Field-screening *Prunus* for Longevity in the Southeastern United States

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Abstract. Long-term field trials of a wide range of peach [*Prunus persica* (L.) Batsch] germplasm on two peach tree short-life (PTSL) sites revealed marked differences in survival among lines. Generally, cuttings and seedlings of a given line performed similarly, as did ungrafted seedlings and their counterparts grafted to a commercial cultivar. No apparent relationship existed between a line's chilling requirement and survival. B594520-9 survived best in Georgia and South Carolina, providing significantly greater longevity than Lovell, the standard rootstock for use on PTSL sites. B594520-9 is derived from root-knot-nematode-resistant parentage, and progeny of surviving seedlings have demonstrated root-knot resistance similar to Nemaguard seedlings.

The productive life of peach trees in the southeastern United States is reduced by the syndrome known as peach tree short life (PTSL). Affected trees suddenly collapse and die in the spring, usually 3 to 6 years after planting (Ritchie and Clayton, 1981). The disease complex results from an interaction of weather, ring nematode [*Crictonemella xenoplax* (Raski) Luc & Raski] parasitism, and cultural practices, such as previous crop, rootstock, and pruning date (Sharpe et al., 1989). Scion death is apparently caused by damage to the trunk from either cold injury or bacterial canker (*Pseudomonas syringae* pv. *syringae* van Hall). Chemical control of *C. xenoplax*, and hence PTSL, is currently possible with annual postplant nematicides, but such control is often not cost-effective. Land with no recent history of peach plantings is becoming scarce and expensive; it often has a microclimate marginally suitable for reliable peach production. Currently, Lovell peach rootstock is recommended to maximize tree longevity on PTSL sites.

In field plots and greenhouse pot tests, Lovell often supports lower ring nematode populations than Nemaguard, but both are good hosts (Okie et al., 1987; Sharpe et al.,

1989; Westcott and Zehr, 1991). Although greenhouse tests use less space and time than field tests, reduced host suitability may not

Fig. 1. Number of trees still alive (left axis and lines) and annual tree losses (right axis and bars) by cause overall and for seedlings of selected peach rootstocks. Field screening conducted in Byron, Ga., and Elgin, S.C., 1983-91. All South Carolina deaths due to peach tree short life (PTSL). Some Georgia mortality also caused by Clitocybe root rot (RRROT).

translate into longer life in the orchard. Therefore, field screening for longevity remains the definitive test for rootstock selection.

Due to the time and effort involved in field screening for longevity, only a few attempts have been made to identify long-lived *Prunus* germplasm. A few selections were made by C.N. Clayton and F.E. Correll in North Carolina about 40 years ago (unpublished). F.E. Johnstone, Univ. of Georgia, also made a modest effort in the late 1960s to collect long-lived local selections (Johnstone, 1971), but the program was short-lived. S. Doud, Fort Valley State College, continued this work at Byron for a few years in the late 1970s.

Lovell is susceptible to root-knot nematodes (*Meloidogyne* spp.). Where this nematode is common, Nemaguard rootstock is recommended, although trees on Nemaguard die quickly on PTSL sites. None of the other root-knot-resistant rootstock tested in the past, such as Yunnan, Shalil, and S-37, have survived well on PTSL sites in the southeastern United States. A rootstock conferring longer tree life, particularly in combination with root-knot-nematode resistance, would be of great value to the industry and is the primary goal of this research project. Preliminary reports of this work have been published (Cain et al., 1986; Okie et al., 1991; Reighard et al., 1989a, 1989b).

Materials and Methods

Open-pollinated seed of >140 diverse accessions of peach and plum (diploid *Prunus* hybrids) were collected in 1982, mostly at Byron, Ga., and planted in a nursery at Clemson, S.C. Unbudded trees were tested because of

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Table 1. Accession type, total number of trees (N), and percent tree death due to peach tree short life (PTSL) for peach and plum accessions screened at Byron, Ga., and Elgin, S.C., 1983-91. Georgia percentage also is expressed using data set that excludes any trees that died of Clitocybe root rot.

Accession type ^a				Accession	South Carolina		Georgia		Both states
NA/PI	RK/RS	PL	CV		N	% PTSL	N	% PTSL	
							All trees	-Root rot ^b	% PTSL
NA	RK			B594520-9	40	7.5	48	10.5	9.0
	RS			B14DR51	47	23.4	47	21.2	22.3
				J68-271	47	23.4	48	29.1	26.3
		PL		Edible Sloe	43	44.1	14	11.3	27.7
	RK			B594520-8	42	21.4	49	37.1	29.3
NA		PL		BY7789-303	0	---	14	33.2	33.2
		PL		BY7446-14	41	53.6	42	23.8	38.7
	RS			J67-34 = Tennessee Natural OP	48	33.3	42	45.1	39.2
	RS			Tennessee Natural R4	48	54.1	48	27.1	40.6
	RS			B14DR52	46	50.0	33	32.1	41.1
NA	RK			Nemaguard cutting	22	45.4	48	37.5	41.5
		PL		Blue Goose	35	62.8	29	20.8	41.8
	RS		CV	Lovell cutting	48	56.2	47	29.1	42.7
			CV	Transvaal Yellow	44	40.9	50	45.2	43.1
				SCRS3	47	53.1	48	33.5	43.3
NA				GA102 = Indian Cling	46	50.0	48	37.5	43.8
	RS		CV	Lovell VF	48	40.4	48	48.0	44.2
	RS		CV	Halford	49	53.0	49	35.5	44.3
	RK			J67-14 = Okinawa OP	47	46.8	49	42.1	44.5
			CV	Baladi	44	47.7	48	43.8	45.8
NA			CV	Pekin/Lovell	46	60.8	48	31.3	46.1
	RS			NA2	47	55.3	48	39.5	47.4
	RK		CV	NC152-AI-2RH = S-37 OP	43	55.8	48	39.6	47.7
	RS		CV	Halford cutting	38	60.6	48	35.5	48.1
		PL	CV	Satsuma	46	65.2	32	31.0	48.1
PI			CV	Herholdt Cling	39	71.7	11	25.0	48.4
	RK			BY20-11	48	62.5	49	34.6	48.6
	RK			FLA9-4	48	62.5	47	35.3	48.9
	RS			B14DR56	48	58.3	48	39.6	49.0
		PL		BY4-1050	37	81.0	18	17.0	49.0
NA				J68-184 = Indian Cling	43	44.1	47	54.1	49.1
				SCRS1	48	50.0	83	50.3	50.2
				SCRS10	39	76.9	47	25.0	51.0
	RK			ARK7771 = Nemaguard*Siberian C	45	51.1	0	---	51.1
				GA107	41	51.2	46	52.1	51.7
NA	RK			Nemaguard	48	54.1	49	49.2	51.7
	RK			B16-167	42	66.6	42	38.1	52.4
		PL		BY7797-12	0	---	22	53.2	53.2
	RS			B14DR53	40	67.5	48	39.5	53.5
				J68-69 = Indian Blood	43	48.8	48	58.2	53.5
PI	RK			FV3-2 = Nemaguard*(Nemaguard*S-37)	47	53.1	48	54.2	53.7
			CV	Gaschina Novembre	45	57.7	48	50.0	53.9
			CV	Nooiens Herholdts	44	63.6	33	44.5	54.1
				J68-52	47	61.7	48	47.7	54.7
	RS			Tennessee Natural R27	49	59.1	49	51.0	55.1
PI			CV	Eagle Beak	48	68.7	50	41.7	55.2
	RS			Lovell RL	48	47.9	48	62.5	55.2
			CV	Redglobe	46	58.6	48	52.1	55.4
			CV	Quetta	18	55.6	0	---	55.6
				<i>P. davidiana</i> VB	28	85.7	25	26.7	56.2
NA	RS			Boone County	24	66.6	14	46.0	56.3
			CV	China Flat	40	80.0	18	33.3	56.7
			CV	Peregrine	47	59.6	17	54.6	57.1
	RK		CV	Shalil	47	76.6	43	39.1	57.9
	RK			FLA14-11	44	70.4	21	46.0	58.2
PI	RK			BY3-6	45	54.3	48	62.5	58.4
		CV		Terzarolo Col Pizzo	43	65.1	48	52.1	58.6
	RS			B14DR57	46	76.0	48	41.6	58.8
	RS			GF677	27	59.2	0	---	59.2
	RS			Ferris	48	70.8	48	48.0	59.4
NA	RS			Tennessee Natural R2	46	78.2	48	41.7	60.0
				Ferganensis 2446	48	79.1	42	45.1	62.1
			CV	Rogani Gow	45	73.3	47	51.3	62.3
				Tos China #1	48	83.3	46	44.7	64.0
	RS			Rutgers Redleaf	46	73.9	48	54.1	64.0
PI			CV	Saharan Pur 1	48	79.1	48	50.0	64.6
			CV	Saharan Pur 2	47	55.3	48	75.0	65.2
	RK			B594520-3	47	87.2	48	43.7	65.5
	RS			NA8	42	83.3	48	47.8	65.6
	RK			BY49-12	48	79.1	48	52.1	65.6
PI	RS			Siberian C	51	90.1	48	41.7	65.9

Continued on next page

Table 1. Continued.

Accession type ²				South Carolina		Georgia			Both states
NA/PI	RK/RS	PL	CV	Accession	N	% PTSL	N	% PTSL	
	RK			BY9-10	45	82.2	48	49.8	66.0
PI	RS			Chui Lum Tao	48	79.1	48	54.1	66.6
PI			CV	Angel	48	85.4	48	47.8	66.6
	RS			B14DR60	46	78.2	48	56.3	67.3
PI			CV	De Coosa	47	65.9	48	68.7	67.3
	RK			BY40-2	46	97.8	48	37.5	67.7
PI	RS			Harrow Blood	41	95.1	48	41.1	68.1
	RS			ARK7768 = Boone* Siberian C	44	86.3	4	50.0	68.2
PI			CV	Violette Hative	48	68.7	0	---	68.7
PI			CV	Sary Oiler	47	89.3	47	48.7	69.0
	RK			J67-30 = Rancho Res. OP	45	53.3	48	84.8	69.1
PI			CV	Soleil D'Octobre	3	100	48	39.5	69.8
	RS			ARK7774 = Boone*NJ5110435	40	70.0	0	---	70.0
PI				PI117679	39	87.1	48	56.3	71.7
NA	RS		CV	J67-4 = Elberta OP	48	87.5	48	56.3	71.9
PI				Shau Thai Tao	40	77.5	48	66.7	72.1
	RK			BY3-12	47	87.2	49	57.8	72.5
	RK			BY9-1	46	82.6	48	62.5	72.6
PI				Mao Tao	38	89.4	48	56.1	72.8
	RK	PL		Marianna 2624 cutting	14	100	24	45.7	72.9
	RK			BY40-12	45	86.6	10	60.0	73.3
NA	RS			Stark Redleaf	48	91.6	49	56.2	73.9
NA	RS			J68-55 = Tennessee Natural OP	44	75.0	48	73.0	74.0
PI	RS	PL		Damas 1869	20	75.0	0	---	75.0
	RK			R76	47	95.7	42	57.1	76.4
	RS			RL8	47	78.7	50	74.5	76.6
	RK			BY9-13	48	79.1	48	75.0	77.1
	RS			Lovell x Nemaguard	48	85.4	48	68.7	77.1
PI				PI146137	47	87.2	49	67.0	77.1
	RK			BY3-10	48	89.6	48	66.6	78.1
	RK			BY20-8	46	100	30	56.6	78.3
			CV	Redglobe cutting	38	84.2	49	73.0	78.6
	RK			B58RL255	42	85.7	48	73.0	79.4
PI	RS			Tzim Pee Tao	48	85.4	48	75.0	80.2
PI	RS			J68-59 = <i>P. davidiana</i>	44	97.7	48	64.5	81.1
NA				J68-254 = Red English	47	93.6	48	68.7	81.2
NA				J68-14	38	92.1	49	71.6	81.9
	RK			ARK7861	45	82.2	0	---	82.2
	RK			BY20-4	47	91.4	48	75.0	83.2
PI			CV	Genovese	49	83.6	0	---	83.6
	RS			ARK7763 = Siberian C*Rut. RL	31	83.8	0	---	83.8
PI	RK		CV	Yunnan	40	82.5	48	85.3	83.9
PI			CV	Killiekrankie	48	89.6	48	79.1	84.4
	RK			BY49-7	45	100	48	70.7	85.4
	RK			ARK7860 = S-60*Boone	39	87.1	0	---	87.1
PI				PI119840	48	87.5	0	---	87.5
	RS			ARK7772 = Boone*Rut. RL	16	87.5	0	---	87.5
PI	RS			Montclar	39	89.7	0	---	89.7
		PL	CV	Opata	21	90.5	0	---	90.5
PI			CV	Royal George	18	94.4	0	---	94.4
PI			CV	Pineapple	42	95.2	0	---	95.2
PI			CV	Bolivian Cling	22	95.4	0	---	95.4
PI			CV	Khodjent Kostokos	29	96.6	0	---	96.6
	RK			BY40-3	32	100	0	---	100
	RK			ARK7762 = S-60*Rut. RL	23	100	0	---	100
PI				PI134401	14	100	0	---	100
	RS			ARK7764 = Siberian C*NJ5110435	14	100	0	---	100
	RS			ARK7759 = Siberian C*RR62-416	20	100	0	---	100
Waller-Duncan MSD ³						31.8		27.0	24.3

²Accession type: NA = natural or feral (U.S.) selection; PI = plant introduction or of foreign origin; RK = root-knot-nematode-resistant rootstock; RS = other rootstock; PL = plum; CV = fruit cultivar.

³Percentage based on limited data set includes only trees dead from PTSL or still alive at end of experiment [number of trees dead from PTSL/(initial tree total - trees dead from root rot) × 100].

⁴Minimum significant difference (k ratio = 100) for separating means within a column.

the difficulty of budding so many trees. About 85 accessions produced enough seedlings to be fully replicated at both sites. 'Redglobe' and four standard lines were included as rooted cuttings. Commercially budded trees of 'Pekin'/Lovell from North Carolina were also added as standards. Trees were dug Jan. 1983,

sorted by size for blocking purposes, and planted at the Sandhill Experiment Station, Elgin (near Columbia), S.C. (lat. 34°8'N; climate zone 7B), and at the U.S. Dept. of Agriculture (USDA) facility at Byron, Ga. (lat. 32°N; climate zone 8A). The USDA planting consisted of eight randomized blocks,

each containing a six-tree plot of most accessions. Soil type was a Faceville fine sandy loam. The site had a history of PTSL and had last been in peaches 2 years earlier. Preplant ring nematode populations obtained in Nov. 1982 ranged from 50 to 360 per 150 cm³ soil. The Elgin site consisted of six randomized

blocks of eight-tree plots. each on a site long planted to peaches. Soil type was a Lakeland fine sand. Tree spacing at both sites was 0.6 m within the row and 4-5 m between rows.

Trees were not thinned, and sprayed only on the trunk each fall for peachtree borer (*Synathedon* spp.). Fertilizer and herbicide application followed commercial recommendations. Trees were minimally pruned of lower limbs when young, then left unpruned, except for hedging in Fall (typically Dec.) 1985, 1986, 1988, and 1990 at Byron and Fall 1989 at Elgin. Each fall through 1986, all plots in four selected blocks at Byron were sampled for ring nematodes. Two probes of soil per tree were obtained and combined from the inner four of six treatment trees. Nematodes were extracted from 100-cm³ subsamples using elutriation (Byrd et al., 1976) combined with sugar-centrifugal flotation (Jenkins, 1964) and counted.

Survival data were tested using analysis of variance (SAS Institute, 1987). Transformation was ineffective in reducing the modest correlation between means and variances; therefore, no transformation was used. Means are based on plot means and separated using Wailer-Duncan k ratio test. Lines lacking substantial replication were excluded from the Wailer-Duncan test. Each spring (generally April) and fall (Byron only, 1983-86), dead trees were removed and the cause of death determined by digging around the roots. A few trees died from transplant shock, crown gall, or unknown causes. When mycelium of *Armillaria tabescens* (Stop.Fr.) Dennis was seen on the trunk or roots, Clitocybe root rot was designated the cause of death. This disease is endemic in the southeastern United States and causes substantial tree losses, particularly in heavier soils. Typical symptoms of PTSL were trunk cambial browning ending at the soil line and healthy roots, often with rootstock suckers appearing from below the ground. In South Carolina, PTSL symptoms often included bacterial canker.

Results and Discussion

Tree losses due to PTSL in Georgia were highest in 1986 and 1987 (Fig. 1). Tree losses were higher in years following fall pruning (hedging). Early losses were higher in Georgia than South Carolina (Fig. 1). Correlations of nematode counts and tree death were low (Georgia data not shown; South Carolina data in Reighard et al., 1989b), probably because the sample did not accurately reflect the true population under the trees. Root rot was not a cause of tree death in South Carolina. Death from root rot at Byron was fairly constant until tree counts declined in 1990. By 1991 only 11% of the original 4885 trees survived at Byron compared to 30% of the original 5366 at Elgin in 1990.

The large variation present in mean survival (Table 1) can be attributed to environment, nematode population density, and genetic heterogeneity. The ring nematode was detected under all test lines, but populations varied across the block (Fig. 2, Table 2). The

large degree of variation in the initial ring-nematode population density in the test plot at Byron was attributed to tree row influence resulting from a prior planting. Higher nematode counts were detected in soil taken closest to old tree rows. Such effects must be considered when establishing a new test orchard on an old site.

Tree losses at Byron due to Clitocybe root rot confound the losses due to PTSL. However, PTSL is more common in years 3 to 6 of an orchard, whereas root rot tends to kill trees later. Some trees may have been killed by both pathogenic agents together. The second column of percentages for Georgia in Table 1 presents PTSL losses as a proportion of live trees plus trees that died from PTSL (= total trees minus root-rot losses). A large difference in the two percentages for a given line in Georgia indicates higher root-rot losses.

Some variability in tree survival within lines may relate to genotype. Recent results indicate substantial genetic variability for longevity within a line (Beckman et al., 1993). Therefore, some survivors from otherwise poorly performing lines have been propagated for further testing.

The performance of standard rootstock (means for Lovell, Halford, Nemaguard, Siberian C) closely resembles that reported for budded trees in the southeastern United States (Dozier et al., 1984; Ritchie and Clayton, 1981; Sharpe et al., 1989). Lovell and Halford survived longest, followed by Nemaguard, with Siberian C surviving the shortest period of time. Losses for all lines are shown in Table

1. *Criconebella xenoplax* populations are poor indicators of tree survival (Table 2). All lines were good hosts and overall populations were high.

Tree losses were similar for rooted cuttings compared to seedlings of Nemaguard, Lovell, and Halford. 'Pekin' /Lovell trees survived slightly better than unbudded Lovell seedlings. 'Redglobe' rooted cuttings did not survive as well as 'Redglobe' seedlings. Lines with the prefix "J" or "GA" (Table 1) are from the naturalized and long-lived peach collections of F.E. Johnstone and W.E. Corley (USDA-Soil Conservation Service). Most were not exceptional, although J68-271 (collected in Gibson, Ga.) was one of the better survivors. Many of the poorer-surviving lines were root-knot-resistant lines.

Reighard et al. (1989a) found a low negative correlation (4.43) between a line's vegetative chilling requirement and tree survival for 28 selected lines in the Elgin planting. Trees from some lines with the lowest chilling requirements, such as 'Killiekrankie', were killed in 1985 following an unusually cold winter. FLA9-4, a selection from the Univ. of Florida rootstock breeding program, was the best-surviving, low-chilling line. However, comparatively high-chilling, cold-hardy rootstock, such as Chui Lum Tao, Tzim Pee Tao, and Siberian C, survived poorly. Clearly, scion chilling requirement does not determine susceptibility to cold injury from PTSL.

Planting unbudded seedlings or cuttings at high density appears to be a low-cost way to test a large number of genotypes. Unbudded

Fig. 2. Ring nematode population density beneath a portion (four blocks) of the Byron, Ga., rootstock planting that was established on a site previously planted to peach. Sampled Nov. 1983, about 10 months after planting trees. Each plot in each row was sampled (400 total).

Table 2. Mean ($\pm$ SE) *Criconebella xenoplax* populations per 100 cm³ of soil under seedlings of selected peach rootstocks and overall (102 accessions) on a PTSL site in Byron, Ga., 1983-89. Means of four blocks using pooled sample from each 6-tree plot.

Accession	1983	1984	1985	1986	1987	1988	1989
B594520-9	66 $\pm$ 23	1176 $\pm$ 242	1617 $\pm$ 879	598 $\pm$ 190	213 $\pm$ 19	67 $\pm$ 67	502 $\pm$ 248
Lovell	39 $\pm$ 17	1559 $\pm$ 762	1255 $\pm$ 323	506 $\pm$ 88	237 $\pm$ 49	184 $\pm$ 130	105 $\pm$ 34
Pekin/Lovell	15 $\pm$ 5	803 $\pm$ 432	1507 $\pm$ 497	690 $\pm$ 157	180 $\pm$ 30	92 $\pm$ 53	---
Halford	23 $\pm$ 4	766 $\pm$ 102	793 $\pm$ 250	1748 $\pm$ 1442	285 $\pm$ 154	184 $\pm$ 130	---
Nemaguard	85 $\pm$ 31	1564 $\pm$ 643	1071 $\pm$ 287	874 $\pm$ 138	254 $\pm$ 47	61 $\pm$ 61	311 $\pm$ 90
Siberian C	179 $\pm$ 145	1176 $\pm$ 385	992 $\pm$ 361	1656	---	---	---
Overall	119 $\pm$ 11	1187 $\pm$ 46	1567 $\pm$ 59	1149 $\pm$ 49	306 $\pm$ 15	305 $\pm$ 26	331 $\pm$ 83

seedlings reacted similarly to budded trees in this test. It would be more laborious and expensive to do such tests on budded trees. However, screening with unbudded trees may select for genotypes that survive well because of scion physiology, rather than because of rootstock effect.

B594520-9 was the best survivor at both sites (Table 1, Fig. 1), and sibling line B594520-8 also survived well. However, statistical superiority to Lovell was not evident until 1989, 6 years after planting. In a follow-up planting consisting of budded trees at a commercial spacing on a severe PTSL site in South Carolina (Reighard et al., 1991), BY520-9 (bulked seed of B594520-9 seedling selections) is surviving substantially better than Lovell in the 4th year. This increased longevity is not due to *C. xenoplax* resistance (Table 2).

As expected, based on B594520-9's parentage, which traces back to S-37 and Nemaguard, preliminary results also indicate that B594520-9 selections exhibit resistance comparable to Nemaguard to several root-knot species. B594520-9 was a remnant of the root-knot-resistant rootstock development program carried on by the USDA and de-emphasized after the introduction of Nemaguard in 1959. The source and nature of the factors resulting in greater longevity for B594520-9 and its surviving seedlings (collectively known as BY520-9), as well as for B594520-8, are

unknown, but they may have resulted from outcrossing that occurred during several cycles of open pollination. Unfortunately, the original B594520-9 selection no longer exists. BY520-9 has been released cooperatively by the USDA-Agricultural Research Service and Clemson Univ. (Okie et al., 1994).

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