Growth, Yield and Physiological Behavior of Size-Controlling Peach Rootstocks Developed in California

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Abstract

A collaborative research program between the University of California, Department of Pomology and the Fresno USDA Horticulture Crops Research Laboratory has identified several promising clonal, size-controlling rootstocks for California peach production. An ongoing production trial with two peach scion cultivars (Flavorcrest and Loadel) on five of these interspecific hybrid rootstocks (Hiawatha (open pollinated seedling of *Prunus besseyi* × *P. salicina* hybrid), K-146-43, K-146-44, P-30-135 (*P. salicina* × *P. persica* hybrids) and K-119-50 (*P. salicina* × *P. dulcis* hybrid), compared with Nemaguard (the California *P. persica* standard) has yielded very positive results. After six years in the orchard, trees on the five experimental rootstocks have reduced trunk circumferences (60-95% of trees on Nemaguard), reduced dormant pruning weights (22-80%), reduced summer pruning weights (40-80%) with acceptable fruit size and crop yields (54-98% of trees on Nemaguard.) An analysis of the relative efficiency of each scion/rootstock/training system, using a calculated modified harvest increment (annual fruit dry weight/annual pruning dry weight), indicated that trees on the size controlling rootstocks were more efficient in partitioning dry matter to crop than trees on the vigorous Nemaguard rootstock.

INTRODUCTION

The annual production costs for peaches grown in California are heavily dependent on the costs of land 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). 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 and plum 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 (cv. O'Henry) and Japanese plum (cv. Santa Rosa). 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 most promising eight of these nineteen rootstocks was initiated to test their growth and production characteristics under semi-commercial conditions. This paper presents growth and productivity results from the first six years of this 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 scion cultivars (*Prunus persica* L. Batsch cvs. Loadel (clingstone) and Flavorcrest (freestone) bud-grafted onto ten different rootstock genotypes. The ten rootstocks were Alace, Hiawatha, Sapalta (open pollinated seedlings of Sapa, 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 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 4.88m (420 trees/ha) for Nemaguard and P-30-135, 4.27m (480 trees/ha) for K-119-50 Alace, Hiawatha, Sapalta and K-145-5, and 3.66m (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).

The soil at the site is a well-drained Handford, 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.

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). 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. 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 are not reported in this paper).

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 K-119-50, P-30-135, Hiawatha, K-145-5, K-146-43, Alace, Sapalta, K-146-44 and Citation, respectively. However, in the fall of the first year in the field several trees of Citation, K-145-5, Alace and Sapalta appeared unhealthy with premature leaf fall and leaf "boating" and "bronzing". During the subsequent spring several of these trees died while others appeared to recover. But by the following fall, additional trees appeared unhealthy and more died. As a consequence these scion/rootstock combinations were eliminated from the formal experiment and no further data on them was collected. Thus, the remainder of this paper will only report on data from the remaining six rootstocks in the trial (Nemaguard, K-119-50, P-30-135, Hiawatha, K-146-43, K-146-44).

After six years in the orchard, overall tree size as indicated by trunk circumference was consistently reduced across all scion/training system combinations by each size-controlling rootstock. (Table 1). Trees on the two most size-controlling rootstocks (K-146-43 and K-146-44) had trunk circumferences that were 61-72% of trees on Nemaguard whereas trees on the least dwarfing rootstock (P-30-135) had trunk circumferences that were 92-95% of those on Nemaguard. Trees on Hiawatha were 76-87% of those on Nemaguard, while trees on K-119-50 were 83%-86% of trees 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. Although there were yearly variations in the amount of brush pruned from each combination over the first six 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 six years of the trial (Figs. 1 and 2). 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 six years of the trial compared to the more modest differences in trunk circumference which is also a cumulative measurement. For example, the cumulative pruning weights for trees on K-146-44 over six years were 17, 23, 32 and 26% of trees on Nemaguard for the Loadel/KAC-V, Flavorcrest/KAC-V, Loadel/Vase, Flavorcrest/Vase, respectively, while differences in trunk circumferences ranged from 61-72% of trees on Nemaguard. Similarly, cumulative pruning weights for trees on P-30-135 ranged from 57-70% of trees on Nemaguard while trunk circumferences on the same rootstock ranged from 92-95% on trees on Nemaguard.

Patterns of crop yield per tree during years three through six in the orchard followed patterns of relative tree size in each scion/rootstock/training system combination (Figs. 3 and 4). 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 judgements 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 K-119-50 and P-30-135 tended to be more comparable to those on Nemaguard than for Loadel peaches with the same rootstocks. Although no fruit size data are presented here, mean fruit sizes among the three most vigorous cultivars was very similar but the three more size controlling cultivars tended to have somewhat smaller mean fruit sizes. At this time, it is not clear if the fruit size tendencies are a real function of the rootstock or a result of a tendency for the fruit thinners to leave more fruit on the smaller trees relative to the size of the trees.

In an effort to develop information concerning the relative efficiency of each scion/rootstock/training system combination, we converted fruit fresh weight to dry weight and calculated a modified harvest increment (kg annual fruit dry weight/kg annual pruning weight) for each scion/rootstock/training system combination for the four years that we had harvest data (Table 2). Although there was substantial variation between years, all of the experimental rootstocks had higher mean modified harvest increments than trees on Nemaguard for a given year within each scion/training system combination. Also there was a general tendency for trees in the open vase system to have higher modified harvest increments than trees in the KAC-V system. Similarly, the less vigorous, more heavily cropped Loadel trees tended to have higher values than the Flavorcrest trees for each rootstock/training system combination. The high amount of variability in these data was due to variability in pruning and fruit thinning practices as well as the biological variability inherent in the scion/rootstock/training systems combinations. However, the general trends in the data clearly indicate the size-controlling rootstocks have the potential to increase partitioning of dry matter to fruit, relative to vegetative growth, for a given scion/training system combination. Thus, if training systems and tree densities can be feasibly adjusted so that total annual accumulation of dry matter in an orchard is comparable to what is currently achieved with trees on Nemaguard in California, it should be possible to increase crop yields with smaller trees using these size-controlling rootstocks. Intensive studies of growth characteristics 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., 2002a) and root hydraulic conductance (Basile et al., 2002b).

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Tables

Table 1. Trunk circumferences (cm) of Flavorcrest and Loadel scion cultivars on six rootstocks and two training systems at the end of the sixth growing season (December 2001). 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	56 ± 0.5	39 ± 0.7	65 ± 1.0	46 ± 1.1
K-119-50	48 ± 0.8	33 ± 1.8	54 ± 2.1	38 ± 1.5
P-30-135	52 ± 1.5	36 ± 2.2	62 ± 1.5	43 ± 3.1
Hiawatha	46 ± 0.9	34 ± 1.2	50 ± 2.0	37 ± 2.0
K-146-43	36 ± 0.5	27 ± 0.7	42 ± 0.3	27 ± 0.7
K-146-44	35 ± 1.7	28 ± 0.5	42 ± 0.6	28 ± 0.6

Table 2. Calculated mean modified harvest increments (kg fruit dry weight/kg pruning weight) of years three through six for two peach scion cultivars (Loadel and Flavorcrest) in two training systems (KAC-V and Open Vase) on six root stocks.

Loadel, KAC-V	Year 3	Year 4	Year 5	Year 6
Nemaguard	0.62	1.62	0.92	0.72
K-119-50	0.72	2.26	1.09	1.07
P-30-135	0.95	2.55	1.27	1.05
Hiawatha	0.81	2.29	0.70	1.21
K-146-43	1.07	4.36	1.75	2.12
K-146-44	1.26	4.12	1.59	1.79
Flavorcrest, KAC-V				
Nemaguard	0.20	0.47	0.66	0.42
K-119-50	0.30	0.94	1.13	0.56
P-30-135	0.23	0.79	1.00	0.51
Hiawatha	0.24	0.76	1.06	0.60
K-146-43	0.74	1.53	2.14	0.76
K-146-44	0.50	1.26	1.74	0.97
Loadel, Open Vase				
Nemaguard	0.85	2.10	1.32	1.31
K-119-50	1.19	3.43	1.81	2.08
P-30-135	1.25	2.91	1.81	1.75
Hiawatha	1.57	3.47	2.00	2.09
K-146-43	1.85	4.46	1.79	3.21
K-146-44	3.13	4.41	----	3.08
Flavorcrest, Open Vase				
Nemaguard	0.33	0.80	1.06	0.61
K-119-50	0.36	1.18	1.30	0.88
P-30-135	0.32	1.01	1.10	0.81
Hiawatha	0.44	1.59	1.23	1.09
K-146-43	0.57	1.79	1.88	1.68
K-146-44	0.62	1.38	1.34	1.42

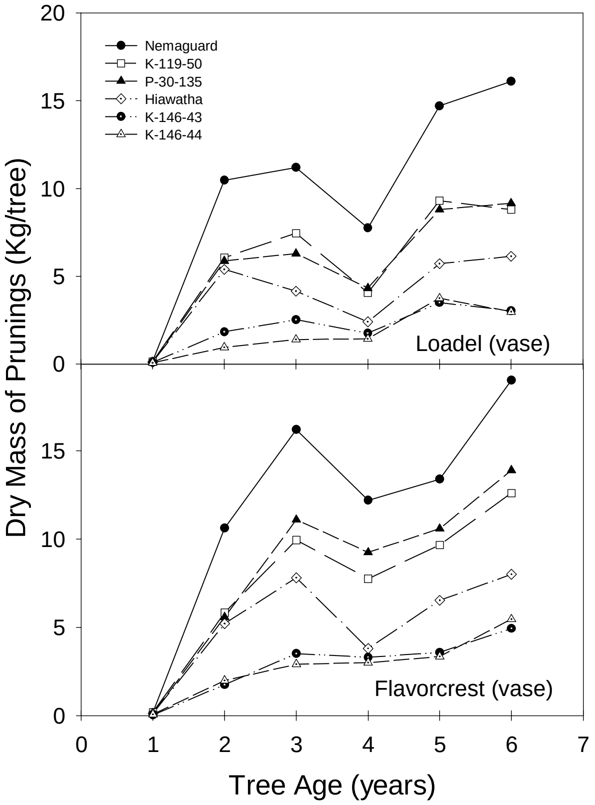


Fig. 1. Comparisons of pruning weights (summer and dormant season combined) for open vase trained Loadel and Flavorcrest peach trees on six different rootstocks during the first six years in the orchard.

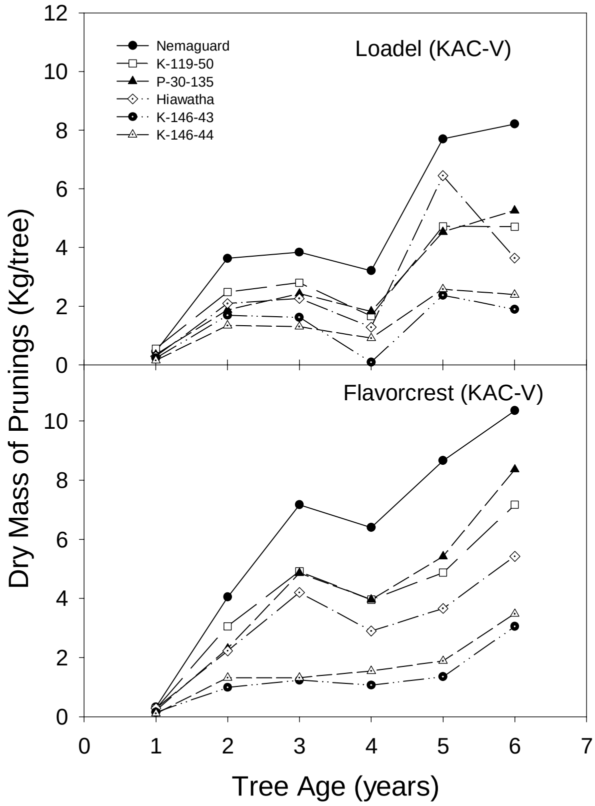
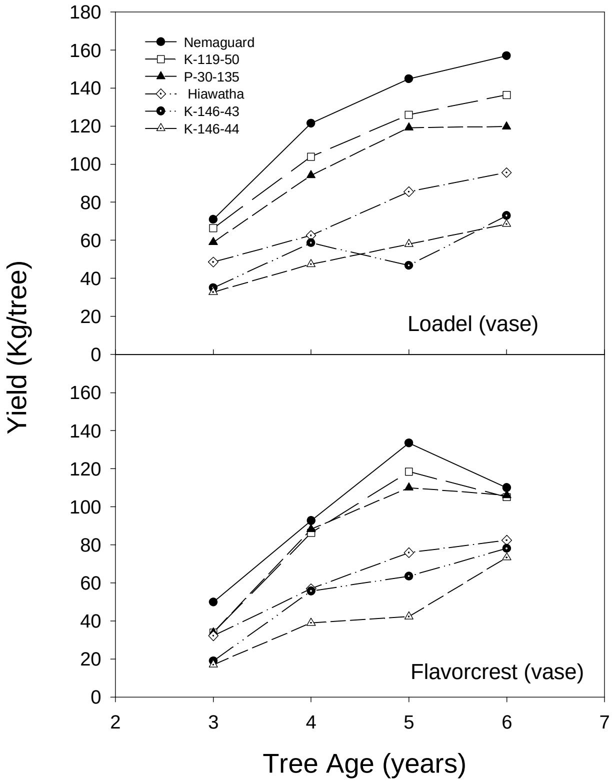


Fig. 2. Comparisons of pruning weights (summer and dormant season combined) for KAC-V trained, Loadel and Flavor crest peach trees on six different rootstocks during the first six years in the orchard.



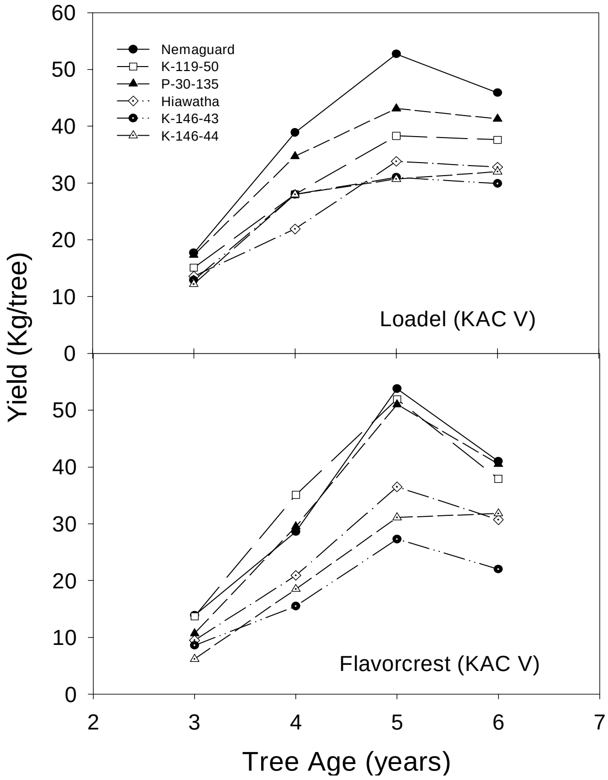


Fig. 3. Fruit yields (fresh weight) of open vase trained Loadel and Flavorcrest peach trees on six different rootstocks in years three through six in the orchard.

Fig. 4. Fruit yields (fresh weight) of KAC-V trained Loadel and Flavorcrest peach trees on six different rootstocks in years three through six in the orchard.