
5. SCHUMACHER, F. X., and T. S. COILE. 1960. Growth and yields of natural stands of southern pines. T. S. Coile, Inc., Durham, N. C. 115 p.
6. SIGGERS, P. V. 1944. The brown spot needle blight of pine seedlings. U. S. Dep. Agr. Tech. Bull. 870, 36 p.
7. WAKELEY, P. C. 1954. Planting the southern pines. U. S. Dep. Agr., Forest Serv., Agr. Monogr. 18, 233 p.
8. ZOBEL, B. J., and R. E. GODDARD. 1955. Preliminary results on tests of drought hardy strains of loblolly pine (*Pinus taeda* L.). Texas Forest Serv. Res. Note 14, 23 p.