Field evaluation of rootstocks for 'Improved French' prune production in California grower trials

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Abstract

Historically, the California dried prune industry uses five rootstocks, 'Myrobalan seedling', 'Myrobalan 29C', 'Marianna 2624', 'Marianna 40', and 'Lovell' peaching seedling. Alternative rootstocks for prune have been identified but not tested under California conditions since the last California prune rootstock experiments were planted in the 1980s. Two rootstock trials were planted in 2011 to evaluate the potential of 10 alternative rootstocks for use in California prune production along with the five historical industry standards, all with 'Improved French' as the scion. Evaluating survival, trunk circumference, survival, yield (dry kg tree^{-1}), fresh:dry fruit ratio, and dry fruit size. Both trials were planted on commercial farms using randomized complete block designs with 14 rootstock treatments and 5 replicates with 6 trees plot^{-1}. Rootstocks include the five standards, as well as 'Marianna 30', 'Marianna 58', 'HBOK 50', 'Krymsk 1', 'Krymsk 86', 'Citation', 'Rootpac R', 'Viking', 'Atlas', and 'Empyrean 2'. 'Viking', 'Atlas', and 'Krymsk 86' had generally high survival and have consistently been among the highest yielding rootstocks at both sites. At both sites 'Myrobalan 29C', 'Atlas', 'Viking', and 'Lovell' had among the largest trunk cross sectional areas while trees on 'Marianna 58' and 'Krymsk 1' were among the smallest. Additional years of evaluation will more clearly define survival and yield of the rootstocks.

Keywords: dried plums, *Prunus domestica*, vigor, yield, size controlling, survival

INTRODUCTION

The California dried prune industry has historically utilized just five rootstocks, 'Myrobalan seedling' ('Myro', *Prunus cerasifera*), 'Myrobalan 29C' ('Myro 29C', *Prunus cerasifera*), 'Marianna 2624' ('M2624', *Prunus cerasifera* × *P. munsoniana*), 'Lovell peach' ('Lovell', *P. persica*) and 'Mariana 40' ('M40', *Prunus cerasifera* × *P. munsoniana*) (Southwick et al., 2012). These rootstocks each have significant flaws. For example, due to the inherent genetic variability of its seedling origin, 'Myro' can have variable susceptibility to various pests and diseases. 'Myro', 'Myro 29C', 'M40', and especially 'M2624' are considered susceptible to bacterial canker (*Pseudomonas syringae*) (Southwick et al., 2012). In addition, 'Lovell' is susceptible to crown rot (*Phytophthora* sp.), 'Myro 29C' and 'M2624' have poor anchorage, especially during establishment, and 'M2624' produces numerous suckers (Southwick et al., 2012).

Since the conclusion of the previous (planted 1987) prune rootstock evaluation in California (Southwick et al., 1999), many more potential rootstocks for prune have been identified. In 2011 two replicated rootstock experiments were planted in grower orchards in northern California testing 10 alternative rootstocks with variable *Prunus* parentage were evaluated in addition to the five historical industry standards all on *P. domestica* 'Improved French'. The commercially available complex hybrids 'Atlas' and 'Viking' (*P. persica* × (*P. dulcis* × (*P. cerasifera* × *P. mume*))), were hoped to impart bacterial canker resistance. 'Citation' (*P.*

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salicina × *P. persica*), 'Empyrean 2' ('Emp2', *P. domestica*), 'Krymsk 1' ('K1', *P. tomentosa* × *P. cerasifera*), 'Marianna 30' ('M30', *P. cerasifera* × *P. munsoniana*), and 'Rootpac R' ('Rpc. R', *P. cerasifera* × *P. dulcis*) were all chosen for their size controlling potential. 'HBOK 50' (*Prunus persica*) was chosen for evaluation because of purported nematode resistance. Finally, 'Krymsk 86' ('K86', *Prunus cerasifera* × *Prunus persica*) was chosen for evaluation because of purported superior anchorage.

Fruit quantity, quality and tree health were evaluated. Amidst increased global competition, delivering a large percentage of the crop as large dried fruit (<157 dried fruit kg^{-1}) has become essential for maintaining farming profitability in California (Thompson et al., 2012). Other key production statistics include a lower (more cost and energy efficient) fresh:dry fruit ratio when drying the 'Improved French' fruit. In addition, classic horticultural attributes including tree survival, trunk circumference, and dry yield $tree^{-1}$ were measured for 'Improved French' on each of the 15 rootstocks at the two sites. The objective of the evaluations was to determine whether alternative rootstocks emerged as superior, both the fruit quality and classic horticultural measures compared to the five historical industry standard rootstocks.

MATERIALS AND METHODS

Rootstock treatments

Two replicated rootstock experiments in grower orchards have been planted in northern California, USA. One in Butte County planted 4/28/11 and a second in Yuba County planted 6/3/11. All trees were nursery grafted to the 'Improved French' cultivar. There are 14 rootstocks planted in a replicated and randomized scheme at both locations, although 'Rootpac R' is only at the Yuba location, and 'Empyrean 2' is only at the Butte location.

Butte County location

The Butte County location was planted 4/28/11. The wet winter delayed soil preparation resulting in the late planting date. The Butte County soil survey lists the soil as Farwell clay adobe alternating with a lighter textured soil described as Nord loam. Nord loam is noted for its higher pH, low nutrient status and a greater association with replant disease. Test trees followed almonds on 'Lovell' peach rootstock with no soil treatments prior to planting. Lesion nematodes were isolated from soil samples.

The layout is a randomized complete block design with 14 treatments and 5 replicates. There are 6 trees $plot^{-1}$ in the original design. The spacing is 3.81 m in-row and 5.18 m between rows (506 trees ha^{-1}). Trees were headed at 102 cm on 5/10/2011 and the test planting is drip irrigated. The 'HBOK 50' rootstock came as potted trees and were delivered 5/4/11 and planted by 5/10/11. The HBOK 50 rootstock produced small bush like trees and did not have sufficient trunk growth to head the first year and were left alone. 'Viking' and 'Atlas' were not available in 2011 and were added to the experiment in 2012 and are consequently one year younger. 'Viking' and 'Atlas' were propagated by Dave Wilson nursery, 'HBOK 50' from Duarte nursery and the remaining trees were propagated by Fowler nursery.

Tree mortality was high during the 2011 season. Missing tree locations were site fumigated with 0.23 kg of chloropicrin on 11/15/11 and replanted 2/10/12. 'Viking' and 'Atlas' were also planted into fumigated planting holes on 2/10/12. Many of the 'Rootpac R' trees did not survive the initial planting, and replacement trees were not available. On 2/10/12 the few remaining 'Rootpac R' were extracted at Butte and replanted in the Yuba plot. The goal was to have one complete set of 'Rootpac R' at one location. Both the Butte and Yuba locations have mixed tree ages because of the high initial tree mortality. Fumigated replant trees grew well, and growth caught up with trees planted the first year.

Trunk measurements on 10/26/20 comprise of scion circumference measured 30.5 cm above the graft union. Trunk circumference is used to calculate trunk cross sectional area in cm^2. The 2020 harvest was the fourth whole plot mechanical harvest for the Butte location. Load cells were installed on the harvester forks so entire green weight $plot^{-1}$ could be measured. As green fruit entered the bin, a 2.3 to 2.7 kg random subsample was collected.

Harvest subsamples were field weighed and transported to Sunsweet for commercial drying. Subsample weights and fruit counts were used to calculate dry ratio, dry yield tree^{-1}, and fruit size distribution using an A, B, C, D, and "under" stainless steel screen sorter. The original experimental design featured 6 trees per individual rootstock. Tree death per plot often resulted in less than the original 6 trees plot^{-1}. Consequently, yield acre^{-1} is presented by taking the whole plot yield, divided by the number of surviving trees per plot and reported as yield tree^{-1}. Butte trees were not fruit thinned to manage crop load in 2017, 2018 and 2020 but were shaker thinned in May 2019. The experiment was harvested 8/29/2017, 8/31/2018, 9/7/2019, and 8/22/2020.

Yuba County location

The Yuba County location was planted 6/3/11. This was a replant site, with prune following prune. Telone® fumigation occurred in the early spring. The wet winter and late fumigation delayed soil preparation and subsequently delayed planting. Like Butte, the plot is a randomized complete block design with 14 treatments and 5 replicates. There are 6 trees plot^{-1} in the original design. The spacing is 4.9 m in-row and 5.5 m between rows (373 trees ha^{-1}). Rootstocks are the same as the Butte site, except for 'Rootpac R' which was transplanted from Butte to Yuba and 'Empyrean '2 which did not survive in the Yuba location. Tree mortality was high during the first growing season. The soil is described as Kilga clay loam. In 2012, 'Atlas' and 'Viking' rooted trees were planted, and missing trees were replanted. In March 2014, 'French' on 'Fortuna', 'WRM2' or 'AP45' trees were planted as replicated observations in the spaces designated for 'Empyrean 2' in the experimental design. The Yuba experiment is complete, and trees are growing well with the stark exception of canker disease (bacterial and *Cytospora*) in some of the varieties. Test trees are micro sprinkler irrigated. The plot was commercially harvested on 9/1/17 and 9/6/18, and 8/31/20 harvest methodology matched the Butte County location. No plot harvest was possible in 2019 because both the Butte and Yuba orchards were being commercially harvested on the same day.

RESULTS AND DISCUSSION

Tree survival (%)

Percent tree survival was assessed at the Butte and Yuba sites on 10/26/20 (Tables 1 and 2), by converting the least square means of the number of surviving trees across the five replicate, six tree plots to percent survival. These survival statistics do not account for the initial poor establishment at both trial sites in 2011, therefore these results show cumulative tree mortality between 2012 and 2020. Survival ranged from 10% ('Empyrean 2') to 93% ('Atlas', 'Viking', 'Myro 29C' and 'Myro') at the Butte site, and 32% ('HBOK 50') to 99% ('Viking') at the Yuba site. Rootstock survival was comparable at both sites 73 and 75% at the Butte and Yuba sites, respectively. At both sites 'Atlas' and 'Viking', which were planted a year later, and in the case of the Butte site received spot fumigation before planting have had excellent survival at both sites (93-99%). 'Emp2' which is only at the Butte site had very poor survival (10%). Finally, 'Marianna 30' had very low survival at both sites (43 and 23%).

Trunk size (cm)

Trunk size (cm) was measured on 10/26/20 at both sites. Across previous years of measurement there were generally consistent differences between rootstocks at the two sites (data not shown). In 2020, 'Atlas', 'Viking', 'K86', 'M30', 'Lovell', and 'Myro 29C' had among the greatest trunk circumferences at both sites. 'K1' had the lowest trunk circumference at both sites. In addition to 'K1'; 'M58', 'Emp2' (Butte only), and 'Citation', were among the smallest trunk circumferences. 'HBOK 50' was among the rootstocks with the largest scion at the Yuba site, but among the smallest at Butte.

Other rootstock trunk related attributes of note include that 'Myro' was observed to produce more suckers than other rootstocks (data not shown). In measures of rootstock anchorage, gauged by the degree of trunk deflection occurring when applying lateral force to the trunk, indicated 'K86' and 'Viking' had excellent anchorage while 'HBOK 50', 'M58', and

'K1' were poorly anchored (data not shown).

Table 1. Butte County location prune rootstock evaluation.

Rootstock	% tree survival	Scion (cm)	Dry yield (kg tree^{-1})	Yield efficiency (kg tree^{-1})	% A&B	Dry away
Atlas	93a	44ab	16abcd	0.36ab	82cd	3.2abc
Viking	93a	44ab	17abc	0.38ab	84bcd	3.2abc
Citation	56ab	37cde	13abcde	0.35ab	89abcd	3.3a
Emp2	10b	36bcdef	10de	0.30ab	93ab	3.2ab
HBOK 50	86a	35def	9e	0.26b	90abc	3.1abcd
K1	46ab	30f	9de	0.29ab	97a	3.1abcd
K86	76a	41abcde	14bcde	0.33ab	87abcd	3.3a
M30	46ab	43abc	18ab	0.43a	89abc	3.1abcd
M40	90a	41abcd	15abcde	0.37ab	90abc	3.0d
M58	80a	35ef	11cde	0.30ab	94a	3.1abcd
Myro S. Rpc. R	93a	39bcde	14abcde	0.35ab	95a	3.0cd
Lovell	73a	42abc	15abcde	0.35ab	79d	3.2ab
M2624	80a	39bcde	16abc	0.41a	89abc	3.1bcd
Myro 29C	93a	46a	20a	0.43a	88abc	3.0cd

Table 2. Yuba County location prune rootstock evaluation.

Rootstock	% tree survival	Scion (cm)	Dry yield (kg tree^{-1})	Yield efficiency (kg tree^{-1})	% A&B	Dry away
Atlas	95a	40ab	11ab	0.27ab	97a	2.7ab
Viking	99a	40a	12a	0.30a	98a	2.7ab
Citation	79a	32de	9abcd	0.29a	91abcd	3.2a
Emp2						
HBOK 50	32c	40ab	10abc	0.24ab	95abc	2.7ab
K1	75ab	26f	4e	0.15b	83d	2.7ab
K86	95a	38ab	12ab	0.30a	92abc	2.7ab
M30	35bc	37abc	7abcde	0.18ab	97ab	2.6ab
M40	85a	36bc	7abcde	0.20ab	96ab	2.5b
M58	65abc	30e	4de	0.15b	87cd	2.9ab
Myro	65abc	34cd	5cde	0.15b	99a	2.6ab
Rpc. R	92a	34cd	7bcde	0.21ab	88bcd	2.6ab
Lovell	89a	37abc	10abc	0.26ab	97a	2.8ab
M2624	82a	34cd	8abcde	0.24ab	98a	2.6ab
Myro 29C	62abc	38ab	8abcde	0.21ab	96ab	2.5b

Dry yield (kg tree^{-1})

Yield in dry pounds per tree was measured at the Butte site 2017-2020 and Yuba 2017, 2018, and 2020, with the least square means across years are presented in Tables 1 and 2. Unlike scion circumference, yield levels have been variable year-to-year (some alternate bearing), and between rootstocks (data not shown). In the least square means across years, 'Atlas', 'Viking', 'Citation', 'M30', 'M40', 'Lovell', 'M2624', and 'M29C' had among the highest yields at both sites. 'Myro' had among the highest yields at Butte, but among the lowest yields at Yuba. Conversely 'K86' and 'HBOK 50' yields at Yuba were among the highest, while at Butte they were average and among the lowest, respectively. 'K1' had the numerically lowest yield

tree^{-1} at both sites.

Yield efficiency (kg tree^{-1})

As a proxy for tree size, scion circumference can be divided into yield tree^{-1} to evaluate how much yield is being produced at a given tree size (i.e., yield efficiency). At the Butte site, 'M30', 'M2624', and 'Myro 29C' had higher yield efficiency than 'HBOK 50', with the other rootstocks falling in-between. At Yuba, 'Viking', 'Citation', and 'K86' had higher yield efficiency than 'K1', and 'Myro seedling', with the others falling in-between. The overall relationship between dry yield per tree and scion circumference was highly significant at both sites, with an R^2 of 0.62 at Butte and 0.43 at Yuba. At Butte each additional cm of circumference equated to 0.35 more kg of dry fruit, while at Yuba it was 0.22 kg.

Dried fruit size: % A and B screen

The percentage of A and B screen fruit (largest dried fruit size classes) in harvest subsamples was determined at the Butte site from 2017 to 2020, but this was only done for the Yuba site in 2018 and 2020. Overall, least square means across years showed sharp differences in the relative ranking of large, dried fruit percentage by rootstock between sites. Mysteriously, 'K1' had the numerically highest % A and B at the Butte site, and lowest at the Yuba site. A similar pattern held true for 'M58'. In addition, 'Viking', 'Atlas' and 'Lovell' had among the lowest proportions of large fruit at the Butte site, but among the highest at Yuba. Part of this discrepancy may be that there were only two years of data for the Yuba site. The trends seen at the Butte site make more intuitive sense, with the lower yielding rootstock treatments (e.g., 'K1', 'M58') generally producing larger dried fruit. 'Myro' had among the highest percentages of large fruit at both sites.

Fruit dry away ratio (dry wt/fresh wt)

The dry away ratio or the subsample dry weight to fresh weight ratio is displayed by least square means across all harvests. Higher cropping years tended to have higher dry away ratios (data not shown), and consistent with this, the overall dry away ratio across years at the higher yielding Butte site was 3.1, while it was 2.7 at the lower yielding Yuba site. There was substantial agreement between sites in the dry away ratio differences between rootstocks. 'M40' and 'Myro 29C' had among the lowest dry away ratios at both sites, while 'Citation' had the highest. The popular 'K86' rootstock produced fruit with among the highest dry away ratios at Butte but was average at Yuba.

CONCLUSIONS

'Viking', 'Atlas' had high survival and have also consistently been among the highest yielding rootstocks at both sites. It is unclear how much of an advantage both rootstocks were given by being planted a year later, and in the case of Butte, receiving spot fumigation before planting. Despite this excellent performance, there are no reports to-date of widespread adoption of either rootstock in California prune production currently. With its excellent anchorage and adoption in almond production, 'K86' has become popular among California growers. The rootstock performed well at the Yuba site, but mysteriously had a more average yield, yield efficiency, and survival performance in Butte. The suspected bacterial canker pressure at the Yuba site underlined a key weakness of industry standards 'Myro', and 'Myro 29C', although the 'M30' and 'HOBOK 50' alternatives fared even worse. 'Lovell', the industry standard which is often planted when there is a concern of bacterial canker, did offer high survival at Yuba.

Results at these two very different sites, often sharply differed. With an industry standard like 'Myro 29C' producing a large and high yielding tree at one site, and suffering high fatality at the other site. The success of vigorous rootstocks like 'Viking' and 'Atlas' underscore that spacing was not optimized for lower vigor rootstocks, and that future investigations should test high and low vigor rootstocks separately and offer more optimized spacing. There is interest in California in the potential for lower vigor rootstocks planted at high densities, unfortunately the lower vigor rootstocks tested at these two sites generally

performed poorly under the moderately spaced/trellised growing conditions.

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