Controller 5, Controller 9 and Hiawatha Peach Rootstocks: Their Performance and Physiology

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Abstract

The primary factor limiting the use of size-controlling rootstocks in California peach and nectarine production is the lack of suitable, commercially available size-controlling rootstocks with a wide range of compatibility with scion cultivars. In 1986, *Prunus* genotypes with widely varying genetic backgrounds were evaluated for their rooting capacity, compatibility with 'O'Henry' peach and size-controlling characteristics. Subsequently a semi-commercial rootstock trial was initiated at the Kearney Agricultural Center (Parlier, CA) to evaluate the commercial potential of eight rootstocks identified in the previous trial. The main part of this experiment involved ten different rootstocks and two scions. The ten rootstocks were: Alace, Hiawatha, Sapalta (open pollinated seedlings of a *Prunus besseyi* × *P. salicina* hybrid), K-145-5, K-146-43, K-146-44, P-30-135 (*P. salicina* × *P. persica* hybrids), K-119-50 (*P salicina* × *P. dulcis* hybrid), and two commercially available rootstocks, Citation and Nemaguard. The two main scion cultivars were 'Loadel' (an early clingstone processing cultivar) and 'Flavorcrest' (an early fresh market freestone cultivar). This trial documented that three rootstocks provided a range of size-controlling (compared to trees grown of the vigorous commercial standard, Nemaguard), were compatible with a broad array of scion cultivars and appeared to have commercial potential for California. As a result of this and other research, in 2004 K146-43 and P30-135 were patented and commercially released as Controller 5 and Controller 9, respectively. We also began recommending commercial trials of these two rootstocks along with Hiawatha because they provided a range of size-controlling options (~50, 70 and 90% of trees on Nemaguard for Controller 5, Hiawatha and Controller 9, respectively). This paper reports on relative tree growth, crop yield and pruning requirements of trees on these three rootstocks compared to the industry standard (Nemaguard) over twelve years.

INTRODUCTION

The annual production costs for peaches grown in California are heavily dependent on the costs of labor for pruning, fruit thinning and harvest, which is done from ladders because of large tree size (DeJong et al., 1999). It is widely recognized that production costs could be substantially reduced if the size of peach trees could be reduced enough to eliminate the need for ladders to do the hand labor. Such benefits of size-controlling rootstocks have been clearly demonstrated with apple and the availability of commercially acceptable size-controlling apple rootstocks has revolutionized that industry around the world.

Until recently, the primary factor limiting the widespread use of size-controlling rootstocks for peach production has been the lack of availability of commercially acceptable size-controlling rootstocks with a wide range of compatibility among cultivars (Rom and Carlson, 1987). Previous work on size-controlling peach rootstocks for California was largely based on trials with rootstocks imported from Europe such as Damas GF 1869 and GF 655-2. These rootstocks did not perform well in California conditions and exhibited scion incompatibility problems with many California cultivars. In the early 1980s Citation rootstock was released by a local plant breeder and was rapidly adopted by several growers. However, within a few years it also exhibited delayed scion incompatibility with many peach and nectarine cultivars and fell out of use. However, it continued to be used as a very good rootstock for Japanese plum (*Prunus salicina* Lindl.) and apricot (*Prunus armeniaca* L.).

Because of the enthusiasm of growers for new size-controlling rootstocks, in 1986 a rootstock screening experiment was initiated at the University of California Kearney Agricultural Center to identify potentially suitable size-controlling rootstocks for California peach production. More than one hundred and twenty *Prunus* genotypes from a broad range of genetic backgrounds were evaluated for their rooting capacity, size controlling characteristics and compatibility with peach ('O'Henry'). At the conclusion of that experiment, nineteen size-controlling rootstocks were selected as having commercial potential for California peach production. In 1996, a second trial involving what were considered to be the eight most promising of these nineteen rootstocks was initiated to test their growth and production characteristics under semi-commercial conditions. The growth and productivity results from the first six years of this trial were reported in by DeJong et al. (2002). This trial was terminated in 2008, and this paper reports on the performance of the three most promising rootstocks compared to the industry standard (Nemaguard) over the 12 years of the trial.

MATERIALS AND METHODS

In February 1996, a field rootstock trial was established at the University of California Kearney Agricultural Center, Parlier, CA. The research block consisted of two peach [*Prunus persica* (L.) Batsch] scion cultivars 'Loadel' (clingstone) and 'Flavorcrest' (freestone) bud-grafted onto ten different rootstock genotypes. The ten rootstocks originally in the trial were Alace, Hiawatha, Sapalta (open pollinated seedlings of Sapa, a *Prunus besseyi* L.H. Bailey × *P. salicina* hybrid), K-145-5, K-146-43(Controller 5), K-146-44, P-30-135 (Controller 9) (*P. salicina* × *P. persica* hybrids) K-119-50 (*P. salicina* × *P. dulcis* (Mill.) D.A. Webb hybrid) and two control rootstocks, Citation (*P. salicina* × *P. persica*) and Nemaguard (*P. persica*). A total of thirty-six trees of each rootstock/scion combination were planted in two different training systems. Four replications of five trees each were planted and trained to the KAC-V perpendicular V system (DeJong et al., 1994), and four replications of four trees each were planted and trained to the standard open vase system (Micke et al., 1980). Between-row spacing was the same for all rootstock/scion/training system combinations (4.88 m) but in-row spacing varied according to expectations of final tree size. In-row tree spacing was 1.98 m (1035 trees/ha) for trees on Nemaguard and P-30-135 and 1.83 m (1120 trees /ha) for K-119-50, Alace, Hiawatha, Sapalta, K-145-5, K-146-43 and K -146-44 in the KAC-V system; and 4.88 m (420 trees/ha) for Nemaguard and P-30-135, 4.27 m (480 trees/ha) for K-119-50 Alace, Hiawatha, Sapalta and K-145-5, and 3.66 m (560 trees/ha) for K-146-43 and K-146-44 in the open vase systems. Replication of the rootstock/scion combinations were randomized within training system/scion cultivar subplots. In-row tree spacing between replications in the open vase system was the shortest tree distance within the replications plus one-half the spacing difference between the replications (i.e. when a Nemaguard replication was planted adjacent to a K-146-43 replication, the in-row spacing between replicates was 4.27 m). Because only three of the experimental rootstocks are being recommended for further commercial tests by growers performance data on four rootstocks; Controller 5 (K146-43), Controller 9 (P30-135), Hiawatha and Nemaguard; will be presented.

The soil at the site is a well-drained Hanford, fine sandy loam. The trees were flood-irrigated to maintain 100% of potential evapo-transpiration prior to harvest and about 80% after harvest. Fertilizer and pesticides were applied according to standard horticultural practices. Weeds were controlled by mowing the row middles and applying herbicides to maintain a 1.5 wide weed-free strip down the tree rows. In most years trees were pruned during midsummer and during the dormant season according to standard recommendations for growing the two systems for each year except for years one and four when they were only dormant pruned (DeJong et al., 1999). For the first seven years severity of pruning was adjusted according to the growth characteristics of each rootstock/scion combination to optimize crop production while developing/maintaining the desired tree shape. By the eighth year of the trial, trees on some of the scion/rootstock combinations reached a height of ~4.5 m and so we decided to use a topping machine to reduce the tree height of all treatments. After harvest in the eighth year all trees were mechanically topped to ~3.3 m. Subsequently, after the crop was harvested in the tenth year two of the scion/rootstock replications in both training systems were topped to ~2.4 m while the other two replications continued to be topped to ~3.3 m. This split topping treatment was applied to gauge differential yield responses of trees on the various rootstocks to topping that would eliminate the need for ladders to do pruning, fruit thinning and harvest. Unfortunately, it was not possible to obtain accurate pruning weights after the topping treatments were initiated because the topping machine scattered the material among rootstock treatments.

The first significant fruit set occurred in the third leaf and crop load was adjusted for tree size by hand thinning to maintain a minimum spacing between fruit. Because patterns of fruit maturity varied somewhat with rootstock, fruit were harvested in several picks but data were combined from all harvests to calculate mean fruit yield. Data on crop load (fruit per tree) and fruit size were also recorded but only data for the 12th year are reported here.

RESULTS

Rootstock related differences in tree size and vigor were apparent after the first year of growth in the field. Nemaguard was clearly the most vigorous; followed by Controller 9, Hiawatha, and Controller 5, respectively. After twelve years in the orchard, overall tree size as indicated by trunk circumference was reduced across all scion/training system combinations by the size-controlling rootstocks compared to Nemaguard except for the Flavorcrest/Controller 9 combination (Table 1). Trees on the most size-controlling rootstock (Controller 5) had trunk circumferences that were 66-70% of trees on Nemaguard, whereas trees on the least dwarfing rootstock (Controller 9) had trunk circumferences that were 92-101% of those on Nemaguard. Trees on Hiawatha were 76-84% of those on Nemaguard.

In spite of the differences in tree size and vigor, all trees were pruned in a manner that was deemed appropriate to maintain optimum fruiting potential for each scion/rootstock/training system combination without limiting the tree height. Although there were yearly variations in the amount of brush pruned from each combination over the seven years of the trial, a clear picture of the effectiveness of each rootstock on reducing excessive vegetative growth compared to trees on Nemaguard was apparent when the annual pruning weights were plotted for each rootstock/scion/training system combination over the first seven years of the trial (Fig. 1). The effectiveness of the size-controlling rootstocks for reducing the amount of dry matter that needed to be removed during pruning relative to trees on the vigorous control (Nemaguard) was greater in the larger open vase trees than the higher density KAC-V system. Similarly, the effect of the size-controlling rootstocks on reductions of pruning weights were greater with the more vigorous scion cultivar (‘Flavorcrest’, an early fresh market peach) compared to the weaker scion cultivar (‘Loadel’, an early processing clingstone peach). Perhaps the most interesting aspect of these data are the relatively large reductions in cumulative pruning weights with the size-controlling rootstocks over the first seven years of the trial compared to the more modest differences in trunk circumference.

Even though it was not possible to get accurate total pruning weights that reflected the amount of regrowth stimulated by the topping treatments from summer pruning weights (Table 2) and field observations, it was obvious that the trees on the more vigorous rootstocks had much greater growth responses subsequent to topping than trees on Controller 5 or Hiawatha. This was especially true for the trees topped at ~2.4 m. From this limited trial it appeared feasible to develop a "pedestrian" orchard that would require no ladder-work with the use of these rootstocks.

Patterns of crop yield per tree during years three through twelve in the orchard followed patterns of relative tree size in each scion/rootstock/training system combination (Fig. 2). Trees on the more size-controlling rootstocks appeared to reach full yield potential at about the same time as trees on the more vigorous rootstocks in the higher density KAC-V system but clearly lagged behind the vigorous rootstocks in the open vase systems so it is difficult to make clear judgments about the final relative yield potentials of the various rootstock/scion combinations in each system other than to note that annual as well as cumulative crop yields per tree are at least 30% lower with the most size-controlling rootstocks compared to trees on Nemaguard. Crop yields of 'Flavorcrest' peaches on Controller 9 tended to be more comparable to those on Nemaguard than for 'Loadel' peaches with the same rootstocks. Detailed cropping data are provided only for the last year of the trial (Table 3). There was a strong interaction between crop load and fruit size so clear differences in fruit size due to rootstock were often difficult to sort out. However, in most years mean fruit sizes at comparable crop loads were similar for trees on Controller 9 and Nemaguard, but trees on Hiawatha and Controller 5 tended to have smaller mean fruit sizes. We noted that fruit set per unit shoot length was often much heavier on trees on Hiawatha and Controller 5 than on trees on Controller 9 or Nemaguard. It is not clear if the tendency for smaller fruit size with the more dwarfing rootstocks was directly related to the physiology of the rootstocks. Alternatively it may have been a result of greater competition among fruits prior to thinning or of a tendency for the fruit thinners to leave more fruit on the smaller trees relative to the size of the trees (Fig. 3). Crop loads per unit trunk cross-sectional area (TCA) of trees on Controller 5 and Hiawatha were always greater than trees on the more vigorous rootstocks (Nemaguard and Controller 9). Perhaps fruit sizes would not have been as different if crop load had been more closely adjusted to TCA. However, this was not done because once the trees were heavily pruned, TCA no longer reflected canopy volume.

Intensive studies of growth characteristics and physiology of the trees on various rootstocks indicate that the primary differences between the scions on the size-controlling rootstocks and trees on Nemaguard are related to shoot internode length and shoot extension growth rate (Weibel et al., 2002). Furthermore, these factors appear to be related to differences in diurnal patterns of stem water potential (Basile et al., 2003a; Solari et al., 2006a) and root hydraulic conductance (Basile et al., 2003b; Solari et al., 2006b; Solari and DeJong, 2006). Additional studies indicate that tree vegetative growth responses to pruning among trees on the different rootstocks are also associated with inherent tree size accumulated over years (Pernice et al., 2007). Thus, once trees are a few years old there is an accumulation of factors that influence tree vigor on the various rootstocks. The differences in hydraulic conductance among rootstocks may be associated with morphological characteristics of the roots (Solari et al., 2006; Basile et al., 2007); however, these relationships were not conclusive.

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Tables

Table 1. Trunk circumferences (cm) of Flavorcrest and Loadel on six rootstocks and two training systems at the end of the twelfth growing season (December, 2007). Values represent the mean (± SE) of measurements of the four replications in the high density "KAC-V" and standard density "open vase" parts of the trial.

Rootstock	Loadel		Flavorcrest	
	Open vase	KAC-V	Open vase	KAC-V
Nemaguard	78.1±0.68	54.6±0.96	90.2±1.97	62.6±1.17
Controller 9	72.2±2.11	52.6±2.21	86.3±2.59	63.4±3.75
Hiawatha	63.0±1.28	45.8±1.34	68.7±2.24	49.4±2.31
Controller 5	53.0±0.36	38.1±1.69	61.7±1.18	41.6±0.39

Table 2. Combined summer and winter pruning weights (kg/tree) of the Flavorcrest and Loadel on four different rootstocks and two training systems and two topping treatments during the eleventh season of growth in the field. The topping treatment were imposed in September of the tenth season.

Rootstock	Topping treatment	Loadel		Flavorcrest	
		Open vase	KAC-V	Open vase	KAC-V
Nemaguard	Topped 3.3 m	10.28	5.77	10.73	6.06
	Topped 2.4 m	27.60	12.06	18.59	11.83
Controller 9	Topped 3.3 m	5.22	3.81	6.53	4.69
	Topped 2.4 m	12.92	7.34	10.72	7.82
Hiawatha	Topped 3.3 m	5.14	3.49	6.08	2.76
	Topped 2.4 m	9.85	5.59	10.53	5.78
Controller 5	Topped 3.3 m	5.82	2.95	6.13	3.20
	Topped 2.4 m	7.17	3.85	7.16	5.24

Table 3. Fruit harvest data for the KAC-V and Vase systems with Loadel and Flavorcrest trees on four different rootstocks and two topping treatments in the 12th year of the trial (TCA is trunk cross sectional area).

Rootstock	Topping treatment	Loadel				Flavorcrest			
		Crop load (kg/tr)	Mean fruit mass (g/fr)	Mean crop load (fr/tr)	Crop/TCA (kg/cm^2)	Crop load (kg/tr)	Mean fruit mass (g/fr)	Mean crop load (#fruit/tr)	Crop/TCA (kg/cm^2)
KAC-V									
Nemaguard	Topped 3.3 m	59.8	156.0	384	0.25	43.5	138.8	314	0.14
	Topped 2.4 m	58.1	142.2	409	0.24	47.5	132.2	359	0.15
Controller 9	Topped 3.3 m	55.2	146.0	378	0.25	45.9	124.6	369	0.14
	Topped 2.4 m	57.9	132.0	437	0.26	40.6	128.4	317	0.13
Hiawatha	Topped 3.3 m	51.6	146.7	352	0.31	29.6	129.5	228	0.15
	Topped 2.4 m	52.0	129.8	400	0.31	37.4	126.4	296	0.19
Controller 5	Topped 3.3 m	41.6	136.2	305	0.36	42.5	117.8	360	0.31
	Topped 2.4 m	47.7	110.6	432	0.41	39.5	111.7	354	0.28
OPEN VASE									
Nemaguard	Topped 3.3 m	117.9	148.4	795	0.24	88.4	143.9	614	0.14
	Topped 2.4 m	88.7	175.2	506	0.18	78.2	146.6	534	0.12
Controller 9	Topped 3.3 m	102.2	124.9	818	0.25	84.9	116.8	727	0.14
	Topped 2.4 m	85.0	142.5	600	0.20	72.0	113.7	633	0.12
Hiawatha	Topped 3.3 m	93.13	125.4	742	0.29	85.5	116.1	736	0.23
	Topped 2.4 m	88.56	133.9	661	0.28	74.1	106.6	695	0.20
Controller 5	Topped 3.3 m	86.76	122.0	711	0.38	83.4	120.5	692	0.27
	Topped 2.4 m	89.09	125.0	713	0.39	61.4	118.6	518	0.20

Figures

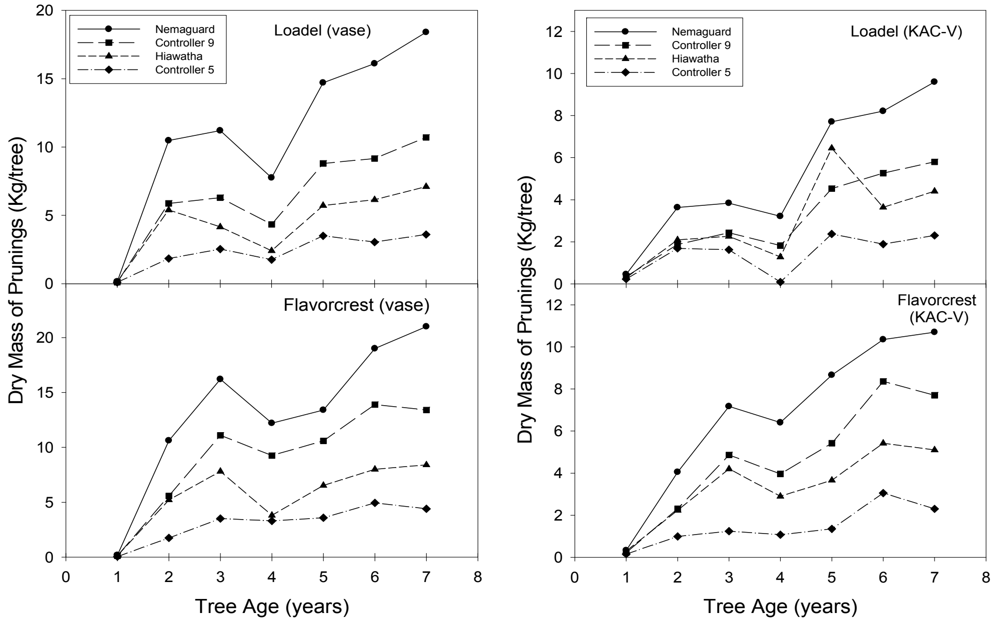

Fig. 1. Mean dry mass of prunings (summer and dormant) from each of the scion (Loadel and Flavorcrest)/rootstock (Nemaguard, Controller 9 and 5, Hiawatha)/training system (open vase and KAC-V) combinations during the first 7 years of the trial.

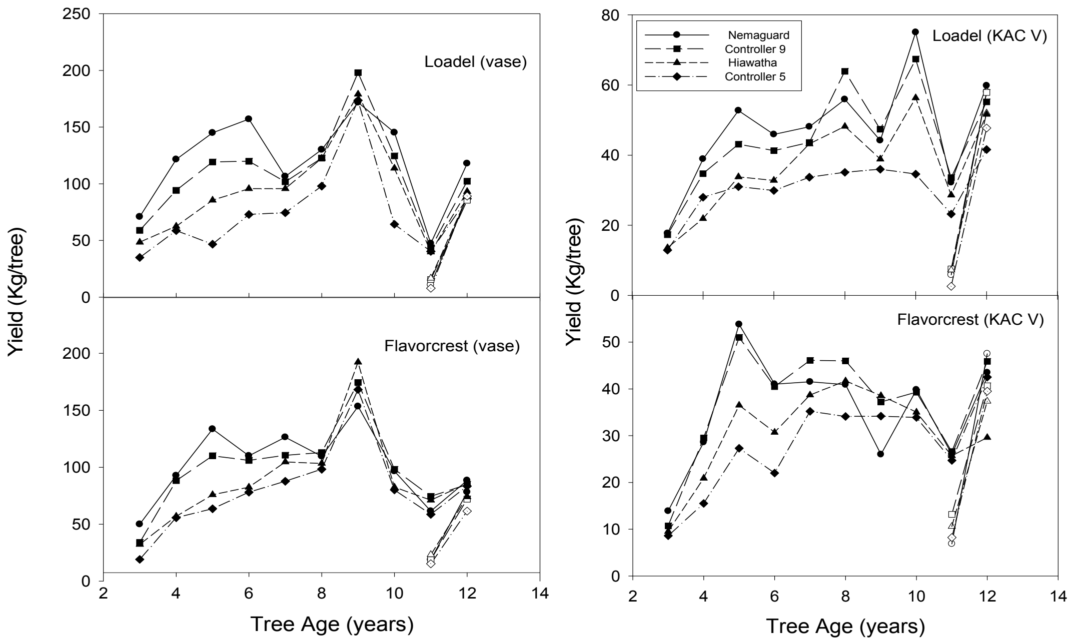

Fig. 2. Mean fruit yields from each of the scion (Loadel and Flavorcrest)/rootstock (Nemaguard, Controller 9 and 5, Hiawatha)/training system (open vase and KAC-V) combinations during years 3-12 of the trial. Open symbols in years 11 and 12 are for trees topped at 2.4 m after harvest in years 10 and 11.