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Survival and Growth of Peach Trees Planted in Killed Bahiagrass at an Old Orchard Site

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Abstract. **More peach *[Prunus persica* (L.) Batsch.] trees survived when planted in killed bahiagrass *(Paspalum notatum* Flugge 'Paraguayan-22') sod growing between previous orchard tree rows (98%) than when planted in previous tree sites (81%) or in previous tree rows, but halfway between previous tree sites (79%). The previous orchard was removed Nov. 1986, and new trees were planted Feb. 1987. Surviving trees in the killed sod grew better than trees at the other two sites. Tilling the sites before planting did not affect nematode populations or tree survival and growth. Soaking the tree roots in a fenamiphos solution (1 g·liter^{-1}) for 20 minutes before planting resulted in 79% tree survival vs. 93% survival for the nonsoaked trees. Fenamiphos sprayed under the trees at a rate of 11.2 kg·ha^{-1} during the spring and fall of the planting year did not change nematode populations, tree survival, or tree growth. The fenamiphos sprays reduced the increase in trunk cross-sectional area by 3 cm^2 for trees in the sod. Other than leaf Zn concentration, which was low, concentrations of the elements were within the sufficiency range for Georgia for all treatments. Trees planted in the killed sod had an increased leaf K concentration and decreased leaf Mg concentration when compared with trees planted in the rows. Chemical name used: ethyl 3-methyl-4-(methylthio)phenyl (1-methylethyl)phosphoramidate (fenamiphos).**

Peach tree short life (PTSL) and other soil-related problems such as oak root rot *[Armillaria mellea* (Vahl.) Quel. and *A. tabescens* (Scop.) ex. Fr.] or crown gall *[Agrobacterium tumefaciens* (E.F. Sm. and Town.) Conn.] tend to increase each time peach trees are planted at a site (Brittain and Miller, 1978; Carter and Bertrand, 1989; Nesmith et al., 1981). Preplant fumigation (Sharpe et al., 1989; Zehr et al., 1982) or postplant nematicide treatment (Ritchie and Bennett, 1985; Zehr et al., 1982) may prevent these problems. Preplant fumigation is expensive because of chemical costs and the extensive land preparation required for effective treatment. Postplant nematicides, which must be applied several times each year, are often ineffective, possibly because of variations in rainfall immediately after application (Bertrand and Nyczepir, 1989; Evert et al., 1992). Also, many fumigants and nematicides have been banned or are being reviewed by the U.S. Environmental Protection Agency. Peach industry survival in the southern United States may depend on controlling soil-borne pathogens biologically to increase orchard life.

Peach trees planted in killed fescue *(Festuca arundinacea* Schreb.) survive and grow well in cool climates (Glenn and Welker, 1989; Hogue and Neilsen, 1987; Welker and Glenn, 1985, 1988, 1989). Fescue sods, however, are not adapted to warm southern climates. Bahiagrass and bermudagrass *[Cynodon dactylon* (L.) Pers.] are adapted to warm climates. Both grasses are poor hosts or nonhosts of root-knot nematodes and most other nematodes that parasitize peach tree roots (Evert and Bertrand, 1987; Evert et al., 1992; McGlohon et al., 1961). Peach trees are severely stunted when planted in living bermudagrass (Weller et al., 1985) or bahiagrass (Evert et al., 1992). Bermudagrass may have an allelopathic effect on peach trees, according to Weller et al. (1985), who reported that competition for nutrients does not alone explain the reduced tree growth caused by bermudagrass. Bermudagrass also spreads rapidly (Horowitz, 1972), a characteristic that makes it undesirable in an orchard. We have observed that bahiagrass spreads more slowly than bermudagrass and that bahiagrass sods in peach orchards are generally free of most other plants, including bermudagrass. To our knowledge, survival and growth of peach trees planted in killed bahiagrass sod have not been reported.

Soaking peach roots in a nematicide solution before planting may be an alternative to preplant fumigation. Soaking the roots of *Cornus florida* (L.) in a fenamiphos solution before planting reduced populations of *Meloidogyne incognita* (Kofoid and White) Chitwood and increased tree growth (Johnson et al., 1970). Soaking tree roots in a nematicide solution before planting should use less nematicide and release less nematicide into the environment than soil applications.

In this study, nematode populations and peach tree survival, growth, and leaf mineral concentrations were measured after soaking tree roots in a fenamiphos solution and tilling the site before planting, applying fenamiphos after planting in the spring and fall, and planting trees in killed bahiagrass sod and herbicide-treated tree rows.

Soil at the orchard site in Brooks County, Ga., consisted of Dothan loamy sand (0-0.5 m) over sandy clay loam (fine-loamy, siliceous, thermic Plinthic Paleudults) (Calhoun, 1979). Two previous peach orchards had been planted at this site. The first orchard had been planted with an unknown peach cultivar and rootstock that was >8 years old when removed in Aug. 1979. The second orchard had been planted in Jan. 1980 with 'Flordagold' peach trees on Nemaguard seedling rootstocks and removed by 15 Nov. 1986. 'Paraguayan-22' bahiagrass, which had been seeded Mar. 1980, covered the entire orchard floor except the 2.4-m-wide herbicide-treated tree rows.

Preparation for the third orchard began 15 Nov. 1986. *N*- (phosphonomethyl)glycine (glyphosate) was sprayed at 2.2 kg·ha^{-1} to kill 1.8-m-wide strips of sod growing perpendicular to the previous orchard rows. New planting sites, which were 2.8 m apart in the strips, were subsoiled and cross-subsoiled on 15 Dec. 1986.

The experiment was a split-plot design with main plots in randomized complete blocks with six replications. Main plots received factorial combinations of the following treatments: preplant tilled sites vs. nontilled; roots soaked 20 min in a water solution of fenamiphos at 1 g·liter^{-1} before planting vs. nonsoaked; and fenamiphos sprayed at 11.2 kg·ha^{-1} under the trees on 19 Mar. and 5 Nov. 1987 after planting vs. nonsprayed. Split plots had individual trees in the following locations: the killed sod halfway between the previous tree rows, in tree rows at previous tree sites, and in

Table 1. Tree survival and increase in trunk cross-sectional area (ITCSA) on Nov. 1987, the end of the first summer, and fresh weight of the canopies of live trees on 7 Oct. 1988, near the end of the second summer, in response to postplant fenamiphos sprays (11.2 kg·ha^{-1} on 19 Mar. and 5 Nov. 1987) and to tree location relative to previous orchard trees.

Treatment	Survival (%)	ITCSA (cm^2)	Tree canopy fresh wt (kg)
Fenamiphos (F) sprayed under trees			
No	89 a[z]	9.3 a	11.7 a
Yes	83 a	8.5 a	11.2 a
Tree location (L)			
Middle of sod	98 a	10.6 a	14.0 a
Row, between trees	79 b	9.0 b	11.0 b
Row, at a tree	81 b	7.1 c	9.4 b
Significance (P = 0.05)	---	F × L	---

[z]Letters within a main effect show significance at P = 0.05 with t test.

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Table 2. Increased trunk cross-sectional area (ITCSA) for combinations of postplant fenamiphos applications (11.2 kg·ha⁻¹ on 19 Mar. and 5 Nov. 1987) and of tree location relative to previous orchard trees.

Tree location	Fenamiphos No	Fenamiphos Yes
	ITCSA (cm^2)	
Middle of sod	12.1 a[z]	9.1 b
Row, between trees	9.0 b	9.0 b
Row, at a tree	6.6 c	7.6 bc

[z]Letters show significant differences at $P = 0.05$ with *t* test.

tree rows halfway between the previous tree sites. The trees, 'Empress' on Lovell seedling rootstock, were planted on 11 Feb. 1987.

Fertilizer (10N-4.3P-8.3K) was broadcast at 513 $kg \cdot ha^{-1}$ on 3 Feb. 1987. After planting, each tree was hand-fertilized with 227 g of 16N-0P-0K on 26 June 1987 and 114 g of 33N-0P-0K on 6 July 1988. Leaf samples collected 12 Aug. 1988 were analyzed for N, P, K, Ca, Mg, Mn, Fe, Al, B, Cu, and Zn by the Soil Testing and Plant Analysis Laboratory, Univ. of Georgia Cooperative Extension Service, Athens. Herbicide applications maintained a 1.8-m-wide weed-free strip centered between the trees. *N,N*- diethyl-2-(1-naphthalenyloxy)propanamide (napropamide) was applied on 12 Feb. 1987 at 4.5 $kg \cdot ha^{-1}$ to suppress seed germination. *(R)* -2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propanoic acid (fluazifop-P) was applied in Mar. 1987 at 0.6 $kg \cdot ha^{-1}$ to kill any grasses missed by the glyphosate application in Nov. 1986. 1,1'-Dimethyl-4,4'-bipyridinium ion (paraquat) was applied at 0.6 $kg \cdot ha^{-1}$ as needed to control weeds for the rest of the experiment.

Nematode population densities were determined by the Nematology Laboratory, Univ. of Georgia Cooperative Extension Service, Athens, using Jenkins' (1964) procedure. Nematodes identified were *Criconemella xenoplax* (Raski) Luc. and Raski, *C. ornata* (Raski) Luc. and Raski, *Helicotylenchus* and *Scutellonema* spp. combined, *Hoplolaimus* spp., *Meloidogyne* spp., *Parathrichodorus christiei* (Allen) Siddiqi, *Pratylenchus* spp., *Tylenchorhynchus claytoni* (Steiner), and *Xiphinema* spp. In Nov. 1986, soil samples were collected from the top 0.3 m of soil in each of the 24 tree rows and the 24 adjacent sod middles of the previous orchard. On 19 Mar. and 6 Nov. 1987, soil samples were collected under each tree in the experimental orchard 1 day before each fenamiphos application.

The increase in trunk cross-sectional areas (ITCSA) was calculated for each tree by measuring trunk diameter at budbreak on 10 Mar. 1987 and at leaf fall on 30 Nov. 1987 at a height of 0.15 m. Tree death was evaluated on 30 Nov. 1987. Tree canopies were cut off at the ground and weighed on 7 Oct. 1988.

The Statistical Analysis System computer program PROC GLM was used for all data analyses except tree survival, for which PROC CATMOD was used (SAS Institute, 1985). Nematode population count data were log-transformed to stabilize the variance in the data analyses. Means of transformed data were back-transformed for presentation.

Soaking the peach tree roots in a fenamiphos solution before planting caused 21% of the trees to die before 1 June 1987 vs. 7% of the nonsoaked trees. No trees died during the rest of the experiment. The same fenamiphos treatment improved growth of *Cornus florida* (Johnson et al., 1970); thus, peach tree roots seem to be more sensitive to fenamiphos than those of *C. florida*. Data for the preplant fenamiphos treatment were excluded from the rest of the analyses because the treatment killed so many trees. Preplant tillage will not be discussed in detail because the only response to preplant tillage was a minor decrease (0.1 $g \cdot kg^{-1}$) in leaf P concentration. Tree survival at the end of the first growing season was independent of postplant fenamiphos application (Table 1). Tree survival varied with tree location. Almost all of the trees in killed bahiagrass sod were alive after the first growing season (Table 1); this survival rate was ≈20% larger than that of trees between previous tree sites in tree rows, or trees in previous orchard tree sites. The survival rate did not vary between the two sites within the previous orchard tree rows. Each treatment influenced tree survival independently of the other treatments.

ITCSA varied with tree location, but the effect of location also varied with postplant fenamiphos applications (Table 1). ITCSA was largest for trees planted in the middle of the killed bahiagrass and not sprayed with fenamiphos after planting (Table 2). Spraying fenamiphos under the trees in killed bahiagrass decreased ITCSA by 3 cm^2 (25%) but produced no changes at either of the tree sites in the previous orchard tree rows. The trees in killed bahiagrass had a 27% higher canopy fresh weight than those located halfway between trees in previous orchard tree rows (Table 1). The canopy weights at the end of the second growing season show that the benefits of planting in killed bahiagrass sod extend beyond the first growing season.

In Nov. 1986 before the experiment began, populations of three nematode species between the tree rows differed from those in the previous orchard sod (Table 3). The higher populations of *Helicotylenchus* and *Scutellonema* spp. in killed sod than in tree rows are consistent with the report that these nematodes seldom damage peach trees in the southeastern United States (Bertrand and Nyczepir, 1989). The low populations of both *Criconemella* species in the sod show that 'Paraguayan-22' bahiagrass is a poor host of *C. ornata*, a grass-feeding nematode (Ratanaworabhan and Smari, 1970), and nearly a nonhost of *C. xenoplax*, the nematode implicated in PTSL (Nesmith et al., 1981; Nyczepir, 1983). Others have found lower populations of *C. ornata* in bahiagrass sod than in herbicide-treated tree rows (Evert et al., 1992). Common bermudagrass, which is a host of *C. ornata* (Nyczepir et al., 1988), was the principal weed in the previous orchard tree rows. Bermudagrass aggressively invades herbicide-treated tree rows, while 'Paraguayan-22' bahiagrass sod does not.

Some of the Nov. 1986 soil samples had populations of three other nematode species: *Parathrichodorus christiei* (stubby-root), *Pratylenchus* spp. (lesion), and *Xiphinema* spp. (dagger). The maximum population of these nematodes in any sample was less than four, and the mean populations were independent of the treatments.

Postplant fenamiphos sprays did not affect any of the nematode populations measured during the experiment (data not shown). The nematode populations were low on the three sampling dates, but populations of four nematode species varied with tree location (Table 3). Of these four, only *C. xenoplax* is known to parasitize peach roots, and *C. xenoplax* populations under trees in the killed sod were <5% of the populations under trees in previous orchard tree rows. *Xiphinema* spp., *Hoplolaimus* spp., and *Meloidogyne* spp. were present in low numbers (<0.2/150 cm^3 of soil), and the populations were independent of the treatments.

By Nov. 1987, populations of *C. ornata* and of *C. xenoplax* were independent of tree

Table 3. Nematode populations under peach trees at locations relative to previous orchard trees.

Tree location	*P. christiei* (stubby-root)	*H.* spp. and *S.* spp. (spiral)	*C. ornata* (ring)	*C. xenoplax* (ring)
		Nematodes/150 cm^3 of soil		
Nov. 1986 (before previous orchard removal)[z]				
Sod, middle	0.3 a[y]	7.1 a	0.4 b	0.0 b
Row, composite	0.1 a	0.3 b	1.8 a	1.1 a
19 Mar. 1987[x,w]				
Sod, middle	0.5 a	2.0 a	1.6 b	0.1 b
Row, halfway	0.1 a	0.1 b	5.4 a	2.2 a
Row, tree	0.1 a	0.0 b	2.3 ab	2.8 a
5 Nov. 1987[x]				
Sod, middle	1.4 a	2.4 a	2.7 a	0.1 a
Row, halfway	0.2 b	0.1 b	5.8 a	0.1 a
Row, tree	0.4 b	0.6 b	5.6 a	0.1 a

[z]Means from 24 soil samples taken in the sod middles and 24 soil samples taken under and between previous orchard tree rows.

[y]Letters within a main effect show significance at $P = 0.05$ with *t* test. Each mean on the two later dates is composed of 48 observations. Nematode populations were log-transformed for analysis and back-transformed for presentation.

[x]Nematode populations determined before fenamiphos was applied at 1.12 kg·ha⁻¹ to half the sites.

[w]None of the fenamiphos applications had any influence on the nematode populations.

Table 4. Leaf elemental concentrations on 12 Aug. 1988 by treatment.

Tree location relative to previous orchard trees	N	P	K	Mg	Mn	Zn
	(g·kg⁻¹ dry wt)				(mg·kg⁻¹ dry wt)	
Middle of sod	30.1 ab[z]	1.7 a	24.8 a	4.3 b	40 ab	12.9 a
Row, between trees	29.6 b	1.7 a	22.4 b	4.8 a	44 a	12.4 a
Row, at a tree	31.2 a	1.8 a	22.2 b	4.7 a	36 b	12.9 a
Sufficiency range for Georgia[y]						
From	27.5	1.2	15.0	2.5	20	15
To	35.0	5.0	25.0	5.0	150	50

[z]Letters within a main effect show significance at $P = 0.05$ with t test.
[y]Taken from Plank (1989).

site. Populations of *P. christiei* and the combined populations of *Helicotylenchus* spp. and *Scutellonema* spp. were highest in the killed sod. Nematode populations of *Meloidogyne* spp. and other nematodes present in low numbers on Mar. 1987 (data not shown) remained <0.2/150cm^3 of soil in Nov. 1987.

Leaf concentrations of N, K, Mg, and Mn varied with tree location (Table 4). Differences in leaf K and Mg concentrations were significant at $P < 0.002$. Trees in the killed sod had higher K and lower Mg concentrations than trees at either site in the previous orchard tree rows. The higher K concentration was unexpected, because K fertilizer was band-applied during the experiment and most fertilizers were band-applied to previous orchard tree rows. The live bahiagrass may have accumulated K, which would have been released to the growing peach trees as the killed sod decomposed. Bahiagrass increases the soil organic matter and concentrates bases such as K in the top layer of the soil (Beaty and Tan, 1972). The lower Mg concentration in leaves of trees in killed sod may reflect an antagonistic interaction between K and Mg. The positive association between K concentration and ITCSA may mean that trees would benefit from additional K fertilizer. If so, the adequacy range for this element should be modified. It seems less likely that fertilizing with additional N and Mn would result in a larger ITCSA, because ITCSA and canopy weight values were highest for trees in killed sod, where the concentrations of N and Mn were intermediate.

Leaf concentrations of Ca, Fe, Al, B, and Cu averaged 15.1 g·kg^{-1}, and 75, 67, 30, and 7 mg·kg^{-1}, respectively. Leaf concentrations of these elements were independent of treatment and within the sufficiency range for Georgia (Plank, 1989).

Postplant fenamiphos sprays did not affect any of the leaf mineral concentrations (data not shown) except leaf Zn concentration in trees planted in the row midway between previous orchard trees. The Zn concentration in these leaves was 14.0 vs. 11.9 mg·kg^{-1} in nontreated trees ($P = 0.05$). This difference in leaf Zn concentration may be unimportant, because the average ITCSA for these two groups of trees was identical.

In summary, the presence or absence of 'Paraguayan-22' bahiagrass sod was the major influence on nematode populations and tree survival, growth, and mineral nutrition. In addition to lowering populations of *C. xenoplax* and *Meloidogyne* spp., bahiagrass improves soil structure and adds organic matter to the soil. These changes could have contributed to the improved peach tree survival and growth. Trees did not benefit from preplant tilling, preplant root soaking in a fenamiphos solution, or spraying fenamiphos semiannually under the trees. This research shows that growing bahiagrass sod between peach orchard tree rows may help peach growers in the southern United States keep the best orchard sites continuously planted with peach trees. Using bahiagrass to control nematodes that cause PTSL may be an effective, economical, and environmentally sustainable alternative to chemical fumigants and nematicides.

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