Seedling Production and Pest Problems at a South Georgia Nursery

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Abstract

Pine seedling production and pest problems were evaluated in methyl bromide-fumigated and nonfumigated plots in two fields at a South Georgia nursery. In one field, fumigation increased loblolly pine seedling bed density in only 1 of 4 years. Seedlings were often significantly larger in fumigated than nonfumigated plots. In the other field, no differences were observed between treatments for bed densities or morphological characteristics. The primary pest problem in nonfumigated plots was nutsedge; most other weeds were controlled through the nursery's weed control program. Plant-parasitic nematode populations did not increase over time and were not viewed as a problem. *Macrophomina phaseolina* was rarely recovered from soil or roots. Although *Fusarium* spp. and *Pythium* spp. were more common in soil and on roots in nonfumigated than fumigated plots, evidence of disease was rare. At present, studies have not found isolates of *F. oxysporum* that are pathogenic to southern pines. A recent study conducted in a fallow field found that single and multiple applications of glyphosate were effective for control of nutsedge.

Key Words

Experimental design, research, bareroot nursery, container nursery, statistics, pest biology, fumigation, herbicides

Methyl bromide has been identified as an ozone-depleting chemical, and a complete phaseout of the production and consumption of this chemical is scheduled to occur by 2005 in accordance with the United States Clean Air Act and the Montreal Protocol (Environmental Protection Agency 1999). The loss of this chemical will require a better understanding of pest problems that affect pine production in southern nurseries and the development of alternative pest-management strategies. In the future, it is likely that nursery managers will have to rely on more complex integrated pest management programs that are based on information about the biology of the pests and a variety of strategies to provide for their prevention and control.

The Flint River Nursery (Byromville, GA) was established by the Georgia Forestry Commission in 1986. Since that time, fumigation with methyl bromide has been a standard practice for weed control and to ensure the elimination of possible soilborne pathogens and plant-parasitic nematodes. Studies have been underway at this nursery since 1995 to better understand the types and extent of pest problems that could adversely affect pine seedling production if fumigation with methyl bromide was not utilized, and to develop cost-effective means for pest control. In this paper, we present information on three studies that provide an initial framework for an integrated pest management program that could ultimately reduce dependency on fumigation. These studies include: 1) an evaluation of seedling production and pest problems in fumigated and nonfumigated soil in two fields; 2) results of pathogenicity tests of *Fusarium oxysporum* Schlecht. isolated from soil and roots; and 3) an evaluation of the effectiveness of glyphosate for the control of nutsedge.

Materials and Methods

Evaluation of seedling production and pest problems

The studies were established in two compartments at the Flint River Nursery in the spring of 1995. Compartment 8S (C8S) was regarded as a problem area because seedling losses were observed in this field in the late 1980's and early 1990's. The precise cause of the losses was not known, but disease due to fungi and nematodes was suspected. The field was removed from operational production and since then had not been fumigated. Compartment 4N (C4N) was being placed back into production in May of 1995 after being in cover crops for 2 years. Three blocks were used in C8S. Each block consisted of the area between two irrigation risers and consisted of six nursery beds. The blocks were divided evenly into two plots, and each plot was randomly assigned to either the "fumigation" or "no fumigation" treatment. Each plot was approximately 76 m long and 5 m (three planting beds) wide. Three plots were fumigated with methyl bromide/chloropicrin (67%/33%) (MBC) at 393 kg/ha in the spring of 1995; the other three plots were not fumigated. All plots were sown operationally with loblolly pine (*Pinus taeda* L.) seeds in early May of 1995. The study was repeated in the same plots in 1996, 1997, and 1998, with MBC reapplied in the spring of each year before sowing.

Three blocks were also used in C4N and plots were established as described for C8S. Plots were approximately 38 m long and 5 m (three planting beds) wide. Three of the plots were fumigated with MBC in 1995; the other three plots were not fumigated. The field was sown operationally with loblolly pine seeds. The study was repeated in 1996, but fumigated plots were not refumigated. All plots were sown with slash pine seeds in 1996.

All seedlings were grown under operational conditions. Standard weed control practices included presowing applications of fomesafen (REFLEX®) and oxyflourfen (GOAL®) and weekly applications of oxyflourfen after the seedlings were 6 weeks old until approximately the middle of August.

Seedling measurements and samples were obtained from the center bed in each study plot. Three permanent history subplots, each 0.3 by 0.6 m, were randomly established in each plot immediately after seed sowing in order to monitor and evaluate seedling bed density. Live and dead seedlings were normally counted at 7 to 10 day intervals during the first 6 to 8 weeks after planting. A final assessment was conducted during the fall of each year. Morphological characteristics (root collar diameter, shoot height, and shoot and root weight) were evaluated in the fall or winter following seed sowing. For this study, only the root collar diameter will be presented and discussed. Each year, seedlings were lifted from three 0.3- by 0.6-m sample plots selected at random locations over the length of each plot. Morphological characteristics were measured on 20 to 75 seedlings per plot each year.

Pine root systems were evaluated yearly at mid-season (July-August) and at the end of the growing season (October-November) for species of *Pythium*, *Fusarium*, and other potentially pathogenic fungi using several selective media (Kannwischer-Mitchell and others 1994). The number of colony forming units (CFUs) of *Fusarium* spp. present in fumigated and nonfumigated soil was assessed immediately after fumigation in May of 1995 and again in May of 1998. The presence of the charcoal root rot fungus, *Macrophomina phaseolina* (Tassi) Goid. in soil was assessed (Kannwischer-Mitchell and others. 1994) on all plots in 1995 prior to fumigation, just after fumigation, and at the end of the season. When observed, samples of dead and dying seedlings were collected, examined, and plated on agar media to determine fungal associations.

Nutsedge (*Cyperus* spp.) plants were counted at least once yearly during 1995, 1996, and 1998 on the three 0.3 by 0.6-m permanent history subplots in each treatment plot. Plant-parasitic nematodes were assessed twice yearly during the growing season in all treatment plots in C8S. Nematodes were only assessed in 1995 in C4N. Nematodes were either extracted from soil using the centrifugal-flotation technique (Hooper 1986) and evaluated to genus, or soil samples were processed by the Cooperative Extension Services at the University of Georgia.

Pathogenicity Tests

Isolates of *F. oxysporum* obtained from roots and soil were tested for pathogenicity to pine seedlings grown in containers in a growth chamber at 22 to 24 °C. Inoculum was produced by growing the *Fusarium* isolates on sterilized wheat grains for 14 to 28 days. Four grams of the inoculum were ground and mixed thoroughly with 1,000 grams of nursery soil that had been microwaved to eliminate potential pathogens. Five germinated loblolly or slash (*Pinus elliottii* Engelm. var. *elliottii*) pine seeds were planted in each container. Three containers (15 seedlings total) were used for each fungal isolate and pine species. In order to ensure that pathogenicity could be detected with our system, we also tested isolates of *F. subglutinans* (Wollenw. & Reinking) Nelson, Toussoun & Marasas f. sp. *pini* known to be pathogenic to pine. These isolates had been obtained from contaminated longleaf pine (*P. palustris* Mill.) seeds and diseased longleaf pine seedlings. Six sets of control containers, each set consisting of three containers (18 total containers), were established for each pine species. Soil in control containers was mixed with ground, sterile wheat grains and planted with germinated pine seeds as previously described. Some mortality was observed in control containers and often varied with the experience level of the individual setting up the test. This mortality was most likely due to injury to seedlings that occurred during their transplanting from germination containers.

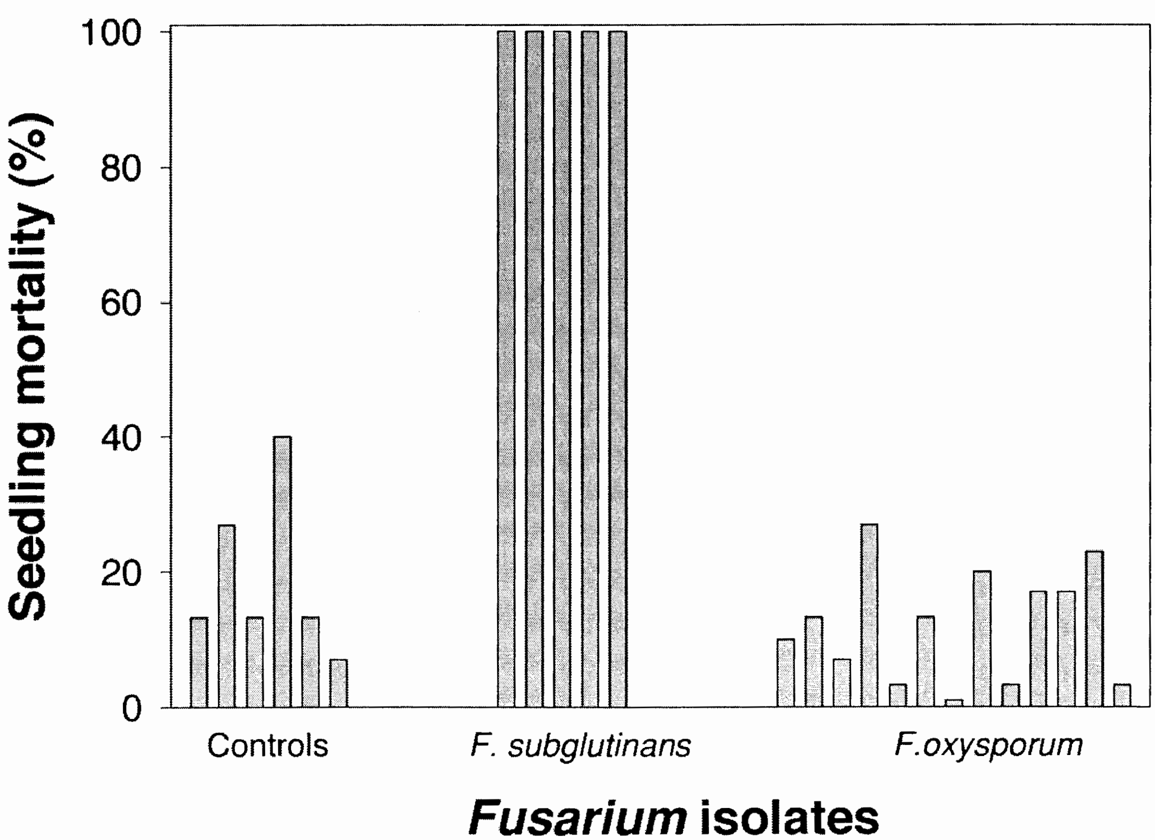

Figure 1. Percentage of seedling mortality in pathogenicity tests of isolates of Fusarium oxysporum *and* F. subglutinans *f. sp* pini. *Each bar represents percent mortality associated with one isolate and is based on results with 30 seedlings (15 slash pine, 15 loblolly pine) in 6 containers (5 seedlings/container) for each isolate.*

Nutsedge control with glyphosate

The effect of repeated glyphosate applications on nutsedge plants was examined during 1999. A 3.7-ha field was left fallow in spring of 1999. The field had been previously fumigated in 1995; however, nutsedge had recolonized throughout this field since that time. Purple nutsedge (C. *rotundus* L.) was the primary species in this field, although yellow nutsedge (C. *esculentus* L.) was also noted. The field was divided into 12 plots each approximately 213 m long by 10 m wide. Plots were randomly assigned to one of four treatments that consisted of glyphosate applications applied zero, one, two or three times during the growing season. Glyphosate was applied at 4.65 L/ha to plots on the following schedule: one application-14 June; two applications -14 June and 2 September; and three applications-14 June, 2 September, and 14 October. Originally the spray schedule was to be at 6-week intervals, but this schedule had to be modified due to drought and water shortages during the summer of 1999. The number of nutsedge plants was counted on six 0.3- by 0.6-m subplots per treatment plot on 20 October 1999 and again on 22 March 2000. At the October evaluation, soil was excavated from three 0.3- by 0.6-m subplots to a 15-cm depth and sieved to extract nutsedge tubers. Tubers were counted and treated to induce sprouting using the technique of Teo and Nishimoto (1973). Tubers were placed in germination boxes with moistened germination paper, and the percentage of sprouted tubers was evaluated after 2 weeks.

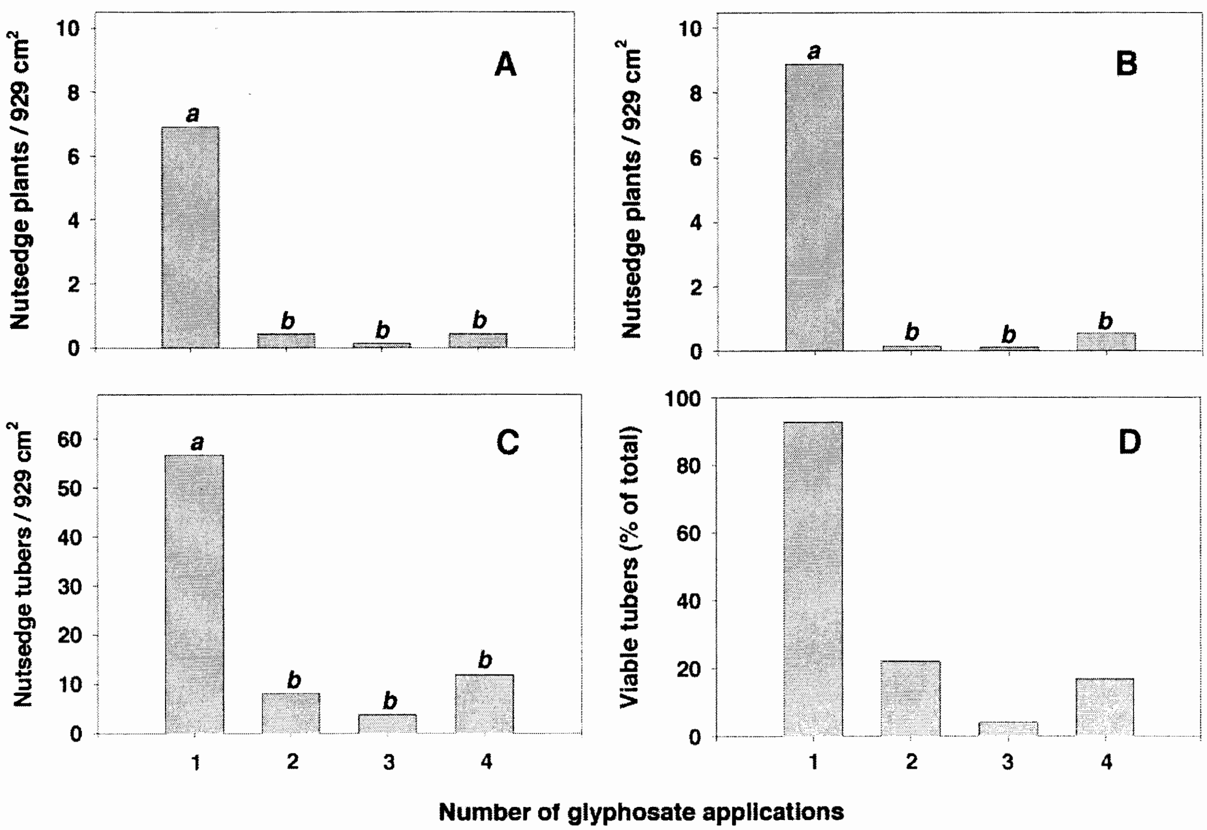

Figure 2. Evaluation of glyphosate for nutsedge control in a fallow field during 1999 with zero, one, two or three applications of herbicide. Effects of glyphosate on (a) *number of plants per 929 cm^2 on 20 October 1999,* (b) *number of plants per 929 cm^2 on 22 March 2000,* (c) *number of tubers per 929 cm^2 collected on 20 October 1999, and* (d) *percentage of viable tubers collected on 20 October 1999. Glyphosate was applied at 4.65 L/ha (2 qts/A) to plots on the following schedule: one application - 14 June, two applications - 14 June and 2 September, and three applications - 14 June, 2 September and 14 October.*

Discussion

Reductions in seedling bed densities or root collar diameters were noted in nonfumigated plots in C8S during most years, but no differences were noted in seedling quantity and quality between fumigated and nonfumigated treatments in C4N. The need for fumigation to prepare for seedling production can be questioned in the latter field.

Table 1. Mean number of loblolly pine seedlings per 929 cm^2, root collar diameter, and mean number of nutsedge plants per 929 cm^2 in methyl bromide-fumigated and nonfumigated plots in Compartment 8S at the Flint River Nursery during 1995, 1996, 1997, and 1998.

Year	Treatment	Seedlings/ 929 cm^2		Root Collar Diameter (mm)		Nutsedge Plants/ 929 cm^2	
1995	Fumigation*	25.6	a†	4.4	a	0.6	a
	Control	25.4	a	3.4	b	14.9	b
1996	Fumigation	24.4	a	4.1	a	0	a
	Control	20.0	b	4.0	a	16.4	b
1997	Fumigation	28.0	a	4.3	a	-	
	Control	26.6	a	3.4	b	-	
1998	Fumigation	23.1	a	5.6	a	0	a
	Control	23.6	a	5.2	a	22.3‡	b

* Plots were fumigated yearly in March or April.

† Means within year followed by a different letter differ at the $P \leq 0.1$ level.

‡ Measurement was made in May 1998. Nutsedge appeared chlorotic with some foliar dieback. Symptoms became progressively worse through May and June. In July 1999, the mean number of living nutsedge plants was only 5.4 per 929 cm^2.

Table 2. Mean number of pine seedlings per 929 cm^2, root collar diameter, and mean number of nutsedge plants per 929 cm^2 in methyl bromide-fumigated and nonfumigated plots in Compartment 4N of the Flint River Nursery during 1995 and 1996.

Year	Treatment	Seedlings/ 929 cm^2		Root Collar Diameter (mm)		Nutsedge Plants/ 929 cm^2	
1995*	Fumigation†	26.3	a‡	4.1		0.1	a
	Control	27.4	a	4.1§		2.2	b
1996	Fumigation	24.9	a	4.3	a	0.7	a
	Control	23.9	a	4.4	a	3.6	b

* Loblolly pine grown in 1995 and slash pine in 1996.

† Plots were fumigated only once in April of 1995.

‡ Means within year followed by a different letter differ at the $P \leq 0.1$ level.

§ One nonfumigated plot operationally lifted before final end-of-year evaluation.

The lower number of loblolly pine seedlings in nonfumigated compared to fumigated plots in C8S during 1996 may have been due to pre-emergence damping-off, although we do not have direct evidence for this. Seeds sown at the nursery were routinely treated with thiram, and a captan soil drench was applied at the time of sowing; both treatments are effective in controlling damping-off (Hodges 1962). In addition, differences between treatments were not observed in subsequent years. Although damping-off is one possible explanation for the observed difference in 1996, it is not inconceivable that some variation in sowing rate may have occurred among plots that could have contributed to the observed difference.

Competition from nutsedge was the most likely cause of the reductions in the size of loblolly pine seedlings. The lack of differences in size of seedlings between treatments in 1998 may have been related to the chlorosis, stunting, and eventual premature dieback of nutsedge plants during the spring and summer. We cannot explain the cause of the nutsedge decline. Personnel at the nursery indicated that they used fomesafen operationally in all pine beds as they had in previous years. Fomesafen is known to control yellow nutsedge but is not listed as effective on purple nutsedge. No effects of this herbicide on nutsedge had been observed in the 3 years prior to 1998, although nursery personnel indicated that the herbicide had provided control of nutsedge in other fields prior to initiation of this study. Nursery records indicated that no other herbicides except oxyflourfen were used in this field.

The lack of significant pest problems other than nutsedge in this study was somewhat unexpected. Nursery personnel thought the study area in C8S experienced nematode and soilborne disease problems in the past, and through continuous production of pines, these problems were expected to develop. This was not the case. Routine fumigation with methyl bromide has been regarded by many managers as essential for the prevention of soilborne diseases (Cram and Fraedrich 1996; Fraedrich and Smith 1994), but throughout this and other recent studies (Barnard and others 1996; Carey 1996; Carey 1998) there has been little evidence of soilborne diseases in nonfumigated areas. Considerable changes have occurred in forest-tree nursery operations since nurseries first began using methyl bromide fumigation in the post World War II era. Since that time, highly selective and effective herbicides have been developed (South 1979; South 1986). In addition, newer nurseries have been placed on sites with soils that are better drained and sandier textured than nurseries in the past (Boyer and South 1984). Many other changes have occurred with respect to practices such as types of cover crops used, seed quality, and fertilization (May 1980; Wakeley 1954). Together, these changes may have reduced the presence of pathogenic soilborne fungi, enhanced seedling growing conditions, and reduced the susceptibility of seedlings to many of the opportunistic soilborne pathogens that caused seedling losses in the past.

Nutsedge is a common weed problem in many southern forest-tree nurseries (Cram and Fraedrich 1996; Fraedrich and Smith 1994). Nutsedge has also been the primary pest problem in many studies that have examined alternatives to methyl bromide (Carey and South 1999; Dwinell and Fraedrich 1998; South and others 1997). Several studies have demonstrated the efficacy of glyphosate for nutsedge control in agricultural fields (Cools and Locascio 1977; Zandstra and others 1974). South (1984) indicated that glyphosate was effective for eradication of nutsedge in fallow fields. In our test at the Flint River Nursery, glyphosate proved very effective for nutsedge control in a fallow field that had been fumigated in recent years but where nutsedge had become reestablished. As noted in a study by Zandstra and Nishimoto (1977), glyphosate not only killed aboveground portions of purple nutsedge plants, but many tubers as well. Where fields can be left fallow for a summer, the use of glyphosate may provide a cost-effective alternative to routine fumigation with methyl bromide. The use of glyphosate in nutsedge-infested areas that border production fields may also help to reduce the rate of reintroduction of this weed into seedbeds.

Fusarium oxysporum has long been implicated in damping-off and root rot problems of pine in the South (Hodges 1962) and elsewhere in the United States (James and others 1991; Juzwik and others 1999). *Fusarium oxysporum* is commonly isolated from asymptomatic roots of crop plants, and nonpathogenic strains can be aggressive root colonizers (Gordon and Martyn 1997). Research in western North America has indicated that there may be pathogenic and nonpathogenic strains of *F. oxysporum* in soils at conifer nurseries (Bloomberg 1976). In our studies at the Flint River Nursery, *F. oxysporum* was frequently isolated from soil and roots of seedlings, but at this time we have been unable to document the presence of pathogenic strains of this fungus. More needs to be learned about the biology of *Fusarium* spp. that occur in southern pine nurseries and their potential for causing disease losses.

The development of integrated pest management programs in the future will require specific knowledge of the pest problems that affect seedling production at any particular nursery, precise information on factors that affect the development of these problems, and knowledge about practices to prevent and control them. While weed control is possible in nurseries through an integrated program that does not rely on fumigation (South 1979), no such claims can presently be made for control of soilborne diseases and nematodes. Although research on finding cost-effective alternatives to fumigation for weed control have been constant since the 1970s, research on soilborne diseases and nematodes declined greatly. This may be due, in part, to a philosophy of research organizations that soilborne disease and nematode problems in nurseries were a low priority because most nurseries routinely fumigate with methyl bromide. With the pending loss of methyl bromide, the shortsightedness of this philosophy is now apparent. Managers that have employed fumigation routinely since the establishment of their nurseries may not be aware of the potential for disease and nematode problems at their location. In the short time that remains before methyl bromide is withdrawn from use, it is imperative that managers acquire information on the potential for disease and nematode problems at their nursery. Through these efforts a manager can better determine which pesticides will be needed in the future, evaluate the frequency at which they will be needed, and determine the timing at which they will be most effective. One method to gain this experience is to establish nonfumigated, control plots in fields that are to be fumigated. However, it is imperative that weed problems be considered in advance and the best possible weed management practices be utilized for nutsedge and other difficult-to-control weeds before plot establishment.

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