Establishment of Peach in a Replant Site as Affected by Soil Fumigation, Rootstock, and Pruning Date

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ABSTRACT

Sharpe, R. R., Reilly, C. C., Nyczepir, A. P., and Okie, W. R. 1989. Establishment of peach in a replant site as affected by soil fumigation, rootstock, and pruning date. Plant Disease 73:412-415.

On a peach tree short life (PTSL) site in Georgia, preplant soil fumigation with methyl bromide decreased nematode population densities and tree loss due to PTSL and increased trunk circumference and tree vigor. Soil fumigation interacted with both rootstock and pruning date, and the effects of the treatments were additive. December-pruned trees on Nemaguard rootstock without fumigation resulted in the greatest number of weak, poorly growing trees and dead trees. When soil was preplant-fumigated, either Lovell or Nemaguard rootstock could be used and time of pruning had less effect. Fumigation also decreased the number of trees with trunk injury caused by cold temperature. Development of cold damage was greater on Nemaguard than on Lovell rootstock and with December than with March pruning. Evidence of weakness and poor vigor was often an indication of susceptibility to PTSL.

Peach tree short life (PTSL) is a serious problem affecting peach (*Prunus persica* (L.) Batsch) tree longevity and production in the Southeast (14,18,19). Trees are usually affected in their third to fifth year, with sudden collapse and death in the early spring of the aboveground portion of the tree. PTSL usually kills trees that appeared healthy the previous year. Careful examination of the trees over time, however, shows that in some cases the sudden collapse and death in the spring are preceded by poor growth and symptoms of stress during the previous years (22).

Factors associated with PTSL include low soil pH (10), ring nematode (*Criconemella xenoplax* (Raski) Luc & Raski), rootstock, fall pruning, and planting orchards on land previously used for peach production ("old" peach soil) (16). Preplant soil fumigation has been recommended for planting peaches in "old" soil (1). Soil fumigation has been shown to improve growth of apple, cherry, and pear trees, especially in replant situations (8,11,12). Preplant soil fumigation also can increase growth of young peach trees. Hendrix and Powell (7) reported a 30% increase in growth after 2 yr when the orchard site was fumigated with Trizone (methyl bromide, chloropicrin, and propargyl bromide). They suggested the increase in growth was due to control of *Pythium* and nematodes. Havis et al (5) also reported increased growth in peach trees due to methyl bromide fumigation and suggested that the increase was due to fungicidal value of the fumigant, since the soil seemed to be free from injurious nematodes.

In PTSL sites, soil fumigation can decrease nematode populations and increase tree growth and longevity (20,22,23). Dibromochloropropane (DBCP) has been the most intensively studied soil fumigant. Zehr et al (22,23) investigated the roles of fumigation and rootstock in PTSL development and found that fumigation with DBCP increased tree longevity, especially when Nemaguard or Elberta rootstocks were used. Wehunt et al (20) found that preplant plus postplant applications of DBCP reduced tree death but liming did not affect mortality. Fall pruning trees in either nonfumigated or DBCP-treated soil has been shown to predispose trees to PTSL (3,13). Hayden et al (6) found increased trunk circumference and tree size when peach orchards were fumigated with either ethylene dibromide or methyl bromide, but few of their check trees died and fumigation did not influence tree survival. Wehunt et al (20) reported that preplant fumigation with methyl bromide had no effect on tree survival after 5 yr, but they did not report on the effectiveness of methyl bromide during the first years of the orchard.

In the Southeast, preplant and postplant fumigation, Lovell rootstock, winter pruning, and liming soil to pH 6.5 are recommended practices for control of PTSL (1). DBCP was the most widely used and effective fumigant but is no longer available. Since the removal of DBCP, only 1,3-dichloropropene (1,3-D) and methyl bromide are registered as preplant nematicides for orchard establishment in Georgia and South Carolina; 1,3-D is considered a true nematicide and methyl bromide, a multipurpose fumigant. Most of the reports in the literature concerning the predisposition of trees to PTSL have dealt with only one or two of the factors at a time, and there is little information available on the relationships among all four factors. Understanding these interactions may result in improvement of control practices against PTSL. The objectives of this study were to determine the interactions of fumigation, rootstock, pruning date, and liming on tree performance and survival and to determine the effects of rootstock and preplant fumigation with methyl bromide on the establishment of a peach orchard on a severe PTSL site.

MATERIALS AND METHODS

The experimental site was on an Orangeburg sandy loam soil (fine-loamy, siliceous, thermic Typic Paleudult) in the major peach-producing area in Georgia. The site had at least three previous plantings of peaches. In the first planting, trees were about 20 yr old when removed; in the second planting, trees were removed after 8 yr; and in the third planting (immediately preceding the experimental planting), trees were removed after only 4 yr. Trees in the third planting were rated for PTSL, root galling caused by root-knot nematodes (*Meloidogyne* sp.), crown gall (*Agrobacterium tumefaciens* (Smith & Townsend) Conn), and oak root rot (*Clitocybe tabescens* (Scop.:Fr. Bres.)) before removal in June 1984. Of the 780 trees in the orchard, 187 were replants. About 40% of the 4-yr-old trees had died of PTSL just before removal. Of the living trees, 13% were infected with root-knot nematodes, 4% with crown gall, and 4% with oak root rot. The replants were not considered in the percentages reported for the pathogens or incidence of PTSL.

Virus-free rootstocks and Redhaven scions were obtained through the South Carolina Department of Agriculture certification program. Treatments were: 1) limed or not limed, 2) fumigated with methyl bromide or not fumigated, 3) pruned in December or pruned in March, and 4) Lovell or Nemaguard rootstock. The treatments were arranged in a split-plot design with lime being the main plots and with a factorial arrangement of the remaining treatments as subplots. Calcitic lime (1,700 kg/ha) was incorporated to a depth of 20 cm in August 1984 and surface-applied in November 1985. Entire plots were fumigated with methyl bromide under plastic (561

Accepted for publication 12 December 1988.

kg/ha) in November 1984. Methyl bromide was injected 15 cm deep when the soil temperature at that depth was greater than 16 C. The site was subsoiled and trees were planted in December 1984. No crown gall or root-knot nematode galling was evident on roots at planting. Pruning treatments were started in December 1985. There were nine trees per treatment and six replications, for a total of 864 trees. Tree spacing was 4.6 m within rows and 6.1 m between rows. There were also three extra trees per plot that were not included in the nine trees per treatment. These extra trees were removed during the winter of 1985–1986 for dry weight determinations of the tops and incidence of crown gall and root-knot nematode galling.

Nematode samples were obtained in the fall of each year. Preplant, prefumigation samples were obtained in November 1984 by compositing 10 probes per main plot, per replication, for a total of 12 samples. Nematodes were extracted from 100-cm^3 soil samples using elutriation (2) combined with centrifugal flotation (9), then counted. Postfumigation samples were obtained in September 1985 and December 1986 by sampling under the middle three trees per subplot. One probe was obtained from each tree quadrant, and the four samples were composited. Nematodes were extracted and counted as previously described.

Trunk circumference was measured at a height of 20 cm from the soil line in March 1985, January 1986, December 1986, and December 1987. The number of weak and injured trees and the incidence of PTSL were assessed in May of each year. Each tree was determined to be healthy or unhealthy (weak, poor vigor) by visual observation. Healthy trees had thick, dark green foliage, whereas unhealthy trees had small chlorotic leaves and uneven willowy growth. Trunk injury, caused by cold temperatures during the 1985–1986 winter, also was determined for each tree. The percentage of injured or PTSL trees was determined for each plot, and treatment differences were determined by chi-square analysis of log odds ratios, using the maximum likelihood method. The percentage of PTSL trees was a cumulative value based on the total number of trees killed by PTSL since the beginning of the test. The percentage of weak and injured trees was based on the number of trees remaining in the plot at the time of rating.

RESULTS

In May 1985, soil pH of the top 15 cm was approximately 6.7 and 5.9 in the limed and nonlimed treatments, respectively. By May 1988, soil pH had decreased to 6.2 and 5.7 in the limed and nonlimed treatments. Liming did not significantly affect any of the parameters measured, however.

Neither fumigation nor liming significantly affected trunk circumference in March 1985, but trees on Nemaguard rootstocks were larger than trees on Lovell rootstocks (Table 1). In January 1986, trunk circumferences of trees on Nemaguard were still larger than those on Lovell, but this difference was due entirely to the nonfumigated treatments, since there was no significant difference between rootstocks in the fumigated treatments. Overall, trunk circumference was increased 16% by fumigation treatment (Table 1). Trunk circumference data in December 1986 and December 1987 followed the same pattern as in January 1986. Fumigation increased the circumference of both Lovell and Nemaguard, and Nemaguard nonfumigated trees were larger than Lovell nonfumigated trees (Table 1).

The percentage of trees with nematodes and crown gall was based on the extra trees removed during the 1985–1986 winter. Approximately 5% of the Nemaguard trees had crown gall, whereas 47% of the Lovell fumigated trees and 72% of the Lovell nonfumigated trees were infected with crown gall. No Nemaguard trees had root-knot nematode galls, but 8% of the Lovell fumigated trees and 28% of the Lovell nonfumigated trees had galls. The dry weights of the aerial portion of the extra trees indicated that trunk circumference was a reliable measure of relative growth for young trees. Dry weights of trees in fumigated soil were 50% greater than those of trees in nonfumigated soil. There was no significant interaction in plant weight between fumigation and rootstock, but the general trends were the same as for trunk circumference.

There was a significant three-way interaction among rootstock, fumigation, and pruning in the development of PTSL in 1986 and 1987 (Table 2). December pruning of trees on Nemaguard rootstock in nonfumigated soil was very detrimental. The only PTSL occurring in 1986 was in December-pruned, nonfumigated trees on Nemaguard rootstock; by 1987, 22% of the trees in this treatment combination had died (Table 3). About 4% of the March-pruned, nonfumigated Nemaguard trees also were killed by PTSL in 1987, but this percentage was not significantly different from zero. There were no significant interactions in the development of PTSL in 1988 (Table 2), but main effects were significant, with December pruning, Nemaguard rootstock, and no fumigation increasing the incidence of PTSL (Table 3). The effects of the treatments appeared to be additive. If each factor is considered alone, 24% of the nonfumigated, 19% of the Nemaguard rootstock trees, and 18% of the December-pruned trees were killed by PTSL. The addition of a second factor increases

Table 1. Effect of fumigation and rootstock on trunk circumference of peach trees planted in December 1984

Treatment	Rootstock	Trunk circumference (cm) March 1985	January 1986	December 1986	December 1987
Nonfumigated	Nemaguard	3.14	12.6 b[x]	21.8 b	28.3 b
	Lovell	2.80	11.8 c	21.3 c	27.5 c
Fumigated[y]	Nemaguard	3.17	14.3 a	24.3 a	30.5 a
	Lovell	2.81	14.0 a	24.3 a	30.6 a
Mean	Nemaguard	3.15**[z]	13.5**	23.0	29.5**
	Lovell	2.80	12.9	22.8	29.1

[x] Means followed by the same letter within columns are not significantly different according to Duncan's multiple range test ($P = 0.05$).
[y] Applied as 98% methyl bromide plus 2% chloropicrin at 561 kg/ha.
[z] ** = Significant at the 0.01 level of probability.

Table 2. Chi-square analysis for treatment and interaction effects on the number of trees with peach tree short life (PTSL) and on the number with weak, willowy growth and (in 1986) with cold damage

Source of variation	1986	1987	1988	
	Number of trees with PTSL			
Intercept	164.2***[z]	163.9***	178.2***	
Fumigation (Fum)	4.3**	12.6***	56.3***	
Rootstock (RST)	6.4***	14.1***	37.0***	
Pruning date (PD)	6.5***	5.8**	30.0***	
Fum × RST × PD	4.2**	3.3*	NS	
	Number of trees with weak, willowy growth			Cold damage 1986
Intercept	156.9***	210.9***	199.9***	191.1***
Fumigation	4.4**	8.8**	31.6***	17.7***
Rootstock	6.9***	1.9 NS	0.9 NS	9.1
Pruning date	3.7**	0.3 NS	1.2 NS	12.8***

[z] Significant at * = 0.1, ** = 0.05, and *** = 0.01 levels of probability; NS = not significant.

the incidence of PTSL; 39% of the nonfumigated trees on Nemaguard rootstock and 36% of the nonfumigated, December-pruned trees died. The combination of no fumigation, December pruning, and Nemaguard rootstock resulted in death of 53% of the trees by 1988.

The number of trees showing poor vigor also indicates that Nemaguard rootstock should not be used in nonfumigated soil (Table 4). A few March-pruned trees in the nonfumigated Nemaguard treatments were injured during the first winter, but December pruning greatly increased the percentage of weak and injured trees. Neither fumigation nor pruning date affected trees on Lovell rootstock in 1986, and fumigation was the only treatment to significantly affect the percentage of weak trees in 1987 and 1988 (Table 4).

Fumigation was the most important factor in decreasing the number of trees with trunk injury caused by cold temperature (Table 4). About 9% of the nonfumigated trees were damaged by cold in 1986, but only 2% of the fumigated trees showed symptoms. Rootstocks and pruning date were also factors in the development of cold damage. Damage was greater on Nemaguard than on Lovell trees, and December pruning increased the number of injured trees, primarily in nonfumigated soil (Table 4). Our data also indicate that for 3 yr, population densities of *C. xenoplax* were lower with preplant fumigation with methyl bromide than with nonfumigation (Table 5). Populations of *C. xenoplax* and *Meloidogyne* sp. increased in both fumigated and nonfumigated treatments from 1985 to 1986 but remained about the same from 1986 to 1987.

DISCUSSION

The lack of response to liming may have been due to the relatively high soil pH in the nonlimed treatments (5.7) or to the depth of lime incorporation (15–20 cm). In several tests in which initial soil pH was less than 5.0, Perkins et al (15) reported that liming significantly increased peach tree longevity and that incorporation of lime to a depth of 35–40 cm increased tree survival more than incorporation to a depth of 15–20 cm. Cummings (4) reported that liming can increase tree longevity if initial soil pH is below 5.6. At higher pH ranges, 5.6–6.2 and 6.0–6.6, Cummings (4) noted only small differences in the survival of Loring peaches during the first 8 yr of the study.

The greater trunk circumference with Nemaguard than with Lovell rootstocks in March 1985 reflects differences between rootstocks at planting, since the trees grew little, if at all, during the first 3 mo. These differences are consistent with other reported results and field observations that scions on Nemaguard show greater initial growth than those on Lovell (17). The difference in trunk circumference between Lovell and Nemaguard in nonfumigated soil in January and December 1986 may have been due to root-knot nematode and crown gall infections, since the percentage of trees infected was greater with Lovell than with Nemaguard rootstock.

Fumigation is an important practice to consider in establishing a new peach orchard in "old" peach soil. DBCP, which has been shown to be an effective fumigant for decreasing losses caused by PTSL, is no longer available. Methyl bromide and 1,3-D are the only two preplant soil fumigants available. In this test, preplant fumigation with methyl bromide increased trunk circumference and decreased the number of weak, poorly growing trees. Fumigation also decreased tree loss caused by PTSL, and with fumigation, both Lovell and Nemaguard trees became established and started producing. This is in contrast to the data of Wehunt et al (20), which indicated that preplant soil fumigation with either DBCP or a methyl bromide-chloropicrin mixture must be followed by postplant applications of DBCP to significantly decrease tree loss. One possible reason for the decrease in early tree loss in our study as compared with the results of Wehunt et al (20) was the difference in the amount of methyl bromide used. We applied 561 kg/ha of 98% methyl bromide, whereas Wehunt et al (20) applied 336 kg/ha of 67% methyl bromide.

The incidence of cold damage in our study is consistent with that of Nesmith and Dowler (13); in their study, cold hardiness increased with fumigation and decreased with fall pruning, but they were unable to show any interaction between fumigation and pruning date. Carter (3) also reported that fall pruning decreased cold hardiness, but his data indicated that there were no differences between fall-pruned trees in fumigated and nonfumigated soil, although fumigated winter-pruned trees were more cold

Table 3. Effect of fumigation, pruning date, and rootstock on percentage of trees killed by PTSL after four growing seasons

		Cumulative PTSL mortality (%)[y]					
		1986		1987		1988	
Treatment	Pruning date	Nemaguard	Lovell	Nemaguard	Lovell	Nemaguard	Lovell
Nonfumigated	December	14.8	0.0	22.2	0.0	53.3	17.9
	March	0.0	0.0	3.7	0.0	22.2	2.8
Fumigated[z]	December	0.9	0.0	0.9	0.0	1.9	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0

[y] Percentage of trees that died since start of test.
[z] Applied as 98% methyl bromide plus 2% chloropicrin at 561 kg/ha.

Table 4. Effect of fumigation, pruning date, and rootstock on percentage of peach trees planted in 1984 with weak, willowy growth and (in 1986) with cold damage

			Weak, willowy growth (%)			Cold damage
Treatment	Rootstock	Pruning date	1986	1987[y]	1988[y]	1986 (%)[y]
Nonfumigated	Nemaguard	December	11.0	7.2	13.7	22.0
		March	1.9	4.8	15.3	5.5
	Lovell	December	0.0	2.8	14.8	7.4
		March	0.0	3.7	5.7	0.9
Fumigated[z]	Nemaguard	December	0.9	0.0	1.9	4.6
		March	0.0	0.0	0.0	0.9
	Lovell	December	0.0	0.0	0.9	0.9
		March	0.0	0.9	0.0	0.9

[y] Based on number of trees remaining in treatment at time of rating.
[z] Applied as 98% methyl bromide plus 2% chloropicrin at 561 kg/ha.

Table 5. Effect of fumigation on mean population densities of *Criconemella xenoplax* and *Meloidogyne* sp. over time on peach

	Number of nematodes per 100 cm^3 of soil[y]			
	Fumigated[z]		Nonfumigated	
Sampling date	*C. xenoplax*	*Meloidogyne* sp.	*C. xenoplax*	*Meloidogyne* sp.
November 1984 (preplant, prefumigation)	...	...	4	0
September 1985	24	6	44	7
December 1986	279	49	983	108
December 1987	268	84	744	81

[y] *C. xenoplax* = mean of 48 samples under Lovell and Nemaguard rootstocks; *Meloidogyne* sp. = mean of 24 samples under Lovell rootstock.
[z] Applied as 98% methyl bromide plus 2% chloropicrin at 561 kg/ha.

hardy.

The cumulative effects of fumigation, rootstock, and pruning date on tree health and survival indicate the importance of all three factors in orchard establishment. When the soil was preplant-fumigated, then either Lovell or Nemaguard rootstock could be used and time of pruning had less effect. Fumigation, however, is seldom practiced in the Southeast, and without fumigation, both rootstock and time of pruning become critical because the detrimental effects of the treatments are additive. Death of March-pruned trees on Lovell rootstock was minimal (3%) even in nonfumigated soil. Changing rootstock from Lovell to Nemaguard increased the incidence of PTSL to 18%, and changing time of pruning from March to December increased the incidence to 22%. Using all three factors associated with PTSL (no fumigation, Nemaguard rootstock, and December pruning) resulted in the death of 53% of the trees after 4 yr. The 97% survival rate for March-pruned trees on Lovell rootstock indicates that an orchard can be established without fumigation. Orchard establishment on a short-life site without fumigation, however, should be viewed with caution because of the variability in the incidence of PTSL between years and among orchards. Zehr and Golden (21) and Zehr et al (22) found only 85 and 77% survival after 2 yr in orchards in South Carolina without fumigation, even though recommended practices were followed.

Fumigation had the greatest influence on tree survival, and rootstock and time of pruning had a similar impact on tree survival. Preplant soil fumigation usually is effective for up to 2 yr (21,22). The longer lasting effects of fumigation in the study may have been due to broadcast rather than strip application of methyl bromide. Zehr and Golden (21) reported that broadcast application of dichloropropene increased tree survival longer than strip application. The long-term effects of the treatments on tree longevity and orchard productivity need to be determined.

PTSL is often described as the collapse and sudden death of trees that appeared healthy the previous year. Our results substantiate those of Zehr et al (22), which indicate this is not always true. About 70% of the trees that were killed by PTSL in 1987 and 1988 showed some type of injury the previous year, either poor vigor or trunk damage caused by cold or a combination of both.

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