Field Performance of Guardian™ Peach Rootstock Selections

B.S. Wilkins¹, R.C. Ebel², W.A. Dozier³, J. Pitts⁴, D.J. Eakes³, and D.G. Himelrick³

Department of Horticulture, Auburn University, 101 Funchess Hall, Auburn, AL 36849

T. Beckman⁵ and A.P. Nyczepir⁶

U.S. Department of Agriculture, Agricultural Research Service, Southeastern Fruit and Tree Nut Research Laboratory 21 Dunbar Road, Byron, GA 31008

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Abstract. Twelve peach [*Prunus persica* (L.) Batsch] seedling rootstocks [Lovell, Nemaguard, Flordaguard, 14DR51, five Guardian™ (BY520-9) selections, and three BY520-8 selections] budded with 'Cresthaven' were planted in 1994 and evaluated through 2000 to determine performance under commercial management practices. *Mesocriconema xenoplax* population densities were above the South Carolina nematode treatment threshold of 50 nematodes/100 cm³ of soil after 1996. However, symptoms of peach tree short life (PTSL) were not observed. Tree mortality was less than 14% through 1999, with most of the dead trees exhibiting symptoms consistent with *Armillaria* root rot. About 13% of the surviving trees in 1999 were removed in 2000 due to symptoms of phony peach. There were no differences in tree mortality among rootstocks. Tree growth, photosynthesis, and suckering varied among rootstocks, but leaf conductance, internal CO₂, and leaf transpiration did not. Foliar calcium, magnesium, iron, and phosphorus varied among rootstocks, but all were within the range considered sufficient for peach trees. Fruit yield varied among rootstocks, but yield efficiency did not, indicating that higher yield corresponded with larger trees. Bloom date did not vary among rootstocks, but harvest date was advanced as much as 2 days for some rootstocks, compared to Lovell. Fruit weight varied among rootstocks but skin color, flesh firmness, and soluble solids content were similar. All rootstocks performed satisfactorily for commercial peach production.

Peach tree short life (PTSL) is one of the most important causes of tree mortality in the southeastern United States (Miller, 1994; Weaver et al., 1974; Wehunt et al., 1980). PTSL is a disease complex that results in sudden collapse and death in early spring of peach trees that appeared healthy the preceding growing season (Brittain and Miller, 1978; Dozier et al., 1983, 1984; Zehr et al., 1976, 1982). The mechanism causing PTSL is not known, but time of pruning, soil pH, and especially ring nematode [*Mesocriconema xenoplax* (Raski) Loof & de Grisse] have been identified as predisposing factors, and bacterial canker (*Pseudomonas syringae* pv. *syringae* van Hall) and subfreezing temperatures appear to be the ultimate cause of death (Brittain and Miller, 1978; Dozier et al., 1983; Nesmith et al., 1981; Nyczepir et al., 1983; Okie et al., 1994; Reilly et al., 1986; Ritchie and Clayton, 1981; Zehr et al., 1976, 1982).

A severe outbreak of PTSL in the 1970s, coupled with the recognition that PTSL is

related to soil factors, led breeders at the USDA-ARS Southeastern Fruit and Nut Laboratory in Byron, Ga., to shift research efforts to identify rootstocks that were more resistant to PTSL than Lovell, the commercial standard at that time (Beckman et al., 1997; Okie et al., 1994b). Much of the early screening was of open-pollinated seedlings, including selections B594520-8 and B594520-9 (Okie et al., 1994a). The original B594520-8 and B594520-9 trees were destroyed, but seedlings from these original trees survived field trials and have been collectively designated as BY520-8 and BY520-9, respectively. Field studies demonstrated that seedlings from BY520-9 had the lowest incidence of tree death due to PTSL (Beckman et al., 1994; Okie et al., 1994b; Reighard et al., 1994). Based on the survival data and grower demand, bulked open-pollinated seeds from about 30 of the surviving trees of BY520-9 have been released jointly by the USDA-ARS Southeastern Fruit and Nut Laboratory and Clemson Univ. under the trade name Guardian™ (Beckman et al., 1997).

Because of the inherent genetic diversity among the 30 BY520-9 lines that contribute to the bulked commercial Guardian seedlot, studies were initiated in 1992 in Georgia and South Carolina, and in 1994 in Alabama to identify individual selections whose seedlings would not only have resistance to PTSL, but also yield and other horticultural characteristics

similar to or better than commercial rootstocks. The Georgia and South Carolina studies demonstrated enhanced survivability of the Guardian selections tested against commercial rootstocks, but excessive tree death rendered the trials unsuitable for determining productivity (Beckman et al., 1997). This report describes the results of the 1994 Alabama planting. The specific objectives were to determine differences in growth, productivity, and fruit quality among several Guardian rootstock selections and other commercial and test rootstocks. Comparisons were principally made to Lovell because more is known about this particular rootstock due to its prevalence in the commercial industry in the last few decades. It is anticipated that once superior selections of Guardian have been identified, the current bulked Guardian version will be withdrawn from commercial use (Okie et al., 1994a).

Materials and Methods

Plant material and field layout. In Jan. 1994, trees of 'Cresthaven' peach budded on 12 rootstocks were planted in a Bama fine sandy loam (fine sandy loam, siliceous, subactive, thermic, Typic Paleudults) at the Chilton Research and Extension Center, Clanton, Ala. The trees were spaced 3.6 × 6.1 m in a randomized complete-block design with 10 blocks, each containing five tree plots on each rootstock. The first and fifth trees of each treatment plot were used as buffer trees whereas data were collected from the second, third, and fourth trees. Rootstocks tested included Lovell, Nemaguard, Flordaguard, 14DR51, five Guardian selections (SL1089, SL1090, SL3576, SL2165, SL2170), and three selections of the sister line BY520-8 (SL2243, SL1923, SL4028).

Incidence of ring nematodes. Population density of ring nematode was determined in Aug. 1996 at five random locations by combining six soil cores 2.5 cm in diameter and 30 cm deep taken at each location. In Aug. 1997 and 1998, Mar. 1999, and Dec. 2000, two soil cores were collected from each of the three data trees for each treatment replication. The six cores were composited by plot within each replicate. Nematodes were extracted from a 100-cm³ subsample with a semi-automatic elutriator (Byrd et al., 1976) and centrifugal-flotation (Jenkins, 1964).

Growth, foliar nutrient analysis, and photosynthesis. In the fall of each year, tree diameter of all data trees was determined 30 cm above the soil, and trunk cross-sectional area (TCA) was computed as an indicator of tree vigor. Rootstock suckers were counted each year.

Foliar analysis was conducted each August by removing a composite sample of 100 fifth or sixth node leaves from the data trees of each of seven replications. Leaves were dried for 1 week in a forced air sample drier at 60 °C, ground in a Cyclotec Model 1093 sample mill, and analyzed following the procedures of the Auburn Univ. Soil Testing Laboratory (Hue and Evans, 1986). Essential nutrients except

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¹Field Research Associate III.

²Assistant Professor; to whom reprint requests should be addressed. E-mail: rcebel@acesag@auburn.edu

³Professor.

⁴Superintendent.

⁵Research Horticulturist.

⁶Research Nematologist.

nitrogen were measured with an inductively coupled argon plasma spectrometer (Jarrell-Ash, ICAP 9000). Total N was determined by the micro-Kjeldahl method in 1995 and by a Leco CHN-600 analyzer (LECO Corp., St. Joseph, Mich.) in subsequent years.

A preliminary experiment was conducted in May, June, July, and Aug. 1996 to determine whether there were differences among rootstocks in the diurnal pattern of gas exchange rates using a portable photosynthesis system (Licor Model 6250, Lincoln, Nebr.). Three of the most recently matured leaves, approximately the fifth node from the terminal and in full sun, were evaluated on three consecutive clear days of similar temperature and at three different time intervals during the day. The time intervals were 0900–1100, 1100–1300, and 1300–1500 HR. Data were analyzed as a blocked (by day) split-plot over time (by time interval) using the General Linear Model procedure (GLM) of the Statistical Analysis System (SAS Institute, 1988). No diurnal differences were found, so sampling was changed in subsequent years by sampling between 1100 and 1430 HR and once per month during the growing season with a portable photosynthesis system (LI-COR Model 6400).

Productivity and fruit quality. There was no crop in 1996 due to a late spring frost. Bloom development was determined in subsequent years from three, 50-cm-long shoots, one each from the SE, SW, and NE side of the tree. Buds were rated at 3- to 7-d intervals for stage of development using a five-stage scale that included dormant, calyx green, first pink (popcorn), open petals (full bloom), and petal fall. Trees were considered to be in full bloom when 80% of the flower buds had opened.

Fruit were harvested from 1997 through 2000, at 3- to 4-d intervals with fruit selected on the basis of ground color change from green to yellow. Fruit were harvested only from the center data tree of each treatment replication, and only five replications per rootstock were sampled. Fruit were sorted on a grader and separated into five diameter categories including <5.1 cm, <5.7 cm, <6.4 cm, <7.0 cm, <7.6 cm, and >7.6 cm. Fruits from each tree were counted and weighed. Harvest date was determined using a weighted means average procedure (Stembridge and Gambrell, 1974).

Fruit quality was determined on the second harvest date each season on 10 fruits from the 7.0-cm-size class from each treatment replication. Firmness was measured using a handheld penetrometer with a 0.8-cm tip (McCormick Fruit Tech, Yakima, Wash.). Soluble solids were measured using a portable refractometer (Westover Model RHB 32ATC). Fruit were rated for the extent of red skin blush using a scale of 0%, 25%, 50%, 75%, and 100% red color.

All data were analyzed as a randomized complete-block design using the GLM procedure of SAS (SAS, 1988). Where appropriate, data were analyzed as a split plot over time. Trunk growth rate (cm²/year) was determined by calculating a regression of the TCA over years for each treatment replication using the SAS Regression procedure. All regressions

Table 1. Soil population density of *Mesocriconema xenoplax* on 12 peach rootstocks planted in 1994 (n = 10).

Rootstock	No. nematodes/100 cm ³ of soil			
	1997	1998	1999	2000
Lovell	96 c	212	96	62
Nemaguard	229 abc	353	513	195
Flordaguard	88 c	503	368	281
14DR51	87 c	287	230	92
Guardian selections				
SL1089	96 c	312	519	312
SL1090	123 bc	195	416	89
SL2165	491 a	253	193	182
SL2170	187 abc	125	278	90
SL3576	477 ab	222	497	81
BY520-8 selections				
SL1923	512 a	362	397	69
SL2243	382 abc	141	388	124
SL4028	261 abc	276	255	191

Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

were significant with the regression coefficient greater than 0.95 for all determinations. Each plot's regression slope, which is equivalent to trunk growth rate (cm²/year), were used as a replication and differences between rootstock treatments were determined using the GLM procedure of SAS. A protected Duncan's multiple range test was used to separate main effect means ($P \leq 0.05$) when all interactions were nonsignificant.

Results and Discussion

Tree survival and ring nematode population density. There were no significant differences in tree survival among rootstocks through the 1999 growing season. Survival ranged from 86% to 100%. Of the few trees that died, the cause of death was not positively determined although many trees had symptoms consistent with *Armillaria* root rot [*Armillaria mellea* (Vahl:Fr.) P. Kumm]. There was an outbreak of phony peach (*Xylella fastidiosa*, Wells) in 1999 that required removal of about 13% of the trees from the orchard, but there was no difference in phony incidence among rootstocks. There were no symptoms of phony in 2000.

In 1996, ring nematode population density was not above 50 *M. xenoplax*/100 cm³ of soil (data not shown), the SC nematode treatment threshold used in the management of PTSL (Nyczepir, 1985; Nyczepir and Okie, 1996). Ring nematode population density increased above the threshold level for all rootstock treatments in subsequent years (Table 1). Despite the high population density of ring nematode, PTSL did not develop in this trial, indicating that other conditions necessary for symptom development were not present. Rootstocks differed significantly in ring nematode population densities only in 1997, when Guardian selections SL2165 and SL3576 and BY520-8 selection SL1923 supported significantly more ring nematodes than Lovell, Flordaguard, 14DR51, and SL1089. Lovell displayed one of the lowest ring nematode population densities in 1997, whereas Guardian selections SL2165 and SL3576 were among the highest. These

data are in agreement with reports from greenhouse trials that demonstrated that Guardian supported populations of *M. xenoplax* similar to or higher than Lovell (Beckman et al., 1997).

Growth, photosynthesis, foliar nutrition, and suckering. Most rootstocks had similar trunk growth rates compared to Lovell during the life of the orchard except BY520-8 selections SL1923 and SL4028, which were significantly greater (Table 2). By the year 1999, BY520-8 selection SL4028 had TCA that was about 25% larger than Lovell, Nemaguard, SL2165, and SL3576, and the other rootstocks were intermediate. There were no differences among rootstocks in TCA in 2000.

Stomatal conductance, internal leaf CO₂, and leaf transpiration did not vary among rootstocks (data not shown). Photosynthetic flux did vary among rootstocks (Table 2), but the rates did not correspond with differences in TCA or trunk growth rate. For example, TCA of BY520-9 selection SL1923 was much larger than Lovell, but the average photosynthetic flux was similar.

Guardian selection SL1089 produced the greatest number of rootstock suckers with an average of 4.4 suckers per tree (Table 2). Lovell was intermediate in suckering with an average of 2.4 suckers per tree, whereas 14DR51 and BY520-8 selection SL1923 were the lowest in suckering. Reighard et al. (1994) reported that suckering of Guardian was similar to Lovell; however, Guardian selection SL1089 suckered significantly more than Lovell in this study.

There were no significant differences among rootstocks in leaf foliar concentration of nitrogen, potassium, copper, iron, manganese, boron, and zinc (data not shown), which were all in a range considered sufficient for peach (Mills and Jones, 1996). Calcium, magnesium, and iron varied significantly among rootstocks (Table 3); however, all concentrations were within the sufficiency range. There was a significant rootstock $\times$ year interaction for phosphorus, but there was no clear pattern with respect to rootstock across years (data not shown). Like the other nutrients, phospho-

Table 2. Effects of peach seedling rootstocks on growth and photosynthetic flux of 'Cresthaven' peach and rootstock suckering at Clanton, Ala. (1997–2000).

Rootstock	Trunk growth rate (cm ² /year)	Trunk cross-sectional area (cm ²)		Photosynthesis ($\mu\text{mol CO}_2\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)	Suckers (no./tree)
		1999	2000		
Significance					
Rootstock (R)	*	*	NS	*	*
R $\times$ month (M)	---	---	---	NS	---
R $\times$ year (Y)	---	---	---	NS	---
R $\times$ M $\times$ Y	---	---	---	NS	---
Means					
Lovell	28.0 c	145 c	168	15.1 abc	2.4 bcd
Nemaguard	29.8 c	154 c	175	14.6 abc	3.0 bc
Flordaguard	30.5 bc	160 bc	182	14.9 abc	1.4 de
14DR51	29.6 c	148 c	180	14.7 abc	0.6 e
Guardian selections					
SL1089	31.4 abc	161 bc	188	14.0 c	4.4 a
SL1090	31.7 abc	170 abc	183	15.2 ab	2.1 bcde
SL2165	28.87 c	152 c	171	15.2 ab	1.3 de
SL2170	31.1 abc	161 bc	187	15.1 abc	2.3 bcd
SL3576	29.7 c	154 c	176	14.1 bc	1.1 de
BY520-8 selections					
SL1923	35.6 ab	196 a	201	14.5 abc	0.9 de
SL2243	29.6 c	150 c	179	15.2 ab	3.4 ab
SL4028	36.3 a	187 ab	211	15.5 a	1.6 cde

NS. *Nonsignificant or significant at $P \leq 0.05$, respectively. Mean separation within columns by Duncan's multiple range test.

rus, which varied from 0.189% to 0.204%, was within the range considered sufficient for peach.

Productivity and fruit quality. A late winter freeze destroyed the flowers in 1996, resulting in no yield that year. Fruit yield from 1997 through 2000 was highest for SL1923, lowest for SL2170, and intermediate for other rootstocks (Table 4). There was no difference in yield efficiency among rootstocks, which indicates that differences in yield corresponded to tree size.

There was no difference among rootstocks in bloom date (data not shown), whereas an earlier study showed that Guardian advances bloom date by several days (Beckman et al., 1994). Harvest date in the current study varied up to 2 d among rootstocks, with trees on many rootstocks having an advanced harvest date compared to those on Lovell. These data support the findings of Beckman et al. (1994), who reported that the harvest date for Guardian was the same or slightly advanced compared to Lovell. It is not known how other peach cultivars will perform on Guardian rootstock or its individual selections.

Fruit weight varied among rootstocks but was acceptable for commercial production for all rootstocks. Fruit weight on all Guardian selections was equal to or larger than on Lovell. There were no significant differences in soluble solids, fruit firmness, and percent red blush among rootstocks (data not shown).

Conclusions. Tree survival was sufficient in this study to properly evaluate growth and productivity of Guardian selections compared to Lovell and other test rootstocks. In general, all rootstocks performed satisfactorily in this study with most differences relatively minor for commercial production. However, Guardian selection SL1089 may sucker excessively, and rootstock-induced differences in tree vigor may necessitate some adjustments in tree spacing.

Table 3. Effects of peach seedling rootstocks on foliar nutrient levels of 'Cresthaven' peach at Clanton, Ala. (1995–99).

Rootstock	Ca (%)	Mg (%)	Fe (ppm)
Significance			
Rootstock (R)	*	*	*
R $\times$ year	NS	NS	NS
Means			
Lovell	1.91 bc	0.516 b	105 ab
Nemaguard	1.86 cd	0.449 c	95 b
Flordaguard	2.04 a	0.515 b	114 a
14DR51	1.78 de	0.454 c	103 ab
Guardian selections			
SL1089	1.89 bcd	0.519 b	106 ab
SL1090	1.73 e	0.544 a	109 a
SL2165	1.90 bc	0.521 b	102 ab
SL2170	1.79 de	0.519 b	104 ab
SL3576	1.78 de	0.521 b	109 a
BY520-8 selections			
SL1923	1.99 ab	0.537 ab	108 a
SL2243	1.99 ab	0.519 b	109 a
SL4028	1.82 cde	0.521 b	110 a

NS. *Nonsignificant or significant at $P \leq 0.05$, respectively. Mean separation within columns by Duncan's multiple range test.

Table 4. Effect of peach seedling rootstocks on productivity, harvest date and fruit quality of 'Cresthaven' peach at Clanton, Ala. (1997–2000).

Rootstock	Yield (kg/tree)	Harvest date compared to 'Lovell' (days) ^a	Fruit wt (g/fruit)
Significance			
Rootstock (R)	*	*	*
R $\times$ year	NS	NS	NS
Means			
Lovell	43.2 bcd	0 a	159 bc
Nemaguard	36.8 cd	-0.3 ab	166 abc
Flordaguard	38.1 cd	-1.9 e	178 a
14DR51	44.4 bc	-1.1 bcde	158 c
Guardian selections			
SL1089	50.0 b	-0.3 ab	165 abc
SL1090	42.7 bcd	-0.7 abc	165 abc
SL2165	38.8 cd	-1.6 cde	175 ab
SL2170	33.8 d	-1.7 de	179 a
SL3576	42.1 bcd	-0.4 ab	156 c
BY520-8 selections			
SL1923	61.4 a	-0.8 abcd	168 abc
SL2243	42.7 bcd	-0.6 abc	170 abc
SL4028	43.1 bcd	-1.1 bcde	180 a

^aDays from Lovell were determined using a weighted means average procedure (Stembridge and Gambrell, 1974).

NS. *Nonsignificant or significant at $P \leq 0.05$, respectively. Mean separation within columns by Duncan's multiple range test.

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