Soil Fumigation and Peach Rootstocks for Protection Against Peach Tree Short-Life

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ABSTRACT

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In peach tree short-life sites in South Carolina, soil fumigation for control of *Criconemoides xenoplax* resulted in improved growth and vigor of peach trees, and fewer losses to bacterial canker and cold injury were observed in fumigated soil over a 3-year period. However, growth response to fumigation, vigor, and tree losses were affected by rootstock as well as by nematode control. Tree losses were negligible when both Lovell rootstock and soil fumigation were used, but some tree loss occurred even in fumigated soil when the rootstocks were Nemaguard or Elberta. Without fumigation, tree losses were very severe in two sites when Nemaguard rootstock was used. Growth response to fumigation of infested soils generally was less on Lovell rootstock than on Elberta or Nemaguard. In noninfested soils, no growth response to fumigation was observed and no tree loss occurred. *Criconemoides xenoplax* appeared to predispose peach trees to short-life, but control of this nematode by fumigation did not prevent tree death from bacterial canker or cold injury if rootstocks other than Lovell were used.

Additional key words: Pseudomonas syringae, Xanthomonas pruni, peach decline.

Peach tree short-life (PTSL) is a term used by researchers in the southeastern United States to describe an ill-defined disease syndrome that results in premature loss of peach [*Prunus persica* (L.) Batsch] trees, frequently before they reach bearing age. As commonly used it encompasses injury due to bacterial canker, cold injury to trunk and scaffold limbs, sudden collapse due to unknown causes, and gradual decline over a period of months or years. Injury or plant diseases of well-defined etiology that may result in similar symptoms (Clitocybe root rot, stem pitting, water logging) are not included in the peach tree short-life syndrome. Cold injury or bacterial canker are the most frequent causes of tree death in short-life situations, but fall pruning (4, 5, 17, 19, 22), root-knot nematodes (7, 8), and pythiaceous fungi (9, 10, 20), are some important predisposing factors. Liming of acid soils promotes peach tree growth and vigor (18), and soil pH may affect susceptibility to bacterial canker (21).

In South Carolina, PTSL is severe in the sandy soils that run in a narrow band from southwest to northeast across the state. In heavier soils of northwestern and northern South Carolina the problem is of much less significance, but it occurs in localized areas where the topsoil is sandy. Losses are more frequent and severe in orchards where peaches grew previously than in new peach land in the sandy areas. In clay soils less difficulty is encountered when peach orchard sites are replanted.

Ring nematodes, especially *Criconemoides xenoplax* Raski, are prevalent in PTSL situations in New Jersey (11), Maryland (3), North Carolina (1, 3), and Georgia (2, 10, 20, 21, 22). Although prevalent in sandy soils of South Carolina, those nematodes seldom occur in substantial numbers in clay soils in the state. The suspicion that *C. xenoplax* might be important in PTSL was reinforced when recent studies in California (13) showed that parasitism by *C. xenoplax* predisposed peach trees to infection by *Pseudomonas syringae*. Edgerton and Parker (6) showed that cherry trees infected with *Pratylenchus penetrans* are less cold hardy than noninfected trees, and Nesmith and Dowler (16) reported that peach trees in fumigated soil were more resistant to cold injury than were those in nonfumigated, *C. xenoplax*-infested soil.

In North Carolina, preplant and postplant soil fumigation and use of Lovell rootstock has been effective for preventing PTSL in sandy soils infested with root-knot nematodes (C. N. Clayton, *unpublished*). To determine whether these practices might be helpful in peach soils infested with *C. xenoplax,* experiments were established in four selected commercial peach orchards in South Carolina with various cropping and tree loss histories. The results after 3 years are reported herein.

MATERIALS AND METHODS

Four commercial orchard sites in South Carolina were selected; each was considered to be a potential short-life problem orchard based on past history of dying peach trees. Descriptions and cropping history follow.

L. D. Holmes farm, Edgefield County.—The soil was a Faceville loamy sand that had been planted in peaches twice previously. The top 15-cm of soil consisted of 76-85% sand, 9-13% silt, and 6-11% clay. Apparent cold injury in 6-year-old trees of cultivar Redhaven had been severe in the spring of 1971, resulting in 50% tree loss. The remaining trees were removed after harvest in 1971, 5.5

metric tons of lime per hectare (ha) was applied broadcast, subsoiling was done at a depth of 45-60 cm in the tree row, and the entire area was plowed to a depth of 30 cm. After preparation, the soil pH at 15 cm in September 1972 was 6.9.

Woodrow Cash farm, Cherokee County.—Cecil loamy sand predominates in this site, but a portion of the orchard is on Cecil clay. The clay fraction in the top 15-cm ranged from 4-49% and sand from 32-80%. Peach trees had been grown in the site almost continuously for 48 years. In late summer, 1971, 4-year-old trees of cultivar Madison in the sandy portion were growing poorly, had yellow foliage, suffered severe necrosis of feeder roots, and scattered tree loss had occurred. In the fall of 1971 the trees in the orchard were removed; fescue sod between the rows was retained, and lime (5.5 metric tons/ha) was applied broadcast before plowing. The soil in the rows was plowed to a depth of 25-30 cm and additional lime (2.75 metric tons/ha) was applied to the surface after plowing. After the lime application, soil pH at 15 cm in November 1971 was 6.1.

Walter Rawl farm, Lexington County.—The soil is deep sand in which peaches had grown before, but not since 1964. Between 1964 and 1972 the soil was in vegetable cultivation. In February 1972, lime (2.75 metric tons/ha) was added broadcast and the soil was plowed to a depth of 30 cm. Soil pH 15 cm in September 1972 was 5.9.

J. H. Keisler farm, Lexington County.—In 1971 a 2-year-old orchard in Fuquay sand suffered loss of peach trees owing to excessive soil moisture in a portion of the orchard. Although neither PTSL nor nematode damage was suspected, a postplant treatment with 1,2-dibromo-3-chloropropane (DBCP) was made in the orchard in the spring of 1972. Trees of mixed cultivars were on Elberta (commercial seedling) rootstock.

In all orchards except the Keisler farm, treatments were arranged in a randomized block with split plot for rootstocks. Treatments consisted of preplant fumigation, postplant fumigation beginning 2 years after planting, pre- and postplant fumigation, or no treatment. In the Holmes orchard, however, a postplant treatment of DBCP (47 liters/ha) was inadvertently applied to the entire orchard near the end of the first growing season (September 1972). Trees were the Redhaven cultivar on Nemaguard, Lovell, or Elberta (commercial seedling) rootstocks. Each treatment-rootstock combination consisted of at least 18 trees and was replicated three times for rootstocks and fumigation. Where preplant treatments were applied 1,3-dichloropropene (Telone, 360 liters/ha treated) was used in the Holmes site and DBCP (Nemagon or Fumazone, 47-66 liters/ha treated) in the Rawl and Cash orchards. The fumigant was applied 25-30 cm deep in a 2.4-m strip centered on the row where the trees were to be planted. In the Keisler orchard the postplant treatment (Fumazone, 47 liters/ha treated) was made to eight rows of trees, 25 trees per row, in strips 1.2 m wide on both sides of the tree, about 45 cm from the trunk at a depth of 10 cm. Two treated rows alternated with two nontreated rows.

Trees on commercial seedling rootstock were obtained from a commercial nursery in Tennessee. Those on Nemaguard and Lovell rootstocks were provided through the courtesy of C. N. Clayton, North Carolina State University. The trees were planted and grown according to each grower's customary farming practices; consequently the experiments were subject to differences in fertilizer practices, pruning, spraying, and weed control that might be expected in commercial orchard situations.

Nematode populations differed in the test sites. In the Cash and Holmes orchards *C. xenoplax* was present when the trees were planted. In the Rawl site plant-parasitic nematodes were not detected by the centrifugation-flotation method (12) when the trees were planted, but a low population of *C. xenoplax* appeared in the nonfumigated soil near the end of the first growing season. In the Keisler orchard *Helicotylenchus* spp. were present when the treatment began, but few *C. xenoplax* individuals were present until 1974.

To avoid root injury in the newly planted trees the number of trees sampled and sampling dates were relatively few during the first growing season. Thereafter samples were collected at 2- to 4-month intervals except during dry weather, when sampling was discontinued. Soil samples were collected at a depth of 7.6-20.3 cm (3-8 inches) from soil within a 2.5-cm radius of peach rootlets, using a garden trowel. Soil was stored at 5-10 C until the nematodes were extracted by centrifugation-flotation (12). Trunk growth was measured once annually 10-15 cm above the soil line, and the trunk diameter was converted to trunk area in cross section.

To determine if treatments were related to vigor, trees in the Rawl and Holmes orchards were rated visually on a 1-6 scale in September 1973. Trees rated 1 were yellow with willowy shoot growth, and had marked upward rolling of leaves; those rated 6 had lush green foliage, robust shoot growth, and no rolling of leaves, and were of excessive vigor for autumn. Trees rated 5 on this scale were considered as being of optimum vigor for September.

In the Holmes orchard, defoliation resulting from infection by *Xanthomonas pruni* became severe in some trees in late summer 1973. On 18 September 1973 each tree was examined and the percentage defoliation estimated visually. Estimations were recorded at 10% intervals from 0-100% defoliation (scale of 0-10). The sum of data for each treatment was divided by the number of trees examined to determine the average percent defoliation.

RESULTS

Nematode control.—*Criconemoides xenoplax* was prevalent in all sites except the Keisler orchard (until 1974) and the high clay portion of the Cash orchard. *Helicotylenchus, Meloidogyne, Scutellonema, Trichodorus, Tylenchorhynchus, Xiphinema,* and *Pratylenchus* spp. were found occasionally. Trees in a small portion of the Rawl orchard and scattered trees in the Holmes orchard were infected with root-knot nematodes.

Preplant fumigation with Telone or DBCP for nematode control was effective in all sites as measured by nematodes extracted after fumigation, but the sites differed in rates at which nematode populations became reestablished following fumigation. In the Rawl orchard, where *C. xenoplax* was at a low level when the treatment was made, the nematodes had not become reestablished in fumigated soil 3 years after treatment, but in orchards where *C. xenoplax* initially was present in significant numbers the population became reestablished 1.5 - 2 years after treatment. The preplant nematicide used was less related to resurgence of the population than to factors such as soil type and level of nematode infestation when the treatment was made.

Postplant fumigation was less effective than preplant treatment for controlling *C. xenoplax*. However, the postplant treatment lowered the nematode population by at least 50% and the effect persisted up to 3 years in the Keisler orchard.

Populations of Criconemoides xenoplax associated with peach roots.—Population levels fluctuated greatly. Lowest populations in nonfumigated soil occurred during and immediately after periods of dry weather in summer and autumn. When dry weather persisted for several weeks populations sometimes approached zero, but rapid buildup occurred after rainfall. Soil samples collected 3-4 weeks after dry periods usually contained a high proportion of larvae. High populations were observed in late winter and spring; in the Cash orchard up to 2,034 individuals/100 cc soil were found in samples collected 1 February 1973.

Rapid increase in populations of *C. xenoplax* sometimes were observed in association with peach roots in nonfumigated soil. In the Rawl orchard the nematodes increased from 368/100 cc soil on 21 June 1973 to 2,264/100 cc on 17 September 1973. In the Keisler orchard an increase from 2/100 cc on 13 June 1974 to 469/100 cc on 13 August 1974 was observed.

Criconemoides xenoplax increased in association with all rootstocks. The rate of increase appeared to be less on Lovell than on Elberta or Nemaguard, but the average for all sampling dates was not significantly different for the three rootstocks (Table 1).

Growth response to fumigation.—Tree growth response was related to nematode populations. In the Cash and Holmes orchards, where nematodes were present when the trees were planted, a growth response was observed the first growing season after the fumigation treatment (Table 2). However, in the Rawl orchard where *C. xenoplax* did not appear in significant numbers until after the first growing season, a growth response to fumigation was not observed until the second year. In the Keisler orchard populations of *C. xenoplax* were negligible until midsummer, 1974, and a growth response was not observed throughout the 3-year test period. Similarly, in the clay portion of the Cash orchard where nematode numbers remained low, the growth response was less than in the remainder of the orchard.

Soil fumigation also affected root growth in infested soil. Fumigation resulted in greater abundance of roots that appeared to be more vigorous and profusely branched than in nonfumigated soil (Fig. 1).

Rootstocks affected growth response to fumigation. In the absence of *C. xenoplax,* none of the trees responded to soil fumigation. When *C. xenoplax* was present, however,

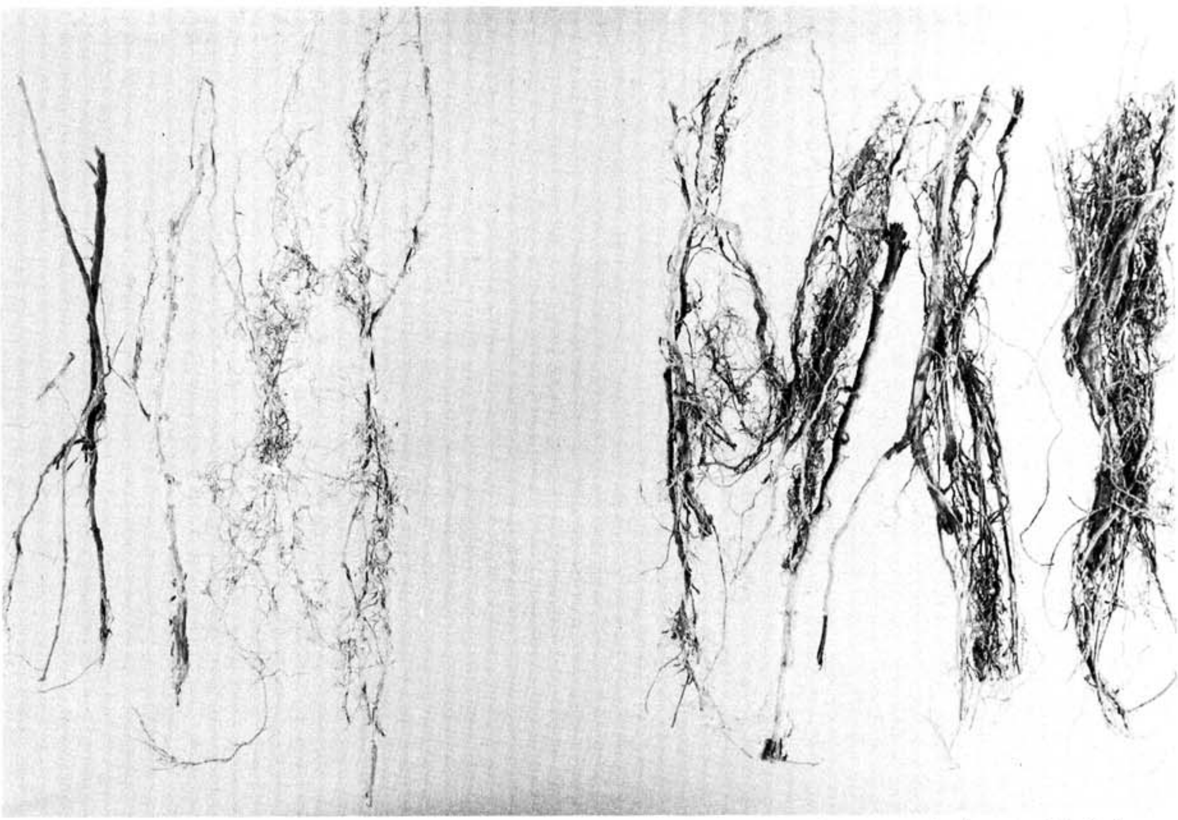

Fig. 1. Roots of 2-year-old peach trees on Nemaguard rootstock growing in fumigated (right) or nonfumigated soil (left) that was infested with *Criconemoides xenoplax* when fumigated. Compare relative abundance of feeder rootlets and diameters of secondary roots.

trees on Lovell rootstock gave less response in terms of growth. Whereas fumigation resulted in 20-25% increased growth on Lovell rootstocks, growth increases of 35-40% or more occurred on Nemaguard and Elberta rootstocks.

Tree survival.—Tree loss with symptoms of bacterial canker or cold injury occurred in the Holmes orchard in 1973 and 1974, and in the Rawl orchard in 1974 (Table 3). The amount of tree loss experienced was greatest in trees on Nemaguard rootstock without preplant soil fumigation and was least in trees on Lovell rootstock with preplant fumigation. Similar losses did not occur in the Cash or Keisler orchards through 1974. Tree loss on Nemaguard or Elberta rootstocks was not prevented by control of nematodes with soil fumigation, but losses were less severe than without fumigation.

Tree vigor.—Though fumigation affected growth rate of peach trees in *C. xenoplax*-infested soil, other growth effects were apparent in the Holmes and Rawl orchards, especially in late summer and autumn. Trees in soil that had received preplant fumigation retained their leaves for a longer period. Fumigation also seemed to result in greener foliage, less upward rolling of leaves in the fall, and more robust shoot growth. Preplant fumigation

TABLE 1. Average population of *Criconemoides xenoplax* associated with three peach tree rootstocks in test orchards in South Carolina, 1973-74[a]

	C. xenoplax/100 cm^3 soil	
Rootstock	Preplant fumigation	Nonfumigated
Lovell	38 A[b]	245 BC
Elberta	47 A	322 BC
Nemaguard	89 AB	630 C

[a]Average of 16 sampling dates in three orchard sites.
[b]Numbers followed by the same letter are not significantly different ($P = 0.05$) by Duncan's multiple range test.

TABLE 2. Growth of peach trees in fumigated and nonfumigated soil in commercial orchards infested or not infested with *Criconemoides xenoplax*, 1972-74, in South Carolina[a]

	Trunk area, transverse section (mm^2)[b]		
Treatment	1972	1973	1974
Cash Orchard			
None	286 A[c]	1321 A	3262 A
DBCP postplant[d]	344 AB	1588 AB	4231 B
DBCP preplant	466 C	2038 C	5098 C
DBCP pre- and postplant	428 BC	1879 BC	4730 BC
Rawl Orchard			
None	266 A	1157 A	1433 A
DBCP postplant[d]	255 A	1167 A	1665 AB
DBCP preplant	246 A	1456 B	1992 BC
DBCP pre- and postplant	283 A	1545 B	2432 C
Holmes Orchard[e]			
None	622 A	2698 A	6519 A
DBCP postplant[d]	635 A	2873 A	6968 A
Telone preplant	901 B	3368 B	7874 AB
Telone preplant; DBCP postplant	989 B	3492 B	7927 B
Keisler Orchard			
None	...	7539 A	11492 A
DBCP postplant[f]	...	7385 A	10950 A

[a]Cash and Holmes orchards infested at planting; Rawl orchard light infestation until 1973; and Keisler orchard was noninfested until 1974.
[b]Averages of trees on Elberta, Nemaguard, and Lovell rootstocks.
[c]For each orchard and date numbers followed by the same letter are not significantly different ($P = 0.05$) by Duncan's multiple range test.
[d]Postplant DBCP was applied at the end of the 1973 growing season in 1.2-m bands on each side of row.
[e]All trees including checks inadvertently received a postplant treatment of DBCP near end of first growing season (1972).
[f]One treatment applied in March 1972, 1 year after planting.

TABLE 3. Incidence of peach tree short-life in two commercial orchards in South Carolina as affected by soil fumigation and rootstocks[a]

	Tree loss (%) by rootstock:		
Treatment	Nemaguard	Elberta	Lovell
Holmes Orchard (1973, 1974)			
No preplant[b]	44 A[c]	28 A	0 C
Telone preplant[b]	25 AB	11 BC	5 C
Rawl Orchard (1974)			
None	30 A	6 B	8 B
DBCP preplant	8 B	3 B	0 B

[a]Immediate causes of tree death were cold injury, bacterial canker, or both.
[b]Received postplant treatment of DBCP in September 1972.
[c]In each orchard numbers followed by the same letter are not significantly different ($P=0.05$) by Duncan's multiple range test.

TABLE 4. Vigor of 2-year-old peach trees as influenced by soil fumigation and peach rootstocks in *Criconemoides xenoplax*-infested soil in South Carolina

	Tree vigor rating[a] on rootstocks:		
Treatment	Nemaguard	Lovell	Elberta
Holmes Orchard			
No preplant[b]	3.4 A[c]	4.1 BC	4.0 BC
Telone preplant[b]	3.9 AB	4.5 C	4.0 BC
Rawl Orchard			
None	3.6 A	3.9 B	3.7 AB
DBCP preplant	4.0 B	4.3 C	3.9 B

[a]Rating scale of 1-6, based on leaf color, rolling of leaves, and diameter of new shoot growth in September 1973. Rating of 5.0 was considered to be optimum vigor for autumn.
[b]Received postplant treatment of DBCP in September 1972.
[c]In each orchard numbers followed by the same letter are not significantly different ($P=0.05$) by Duncan's multiple range test.

TABLE 5. Defoliation of peach trees resulting from infection by *Xanthomonas pruni* as influenced by rootstock and preplant fumigation, Holmes orchard, 1973, in South Carolina

	Defoliation (%)	
Rootstock	No preplant[a]	Telone preplant[a]
Lovell	18 A[b]	18 A
Nemaguard	24 AB	22 A
Elberta	28 B	32 B

[a]All trees received DBCP postplant in September 1972.
[b]Numbers followed by the same letter are not significantly different ($P = 0.05$) by Duncan's multiple range test.

influenced tree vigor, but rootstock was an equally significant factor (Table 4). Trees on Lovell rootstock were more likely to be of optimum vigor than were trees on Nemaguard or Elberta rootstocks.

Defoliation from *Xanthomonas pruni* infection.—Defoliation resulting from infection by *Xanthomonas pruni* became severe in some trees in the Holmes orchard in 1973. Percentage defoliation was not affected by preplant treatment (Table 5), but defoliation was less severe on trees on Lovell rootstock than on Elberta rootstock. Trees on Nemaguard rootstock were intermediate.

DISCUSSION

Peach tree short-life is a complex disease problem that involves many interacting factors. For control of this problem in the southeastern USA, quality nursery stock, rootstocks, soil pH, nutrition, weed control methods, time of pruning, and nematode control must be considered because each of these factors is thought to affect susceptibility of peach trees to injury by cold or bacterial canker. The injury of peach roots by *Pratylenchus* and *Meloidogyne* spp. is well documented (3, 15), but the potentially injurious nature of *C. xenoplax* has been uncertain until recently. Barker and Clayton (1) noted the association of *C. xenoplax* with peach problems in North Carolina and determined that high populations can stunt peach seedlings. Lownsbery et al. (13) showed that infection by *C. xenoplax* can cause extensive root damage on peach trees and inhibit their growth. Mojtahedi and Lownsbery (14) reported that *C. xenoplax* causes destruction of cortical root tissue, darkening of roots, dearth of feeder roots, reduction of plant weight, and lowering of nutrient levels in plum leaves.

Three facts indicate that *C. xenoplax* is an important factor in PTSL. First, PTSL coincides with infestation of *C. xenoplax*. In clay soils of South Carolina where these nematodes are absent, losses to PTSL are minimal. Second, soil fumigation in our experiments resulted in increased growth and vigor only in soils infested with *C. xenoplax*. Fumigation of noninfested soils had no visible influence on growth or vigor. Third, fumigation for control of *C. xenoplax* resulted in reduced tree loss to PTSL, especially when the trees were on Lovell rootstock. Lovell rootstock appeared to tolerate parasitism by *C. xenoplax* to a greater degree than Elberta or Nemaguard rootstocks, as indicated by less growth response to fumigation of infested soils, less tree loss in the presence of the nematodes, and perhaps less rapid nematode buildup on Lovell rootstock.

Use of Lovell rootstock in problem orchard sites appears to be essential if PTSL is to be avoided. Nemaguard rootstock was unsatisfactory even when used with fumigation in such sites. In noninfested commercial orchard soils, however, Nemaguard rootstock has performed well without tree loss, and there is no apparent reason why use of Nemaguard should be discontinued in such sites.

Nesmith and Dowler reported (17) that postplant fumigation of peach trees replanted in soil infested with *C. xenoplax* and *Scutellonema* sp. reduced the severity of infection by *Xanthomonas pruni*. The evidence we have presented indicates that rootstock also affects the percent defoliation resulting from infection by *X. pruni*. Defoliation was less severe in trees on Lovell than on Nemaguard or Elberta rootstocks. Although only half of the trees had received a preplant fumigation treatment, all had been given a postplant treatment. No significant differences were observed in relation to preplant or postplant fumigation under these circumstances.

Based on the results reported here, supporting field observations, and unpublished experimental data, recommendations to South Carolina peach growers are to fumigate routinely in soils infested with *C. xenoplax*, preferably before the trees are planted and then at 2-year intervals thereafter. The use of Lovell rootstock also is advised, especially in potential short-life sites. These practices, together with good horticultural management, have substantially reduced losses to PTSL in South Carolina; nevertheless, further critical evaluation of these practices continues.

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