Rootstock performance in the 2009 NC-140 peach trial across 11 states

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Abstract

From 14 to 18 *Prunus* rootstocks budded with 'Redhaven' peach were planted at 16 locations in North America in 2009. Seven-year performance from 12 remaining locations in 11 states showed that significant differences among rootstocks and sites were found for survival, root suckers, growth, bloom date, fruit maturity date, fruit size, cumulative yield, and yield efficiency. Survival was highest for peach seedling rootstocks at all locations. In contrast, survival of non-peach species and hybrid rootstocks was poor to fair in Missouri (winter cold, wet feet conditions) and Alabama, Georgia, North Carolina, and South Carolina due to bacterial canker. Krymsk®1, Krymsk®86, Penta, Controller™ 5 and Mirobac (aka Replantpac or Rootpac®R) were the most susceptible to tree death from *Pseudomonas syringae* canker in the four southeastern states. Overall, Imperial California had the lowest survival followed by Fortuna and Krymsk®1. Rootstock suckering was excessive on *Prunus americana* seedlings with lesser suckering noted on, Mirobac, Krymsk®1 and Penta. Largest trees were three *Prunus* x almond hybrids (Viking, Atlas, Brights Hybrid #5) and Guardian®. Fruit size varied with location and crop load (i.e., some rootstocks had few fruit). Atlas produced the largest fruit and Fortuna the smallest fruit across all sites. Cumulative yields were highest in the peach rootstocks such as Guardian®, Lovell and KV010127 and on Atlas. The lowest yields were from plum hybrids and plum species. Cumulative yield efficiency was higher on the non-peach rootstocks, but these rootstocks also produced trees much smaller than the peach and almond hybrid cultivars. The clonal *P. persica* rootstocks HBOK 10 (Controller™ 8) and HBOK 32 (Controller™ 7) appeared to be the most promising of the size-controlling rootstocks tested. These data suggest there was no demonstrated advantage to increase yield/ha by using clonal interspecific *Prunus* hybrids for peach production under current cultural practices. However, on higher pH soils in Colorado and Utah, peach seedlings were not the superior rootstocks for production so continuing evaluation of non-peach rootstocks is warranted.

Keywords: *Prunus persica* L., interspecific hybrids, plum, almond, *Pseudomonas syringae*

INTRODUCTION

Prunus interspecific hybrids and plum species have replaced peach [*P. persica* (L.) Batsch] as preferred rootstocks for peach cultivars in Europe and are becoming more important in some areas of North America. Peach is partially to completely graft compatible with several species within its taxonomic Section *Euamygdalus* Schne *Microcerasus*. When breeding new rootstocks for peach from intra- and interspecific crosses, field-testing of budded peach scion cultivars to ascertain good graft compatibility for tree nutrition, growth, fruit quality and survival under normal orchard conditions is the step before commercialization (Zarrouk et al., 2006; Reighard and Loreti, 2008). In addition, adaptation or tolerance to different soils, climates, pests and diseases are also important.

Peach has been budded with many species from Section *Euprunus*. Compatibility has been good with some rootstock selections from *P. insititia* L. (damson plums), *P. spinosa* L. (sloe plum), *P. domestica* L. (European plum), *P. salicina* Lindl. (Japanese plums), and *P. cerasifera* Ehrh. (myrobalan or cherry plum). Myrobalan plums are often more compatible when they are first hybridized with other plums. The best examples are some commercially available selections of *P. americana* Marshall and *P. pumila* L. (Pumiselect®) that are partially to very compatible with peach cultivars, but tend to be dwarfing.

The objective of this study was to evaluate the compatibility and performance of new *Prunus* rootstocks for peach budded to 'Redhaven' across peach growing regions in North America.

MATERIALS AND METHODS

Rootstocks

'Redhaven' peach was grafted to a total of 18 rootstocks represented in 16 replicated orchard trials across the USA (13 states) and in Mexico (Chihuahua). These trials were planted in 2009 in the following states: Alabama, California, Colorado, Georgia, Illinois, Kentucky, Massachusetts, Missouri, New York (2 sites), North Carolina, Pennsylvania, South Carolina and Utah (2 sites). No initial data were provided by Mexico and one New York location. Data was discontinued from California and Illinois in 2013. The rootstock cultivars included 7 interspecific *Prunus* hybrids and 3 *Prunus* species with semi-dwarfing rootstocks considered to be 70-90% and dwarfing rootstocks <70% of Lovell in trunk cross-sectional area (Table 1).

Data Collected and Analyses

Each trial was planted as a randomized block design with 8 replicates of single-tree plots of each rootstock. Some rootstocks such as Tetra, Imperial California and Fortuna were only planted at a few sites. Orchards received standard cultural practices for each location and were irrigated. Annual survival, tree circumference (TC), calculated trunk cross-sectional area (TCSA), root sucker counts, 90% bloom date, 10% maturity date, yield, calculated yield efficiency and mean fruit weight were recorded. Analyses of variance (ANOVA) were used to detect differences among rootstock means and locations using PROC GLM and SAS macro PDMIX612 (SAS, Cary, NC). When a significant difference was detected among rootstock or location means, means were separated by Tukey's Studentized Range (HSD) test, $P \leq 0.05$.

RESULTS AND DISCUSSION

Percent survival, TCSA, or TC for 'Redhaven' on each rootstock are given in Table 2. Rootstocks with poor or below average survival and associated observations were Imperial California (bacterial canker), Fortuna (graft incompatibility), Tetra (unknown), and Krymsk®1 (bacterial canker). All other rootstocks had scion survival rates of 72 to 95% for those planted at multiple sites. Survival was lowest in North Carolina, Georgia and Alabama all primarily due to bacterial canker, and Missouri (waterlogging, windthrow) (Table 3).

Tree growth was significantly influenced by rootstock and location (Tables 2 and 3). Atlas, BH-5, Viking, Guardian® and Krymsk®86 were the most vigorous rootstocks (i.e., vs. TCSA of Lovell). HBOK 10, HBOK 32, and Penta were semi-dwarfing rootstocks, and Krymsk®1, *P. americana*, Fortuna and Controller™5 were the most dwarfing. The largest trees were in South Carolina and Alabama; whereas the smallest trees were in Colorado and one trial in Utah, where both sites had high pH soils. *P. americana* produced significantly more root suckers (data not shown).

Bloom date was only recorded at half the locations (Table 3), but was affected little (< 3 days) by rootstock (data not shown). As expected, however, bloom dates were significantly different between locations, ranging from 24 to 64 day differences within years (only 5-yr mean in Table 3) and as much as 35 days (data not shown) between years for New York.

Rootstock cultivar significantly influenced cumulative yields and fruit weight (Table 4). Vigorous rootstocks had high yields and low vigor rootstocks had low yields. Not unexpected, the high vigor rootstocks such as Viking, BH-5, Replantpac® and Krymsk®86 had lower cumulative yield efficiencies. Most semi-dwarf and dwarfing rootstocks had the highest cumulative yield efficiencies. However, not all of the less vigorous rootstocks with low mortality were yield efficient (e.g., Penta). Yields were also significantly different across locations (Table 5). South Carolina and Missouri had the highest cumulative yields. Colorado had the lowest yields partly due to cold damage and high pH soil. Cumulative yield efficiency was highest in South Carolina, North Carolina, Missouri and Utah, which were also statistically higher than the lowest ranking states of Alabama, Georgia, Colorado and Pennsylvania (Table 5).

Fruit weight was affected by both rootstock and location (Tables 4, 5). Vigorous rootstocks tended to produce fruit slightly larger than the other rootstocks (Table 4). Location had a very large effect on fruit size. South Carolina and one Utah site consistently produced the largest fruit (Table 5). New York and Georgia had the smallest fruit.

Excluding three plum rootstocks (Tetra, Imperial California and Fortuna) with limited representation, ripening date was advanced by some rootstocks as much as four days on average in some years when compared to Lovell (data not shown), which consistently has ripened fruit later than average in rootstock trials (Reighard, personal observation). Overall, maturity dates were significantly influenced by locations (Table 5) with Alabama, Georgia and South Carolina having the earliest maturity dates and New York and Massachusetts the latest. There was an average of a 49-day difference between the earliest and latest locations in 'Redhaven' ripening date.

CONCLUSIONS

Results from this study are still preliminary, but past NC-140 peach rootstock trials have shown rootstock productivity usually does not change much in ranking after three years of bearing (Reighard et al., 2004). However, in this study increasing tree mortality affected performance rankings such that field testing for disease resistance, especially in the southeastern U.S., should be completed first before releasing an untested rootstock commercially. Results for this trial also indicate that Fortuna was potentially incompatible with peach, and Imperial California, Krymsk®1, and Replantpac® rootstocks were susceptible to bacterial canker at several locations.

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Literature Cited

Reighard, G., Andersen, R., Anderson, J., Autio, W., Beckman, T., Baker, T., Belding, R. Brown, G., Byers, P. Cowgill, W., Deyton, D., Durner, E. Erb, A., Ferree, D., Gaus, A., Godin, R., Hayden, R., Hirst, P., Kadir, P., Kaps, M., Larsen, H., Lindstrom, T., Miles, N., Morrison, F., Myers, S., Ouellette, D., Rom, C., Shane, W. Taylor, B., Taylor, K., Walsh, C. and Warmund, M. 2004. Growth and yield of Redhaven peach on 19 rootstocks at 20 North American locations. J. Amer. Pomol. Soc. 58(4):174-202.

Reighard, G.L. and Loreti, F. 2008. Rootstock development. In: Layne, D.R. and D. Bassi (Eds.) The Peach: Botany, Production and Uses. CAB International, Wallingford, U.K., pp. 193-220.

Zarrouk, O., Aparicio, J., Gogorcena, Y. and Moreno, M.A. 2006. Graft compatibility for new peach rootstocks in nursery. Acta Hort. 713:327-329.

Tables

Table 1. Rootstock cultivars in the 2009 NC-140 trial and their species composition.

Rootstock Cultivar	Country Origin	Species	Tree vigor (% of Lovell)
Lovell	U.S.A.	*Prunus persica*	100
Guardian®	U.S.A.	*P. persica*	110
KV 10123	U.S.A.	*P. persica*	100
KV 10127	U.S.A.	*P. persica*	100
Controller™ 8 (HBOK 10)	U.S.A.	*P. persica*	90
Controller™ 7 (HBOK 32)	U.S.A.	*P. persica*	80
BH-5 (Bright's Hybrid #5)	U.S.A.	*P. dulcis x P. persica*	110
Prunus americana	U.S.A.	*P. americana*	60
Empyrean® 2 (Penta)	Italy	*P. domestica*	80
Empyrean® 3 (Tetra)	Italy	*P. domestica*	70
Imperial California	Italy	*P. domestica*	70
Replantpac® (Mirobac)	Spain	*P. cerasifera x P. dulcis*	110
Fortuna	Russia	*P. cerasifera x P. persica*	70
Krymsk® 86	Russia	*P. cerasifera x P. persica*	110
Krymsk® 1	Russia	*P. tomentosa x P. cerasifera*	50
Controller™ 5	U.S.A.	*P. salicina x P. persica*	60
Viking	U.S.A.	*P. persica x* (*P. dulcis x* (*P. cerasifera x P. mume*))	110
Atlas	U.S.A.	*P. persica x* (*P. dulcis x* (*P. cerasifera x P. mume*))	120

Table 2. Mean survival, TCSA, and circumference of Redhaven on each rootstock across locations.[z]

Rootstock cultivar	Survival (%) Fall 2013		Survival (%) Fall 2015		TCSA (cm^2) Fall 2013		TC (cm) Fall 2015	
Viking	86	ab	75	cde	125	ab	46	ab
Atlas	86	ab	75	cde	127	ab	47	a
BH-5	83	ab	72	de	131	a	47	a
Replantpac® (Mirobac)	88	ab	82	a-e	114	bc	44	a-d
Guardian®	95	a	95	a	128	a	47	a
Lovell	96	a	93	abc	123	ab	45	abc
KV010123	93	a	94	a	107	c	42	cd
KV010127	93	a	92	abc	114	bc	44	de
Krymsk®86 (Kuban 86)	92	ab	83	a-d	122	ab	46	abc
Empyrean®2 (Penta)	80	ab	72	def	93	d	40	ef
Empyrean®3 (Tetra)	91	ab	24	h	54	ef	33	hi
Imperial California	43	c	25	h	97	cd	44	a-d
Controller 8 (HBOK 10)	94	a	91	abc	85	de	38	fg
Controller 7 (HBOK 32)	85	ab	76	b-e	88	de	39	fg
Prunus americana	83	ab	75	cde	67	e	34	h
Fortuna	71	b	58	efg	72	de	35	gh
Krymsk®1 (VVA-1)	75	b	52	g	49	f	30	i
Controller™ 5 (K146-43)	82	ab	76	b-e	61	ef	34	h

[z] LS means separation within columns by Tukey's Studentized Range Test ($P \leq 0.05$)

Table 3. Mean survival, TCSA, TC and bloom date of Redhaven at each location.[z]

Location	Survival (%) Fall 2013	Survival (%) Fall 2015		TCSA (cm^2) Fall 2013	Trunk Circum. (TC) (cm) Fall 2015		Full bloom (Julian date) 2011-2015	
New York-Geneva	82	84	a	134	47.7	bc	118.4	a
Kentucky	91	78	abc	89	38.0	f	91.4	c
North Carolina	71	61	cd	72	30.5	g	83.7	e
Alabama	82	38	e	140	52.2	a	80.0	f
South Carolina	93	74	a-d	135	50.6	ab	78.0	h
California	97			156				
Georgia	88	62	bcd	113	45.0	cde	79.1	g
Massachusetts	98	91	a	111	42.0	e		
Utah-Kaysville	95	90	a	83	37.8	f		
Utah-South Shore	86	78	abc	44	26.7	h		
Colorado	85	78	abc	38	26.1	h	88.0	d
Pennsylvania	85	79	ab	105	43.8	de		
Illinois	83			102				
Missouri	66	58	d	122	47.5	bcd	96.6	b

[z] LS means separation within columns by Tukey's Studentized Range Test ($P \leq 0.05$).
Missing data were not recorded for that location.

Table 4. Mean canopy size, fruit weight, yield and cumulative yield efficiency of Redhaven on each rootstock across locations.[z]

Rootstock cultivar	Tree canopy Width (m) 2013		Tree canopy Height (m) 2013		Mean fruit wt.[y] (g) 2011-2015		Cumulative yield (kg/tree) (live+dead)[x] 2010-2015		Cumulative yield (kg/tree) (live trees)[w] 2011-2015		Cumulative yield effic. (kg/cm^2) (2011-2015)	
Viking	4.39	abc	3.39	a	173	a-d	115.4	bc	145.9	abc	0.86	cd
Atlas	4.57	ab	3.44	a	180	a	120.6	abc	156.0	a	0.92	a-d
BH-5	4.62	a	3.40	a	178	ab	96.8	cd	134.2	cde	0.77	d
Replantpac	4.14	cd	3.16	ab	170	b-e	120.0	abc	136.4	bcd	0.88	bcd
Guardian®	4.44	abc	3.30	a	176	abc	147.5	a	155.5	a	0.91	bcd
Lovell	4.24	bcd	3.28	a	169	cde	144.0	ab	154.9	ab	0.96	abc
KV010123	4.23	bcd	3.18	ab	173	a-d	133.3	ab	142.5	a-d	0.97	abc
KV010127	4.29	abc	3.25	a	169	cde	137.3	ab	153.2	abc	0.97	abc
Krymsk® 86	4.12	cd	3.27	a	171	bcd	122.1	abc	136.4	bcd	0.81	d
Empyrean®2 (Penta)	3.89	de	3.13	ab	174	a-d	81.6	d	112.5	fg	0.86	ef
Empyrean®3 (Tetra)	3.33	efg	3.02	abc	179	a	12.4	e	102.2	fg	0.52	de
Imperial California	3.70	de	3.10	ab	165	de	22.0	e	60.4	j	0.66	de
Controller™ 8	3.82	de	2.97	bc	170	b-e	103.8	cd	116.4	ef	1.00	abc
Controller™ 7	3.85	de	3.11	ab	162	e	96.5	cd	123.4	def	1.03	ab
Prunus americana	3.37	ef	2.70	cd	169	cde	76.7	d	104.2	fg	1.06	a
Fortuna	2.70	g	2.48	de	149	f	26.1	e	59.6	j	0.52	e
Krymsk® 1	2.97	fg	2.42	e	171	b-e	46.2	e	76.8	ij	1.07	a
Controller™ 5	3.68	e	2.71	cd	168	cde	76.5	d	94.4	hi	1.02	ab

[z] LS means separation within columns by Tukey's Studentized Range Test ($P \leq 0.05$).
[y] Twenty fruit were randomly collected to determine average fruit weights.
[x] Includes data from trees that died before Fall 2015.
[W] Includes data only from trees alive in Fall 2015.

Table 5. Mean maturity date, fruit weight, and cumulative yield/yield efficiency of Redhaven at each location.[z]

Location	Mean maturity (Julian date) 2011-2015		Mean fruit wt.[y] (g) 2011-2015		Cumulative yield (kg/tree) (live+dead)[x] 2011-2015		Cumulative yield (kg/tree) (live trees)[w] 2011-2015		Cumulative yield efficiency (kg/cm^2)	
New York-Geneva	221.9	a	134	f	121.8	c	146.2	b	0.82	c
Kentucky	183.6	d	176	cd	65.2	ef	78.8	ef	0.71	cde
North Carolina			163	e	61.7	f	87.4	def	1.14	b
Alabama	166.4	e	167	de	71.8	ef	115.4	c	0.55	de
South Carolina	173.0	e	196	b	188.9	a	227.3	a	1.10	b
Georgia	173.2	e	135	f	76.9	ef	103.6	cd	0.63	cde
Massachusetts	216.4	ab	186	bc	90.6	de	95.6	cde	0.74	cd
Utah-Kaysville	209.6	b	216	a	108.6	cd	114.0	c	1.04	b
Utah-South Shore			163	e	51.9	f	64.2	f	1.19	ab
Colorado	184.6	d	166	de	18.8	g	24.8	g	0.52	e
Pennsylvania			174	de	88.7	de	101.5	cde	0.69	cde
Missouri	198.9	c	168	de	153.3	b	246.1	a	1.39	a

[Z] LS means separation within columns by Tukey's Studentized Range Test ($P \leq 0.05$). Missing data were not recorded at that location.

[y] Twenty fruit were randomly collected to determine average fruit weights.

[x] Includes data from trees that died before Fall 2015.

[W] Includes data only from trees alive in Fall 2015.