Relative Susceptibility of Peach and Plum Germplasm to Armillaria Root Rot

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Abstract. Nearly 5000 seedling trees representing more than 100 peach [*Prunus persica* (L.) Batsch.] and plum (*Prunus* spp.) lines were planted at a 4 × 0.6-m spacing in Jan. 1983, on a site with a known history of peach tree short life (PTSL) and Armillaria root rot (ARR). Trees were arranged in a randomized complete-block with eight replicates of six trees each. Beginning in Spring 1984 and each year thereafter the cause of tree death was determined. At the end of 9 years, 50% of the trees had succumbed to PTSL and 35% had been killed by ARR apparently caused by *Armillaria tabescens*. Analysis of the data for trees killed by ARR showed a wide range in mortality, some peach lines appeared significantly more tolerant to ARR than others. Plum lines derived from native North American species also appeared to be a potential source of improved tolerance. We did not establish whether ARR tolerance is affected by PTSL.

The principal causes of tree mortality in stone fruit growing regions in the southeastern United States are peach tree short life (PTSL), induced by the ring nematode [*Cricomella xenoplax* (Raski) Luc & Raski], and Armillaria root rot (ARR), caused by *Armillaria tabescens* (Scop.:Fr.) Dennis et al. and *Armillaria mellea* (Vahl:Fr.) P. Kumm. Together these diseases are responsible each year for more than \$10 million in lifetime production losses (calculated as total value of crops lost in remainder of anticipated 15-year lifespan) in South Carolina alone (Miller, 1994). Considerable progress has been made in identifying both management practices and rootstock selections that minimize tree losses to PTSL (Beckman et al., 1994; Brittain and Miller, 1978; Okie et al., 1994a, 1994b). In contrast, no ARR-resistant rootstocks for peach have yet been identified with proven commercial utility in the United States, and chemical control is generally considered impractical (Bertrand, 1989). Hence, the identification of rootstocks with improved levels of resistance to this disease is highly desirable. The purpose of our research was to determine the relative resistance of a wide variety of peach and plum germplasm to both PTSL and ARR on a naturally infested field site.

Materials and Methods

One-year-old, open-pollinated seedlings (some grafted with commercial scion cultivars) and rooted hardwood cuttings of more than 100 peach and plum lines (Table 1) were planted at a 4 × 0.6-m spacing in Jan. 1983. The site at the USDA–ARS Southeastern Fruit and Tree Nut Research Laboratory in central Georgia had a known history of PTSL and ARR. Soil type was a Faceville fine sandy loam, a clayey, kaolinitic, thermic, Typic Paleudult. A weed-free strip (≈2 m wide) was maintained within each tree row using both the preemergent herbicides terbacil [5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4-dihydro-2H-pyrimidin-2-one], diuron [N-(3,4-dichlorophenyl)-N,N-dimethylurea], and simazine (6-chloro-N,N-diethyl-1,1,3,5-tetrazine-2,4-diamine) and the postemergence herbicide paraquat (1,1'-dimethyl-4,4'-bipyridinium salts). Trees were fertilized each spring prior to bloom with a single broadcast application of ammonium nitrate (N at 56 kg·ha⁻¹). No supplemental irrigation was applied. Commencing in 1987, trees were fall pruned with a tractor-mounted sickle bar mower, which removed about one-third of previous-season's growth from the top and sides of each tree.

The experimental design was a randomized complete block with eight replicates of six trees each. Beginning in Spring 1984 and each year thereafter, the cause of tree death was determined. Trees succumbing to PTSL typically collapse and die in the early spring, usually during or shortly after budbreak. Symptoms include trunk leakage with a distinctive "sour sap" odor, followed by collapse of blossoms and foliage. A distinctive feature of PTSL is that tissue damage initially proceeds only to the soil line, leaving the rootstock alive. The transition between living and dead

tissue is not associated with the graft union. Often the rootstock will sucker profusely following the death of the aboveground portion of the tree.

Trees can die from ARR at any time of the year, although in this region they are more likely to succumb during prolonged drought periods common in the late summer. Symptoms of ARR differ from those of PTSL in that ARR kills the root system, which, in turn, causes the aboveground portion of the tree to collapse and die. Upon inspection, one usually encounters a well-developed mycelial mat beneath the root bark, with a distinctive fan-like structure and perforations. The *Armillaria* mycelium rarely progresses much above the soil line.

Occasionally trees were judged to have died from other causes, such as peachtree borer [*Synanthedon exitiosa* (Say)], crown gall [*Agrobacterium tumefaciens* (Smith and Townsend) Conn], or mechanical injury. Such trees were eliminated from the dataset, as were those lines for which fewer than three replications were available. Survival data were transformed to arcsin square root percent before analysis (Gomez and Gomez, 1984). Data were analyzed by the General Linear Models (GLM) procedure (SAS Institute, 1988).

Results and Discussion

After 9 years, ≈50% of the starting population had succumbed to PTSL and 35% to ARR (Fig. 1). PTSL was the predominant cause of death during the first 7 years (PTSL data reported in Okie et al., 1994b). However, ARR gradually overtook PTSL as the primary cause of death during the last 4 years of this (Fig. 2). In all cases where basidiocarps appeared adjacent to trees determined to have been killed by root rot, basidiocarp morphology was consistent with *Armillaria tabescens*. There was a marginal negative linear correlation between percent mortality due to PTSL and ARR ($r^2 = 0.18$, $P < 0.001$, $n = 108$, suggesting little, if any, relationship between susceptibility to PTSL and that to ARR).

Rootstock lines differed significantly ($P < 0.0001$) in their susceptibility to ARR when expressed either as mean tree life (lifespan) or percent survival at the end of the experiment (Table 1). Since the experiment was terminated before all trees had died, estimates for mean tree life are conservative, especially for those lines displaying superior survival and longevity.

Seedlings of Lovell and Nemaguard, the standard rootstocks used commercially in the Southeast, did not differ significantly in average lifespan or survival, although values for Lovell were somewhat higher for both variables. The longest-lived peach lines are undergoing further testing to determine their commercial adaptability. Selection B594520-9 is of particular interest because very few trees were lost to ARR and it suffered the fewest losses to PTSL of all peach types tested (Fig. 1); in addition it carries resistance to tested populations of root-knot nematode (*Meloidogyne incognita* and *M. javanica*)

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Table 1. Mean lifespan and survival of peach and plum lines after 9 years on a peach tree short life (PTSL) and Armillaria root rot (ARR) infested field site. Lines arranged in order of percent survival.

Line	Type ^a	N total ^b	Lifespan (year) ^c	Survival (%) ^d	Notes ^e
Blue Goose	M	12	8.7	88.4	<i>Prunus angustifolia</i> hybrid?, collected Ala.
PI134151	P	27	8.3	80.8	'Transvaal Yellow', S. Africa
BY7446-14	M	25	8.2	76.7	Japanese-type plum ('Queen Ann' op ^g)F ₂ , Ga.
Edible Sloe	M	9	7.2	75.0	<i>P. umbellata</i> hybrid?, collected Ala.
B594520-9	P	43	7.9	73.9	Rootstock sel., ('S37' op x 'Nemaguard')F ₃ , Md.
BY7797-12	M	9	7.8	73.0	<i>P. americana</i> ('Jacobs' op), Ga.
Ferris	P	24	8.0	64.7	Rootstock
PI82413	P	27	7.5	60.5	'Baladi #1', Palestine
Stark Redleaf	P	22	7.5	54.2	Rootstock
Lovell	P	24	7.7	53.7	Cultivar, rootstock
Pekin/Lovell	P	31	7.6	51.4	Cultivar/rootstock
PI133987	P	19	7.5	50.5	'Nooiens Herholdt's', S. Africa
Satsuma	M	15	7.7	50.0	<i>P. salicina</i> , Japan
BY7789-303	M	7	6.5	50.0	Japanese-type plum ('Robusto' op), Ga.
NC152A12RH2	P	28	7.4	49.1	Rootstock sel., N.C.
B594520-8	P	28	6.8	46.1	Rootstock sel., ('S37' op x 'Nemaguard')F ₃ , Md.
Flordaguard	P	9	7.5	45.8	Rootstock
B14DR51	P	37	7.5	44.7	Rootstock sel., Md.
BY4-1050	M	11	7.6	44.3	Japanese-type plum ('Nubiana' op), Ga.
PI63850	P	25	7.3	43.6	'Shalil' sdlg., India
B594520-3	P	23	6.4	43.6	Rootstock sel., ('S37' op x 'Nemaguard')F ₃ , Md.
SCRS3	P	32	6.8	42.3	Feral sel., N.C.
B9-10	P	24	6.8	40.2	Hybrid ^d rootstock sel., Md.
Halford (cutting)	P	31	7.3	39.0	Cultivar, rootstock
Harrow Blood	P	20	7.4	37.6	Rootstock
Halford	P	30	7.3	37.5	Cultivar, rootstock
J68-254 = Red English	P	15	7.8	37.0	Feral sel., Ga.
PI65821	P	13	5.8	37.0	'Shau Thai Tao' sdlg., China
PI240928	P	20	6.9	36.8	'Mao Tao' sdlg., China
Lovell (cutting)	P	32	7.3	36.3	Cultivar, rootstock
Redglobe/FLA9-4	P	18	6.0	34.4	Rootstock sel., Fla.
B14DR56	P	23	7.1	32.8	Rootstock sel., Md.
Nemaguard	P	25	6.9	32.8	Rootstock
FLA9-4	P	31	6.8	32.0	Rootstock sel., Fla.
J68-69 = Indian Blood	P	20	7.5	30.9	Feral sel., Ga.
B9-13	P	12	6.3	30.9	Hybrid ^d rootstock sel., Md.
SCRS1	P	30	6.7	30.4	Feral sel., N.C.
GA107	P	20	7.1	29.8	Feral sel., Ga.
NA8	P	23	6.5	29.5	Feral rootstock sel., Tenn.
PI104488	P	24	6.1	28.9	'Gaschina Novembre', Italy
Redglobe/Halford	P	16	7.7	28.3	Cultivar/rootstock
J68-59 = FL15-122	P	14	5.0	28.3	<i>P. davidiana</i> sel., Fla.
J68-184 = Indian Cling	P	22	6.7	25.0	Feral sel., Ga.
PI125025	P	8	6.6	25.0	'China Flat', India
Tenn. Nat. R27	P	22	6.4	24.3	Feral rootstock sel., Origin unknown
B14DR53	P	28	6.3	21.4	Rootstock sel., Md.
Tenn. Nat. R2	P	28	6.8	21.0	Feral rootstock sel., Origin unknown
NA2	P	29	6.9	20.5	Feral sel., N.C.
Redglobe/Lovell	P	35	6.6	20.2	Cultivar/rootstock
RL Lovell	P	16	5.7	18.8	Rootstock sel.
Redglobe	P	21	6.9	16.2	Cultivar
Redglobe/Nemaguard	P	28	5.7	14.6	Cultivar/rootstock
J68-27 = Indian Cling	P	8	5.6	14.6	Feral sel., S.C.
B20-4	P	11	5.4	14.6	Hybrid ^d rootstock sel., Md.
GA102 = Indian Cling	P	30	5.9	13.9	Feral sel., Ga.
PI129674	P	22	6.0	13.3	'Angel', S. Africa
Tenn. Nat. R4	P	34	6.3	13.2	Feral rootstock sel.
J68-52	P	24	5.9	13.2	Rootstock sel. ('Nemaguard' x 'Tenn. Nat.'?), Ga.
Elberta	P	21	5.4	11.1	Cultivar, rootstock
J68-271	P	34	5.1	11.1	Feral sel., Ga.
PI112032	P	23	5.5	10.9	'Saharan Pur #1', India
B49-12	P	20	4.8	10.9	Hybrid ^d rootstock sel., Md.
J67-34 = Tenn. Nat.	P	23	6.0	8.7	Feral rootstock sel., Tenn.
J67-14	P	26	6.2	8.4	Hybrid ^d rootstock sel., Fla.
B20-11	P	28	5.1	8.4	Hybrid ^d rootstock sel., Md.
Nemaguard (cutting)	P	29	5.4	6.9	Rootstock
PI104287	P	29	6.0	6.7	'Soleil d'Octobre', Morocco
FV3-2	P	22	5.3	6.7	Hybrid ^d Rootstock sel., Ga.
B14DR57	P	28	4.7	4.7	Rootstock sel., Md.
PI125017	P	22	5.0	3.2	'Sary Oilor', USSR
RL8	P	12	5.0	2.4	Rootstock sel., Md.
Redglobe (cutting)	P	13	4.7	2.3	Cultivar

continued on next page

Table 1. Continued.

Line	Type ^c	N total ^y	Lifespan (year) ^x	Survival (%) ^w	Notes ^v
B14DR60	P	20	5.1	2.0	Rootstock sel., Md.
PI112033	P	10	5.9	1.7	'Saharan Pur #2', India
PI113455	P	23	5.0	1.7	<i>P. ferganensis</i> , USSR
B3-12	P	18	4.1	1.7	Hybrid ^d rootstock sel., Md.
B9-1	P	17	4.7	1.3	Hybrid ^d rootstock sel., Md.
PI77876	P	25	4.6	1.0	'Tos China #1', China
PI113452	P	23	5.1	0.4	'Rogani-Gow', USSR
SCRS10	P	26	4.7	0.4	Feral sel., Tenn.
B40-2	P	29	4.2	0.4	Hybrid ^d rootstock sel., Md.
B16-167	P	25	3.9	0.4	Rootstock sel., Md.
J68-14	P	14	5.7	0.0	Feral sel., Ga.
Rutgers Redleaf	P	16	5.5	0.0	Rootstock
B14DR52	P	19	5.4	0.0	Rootstock sel., Md.
Chui Lum Tao	P	20	5.1	0.0	Rootstock
J68-55 = Tenn. Nat.	P	13	5.1	0.0	Feral rootstock sel., Ga.
PI117679	P	20	4.6	0.0	'#01370', USSR
PI106062	P	9	4.4	0.0	'Killiekrankie', S. Africa
PI133551	P	8	4.4	0.0	'Peregrine', Australia
PI146137	P	15	4.1	0.0	'Selected Sdlg.', Spain
B58RL255	P	13	3.9	0.0	Rootstock sel., Md.
R76	P	18	3.7	0.0	Rootstock sel., Md.
PI78544	P	23	3.6	0.0	'Terzarolo Col Pizzo', Italy
B49-7	P	3	3.6	0.0	Hybrid ^d rootstock sel., Md.
B20-8	P	13	3.5	0.0	Hybrid ^d rootstock sel., Md.
PI65974	P	15	3.5	0.0	'De Coosa', Italy
Marianna 2624	M	12	3.4	0.0	Rootstock
J67-30 = Rancho Res. op	P	7	3.4	0.0	Rootstock sel., Ga.
LOV x NEM	P	15	3.4	0.0	Rootstock sel., Ga.
B3-10	P	14	3.3	0.0	Hybrid ^d rootstock sel.
PI43289	P	28	3.1	0.0	'Eagle Beak', China
Redglobe/Siberian C	P	23	3.0	0.0	Cultivar/rootstock
<i>P. davidiana</i>	P	8	3.0	0.0	---
Siberian C	P	28	2.9	0.0	Rootstock
Tzim Pee Tao	P	11	2.8	0.0	Rootstock
B3-6	P	14	2.7	0.0	Hybrid ^d rootstock sel., Md.
PI55776	P	5	2.3	0.0	'Yunnan' sdlg., China
Overall total or mean (108 lines)	---	2414	5.8	15.9	
MSD ^a			1.7	32.0	

^aM = plum (various *Prunus* species), P = peach (*P. persica* unless indicated otherwise).

^yExcludes losses to PTSL. For most lines maximum total n = 48.

^xMaximum = 9 years.

^wMeans backtransformed for presentation.

^vRootstock = commercial rootstock at one time; Rootstock sel. = selections from rootstock breeding programs; Feral rootstock sel. = locally selected rootstock type ("Tennessee Natural") of unknown pedigree; Cultivar = Commercial cv.; Feral selection = locally selected cultivar of unknown pedigree; PIs are typically cultivars in their country of origin.

^{op} = open pollinated.

^sS37 op x [(Rutgers Red Leaf x Yunnan)F₂].

^t(Okinawa x Hiland)F₂ op.

^uNemaguard x (Nemaguard x S37 op).

^aMSD = Minimum significant difference, K ratio = 100 (Waller-Duncan test).

(Nyczepir et al., 1996). Surviving seedlings of B594520-9 are the source of Guardian (BY520-9) rootstock seed (Okie et al., 1994a).

Clonal Marianna 2624 plum was one of the shortest-lived rootstocks and had been completely eliminated at the end of 9 years. This appears to conflict with previously published reports indicating that it is moderately to highly resistant to *Armillaria* (Norton et al., 1963; Raabe, 1979). This discrepancy might reflect variation in pathogen virulence within or among species; these previous publications do not specify which *Armillaria* species were involved. Hence, Marianna 2624 may not be tolerant to *Armillaria tabescens*. Alternatively, Marianna 2624's tolerance may be diminished by other biotic or abiotic factors in the Southeast, e.g., high temperatures, low soil pH, bacterial leaf spot [*Xanthomonas campestris* pv. *pruni* (Smith) Dye], bacterial canker

(*Pseudomonas syringae* pv. *syringae* van Hall), plum leaf scald [*Xylella fastidiosa* Wells], and ring nematode [*Criconebella xenoplax* (Raski) Luc and Raski]. Trees of Marianna 2624, especially those on their own roots, have generally displayed poor tree health and longevity at Byron, Ga. (W.R. Okie, personal observation).

As a group, the plum lines included in this trial appeared to offer better tolerance to ARR than did the peaches (Fig. 1). Most of the plum selections are complex hybrids (known or presumed) of Japanese plum germplasm (principally *P. salicina* Lindl.) with native North American species, such as *P. americana* Marsh., *P. angustifolia* Marsh., *P. munsoniana* Wight & Hedr., or *P. umbellata* Ell. Preliminary trials have shown that these lines (when used as seedlings) may lack adequate compatibility with peach cultivars for direct commer-

cial use as rootstocks. However, attempts to hybridize these lines with commercial peach rootstocks have been successful, and the hybrids may offer improved *Armillaria* tolerance, combined with adequate graft compatibility with peaches. Alternatively, the use of interstems may allow satisfactory commercial utilization.

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Fig. 1. Cumulative tree losses to peach tree short life (PTSL), Armillaria root rot (ARR), or undetermined causes (Other) of selected peach and plum lines after 9 years of field screening (Byron, Ga.).

Fig. 2. Annual tree losses to peach tree short life (PTSL), Armillaria root rot (ARR), or undetermined causes (Other) expressed as percentage of standing population at Byron, Ga. (1983–91).

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