Developing new prune cultivars for the California dried prune industry

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Abstract

California is a world leader in dried prune production but is almost entirely dependent on the use of a single cultivar, the 'Improved French' prune. This monoclonal situation lends itself to vulnerability to widespread disease, pest outbreaks and annual, statewide variations in yield caused by variable weather conditions that can negatively or positively affect fruit set and/or fruit retention. In addition to the risks of a monoculture system, the entire industry harvests and dehydrates the crop within a few weeks, since the entire crop has a similar developmental pattern. In highly competitive markets, the industry would benefit from the development of new prune cultivars that have cost saving characteristics such as improved tree structure that would require less pruning, improved fruit dry matter content that would decrease drying costs and expanded windows for bloom and harvest. The California prune breeding program at UC Davis has enlarged its germplasm and bred new generations of progeny through traditional horticultural breeding methods since its beginnings in 1985. In addition to expanding periods of bloom that will mitigate against risks of periods of inclement weather during bloom and selecting genotypes that can expand the harvest window, in recent years the program has identified selections with enhanced fruit quality characteristics that increase efficiency and quality of drying and processing. This report will focus on the characteristics of six of the latest selections that are currently being evaluated in advanced grower trials to determine suitability for the commercial California dried prune industry.

Keywords: plum breeding, fruit quality, bloom timing, harvest timing, fruit firmness

INTRODUCTION

California is the world leader in prune production but is almost entirely dependent on the use of a single cultivar, the 'Improved French' prune. This monoclonal situation lends itself to vulnerability to widespread disease, pest outbreaks and annual, statewide variations in yield caused by variable weather conditions that can negatively or positively affect fruit set and/or fruit retention. In addition to the risks of a monoculture system, the entire industry harvests and dehydrates the crop within a few weeks, since the entire crop has a similar developmental pattern. The development of new, acceptable or superior, prune cultivars could increase the efficiency of California prune production and mitigate the risks involved with a monoculture. The California prune industry is also facing increasing marketing competition from other regions of the world and must seek ways to reduce production and processing costs to stay competitive. Thus, the industry would also benefit from the development of new prune cultivars that have cost saving characteristics such as improved tree structure that would require less pruning, improved fruit dry matter content that would decrease drying costs, and increased tolerance to pests and diseases. Introducing new prunes that differ in flavor or color could also promote a broadening of the consumer base.

The UC Davis Prune (*Prunus domestica*) Development and Evaluation program has focused on delivering novel prune cultivars that can strengthen the California dried prune industry since its inception in 1985 (DeJong et al., 2002; Castro et al., 2013). To achieve this, it has enlarged its germplasm and bred new generations of progeny through traditional

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horticultural breeding methods to develop prune cultivars with traits that can help address issues faced by the California prune industry (DeBuse et al., 2007; Castro and DeJong, 2019). Through 30 years of evaluation and selection, the breeding program has increased the occurrence of desired characteristics in the germplasm. To ensure that the germplasm and new cultivars are well adapted to California's dry, hot climate, the program evaluates elite selections at two locations; the UC Wolfskill Experimental Orchards, near Winters, CA, in the Sacramento Valley; and the Kearney Ag Center, near Parlier, CA, in the southern San Joaquin Valley. The breeding program has matured and is now entering what we anticipate to be a very productive period for producing potential new cultivars that are specifically adapted for California growing conditions and markets.

In several years during the last decade prune orchard yields have been low because of poor weather conditions for fruit set during the bloom period. The consensus is that this has been largely due to high temperatures during bloom (DeCeault and Polito, 2010). Since the California industry is composed of one cultivar, in some years the whole industry suffered with poor crops during the years of high temperatures during bloom. Because the time of pollination and fruit set is so critical, we have increased the evaluation of our seedlings and selections for differences in bloom date. In doing so, new cultivars can potentially introduce greater diversity of bloom timing so that the entire Californian crop will not be dependent on the same set of weather conditions during periods critical for fruit set and retention.

In recent years we have also increased our focus on tree and fruit characteristics that will be particularly helpful in reducing grower costs while improving the dried fruit products. To this end we have put a greater emphasis on evaluating tree structure and fresh fruit characteristics that may influence dry-away ratios and ease of dried fruit handling.

MATERIALS AND METHODS

The program uses traditional horticultural breeding practices by making controlled crosses among selected genotypes. Initially, cultivars from California, the eastern United States and Europe were used as germplasm for such crosses. Subsequent to using those cultivars as a germplasm base, we now use parent genotypes that are products of the last 35 years of breeding. These new parents have traits increasingly appropriate for the breeding goals. Parents are selected for their positive horticultural traits, their breeding history and their pedigree. Fruit characteristics such as small pit size, relatively freestone pits, fruit tolerance to heat stress, high sugar content and good flavor are standard positive traits. Tendencies to produce fruit with large or split pits, side or end cracks and double fruits on a pedicle are standard negative traits. Over the first decades of the program we also selected for floral precocity to reduce time between successive generations. The breeding history of each potential parent is also examined. Trees that produce progeny that have been selected for outstanding positive characteristics and a minimum of negative characteristics are selected to be parents and their progeny are expected to have a better likelihood of being a successful parent as well. Pedigree is important because it is desirable to have new cultivars that are very similar to "French" types; and *P. domestica* has shown inbreeding depression if the inbreeding is within the current generation and no selection occurs between generations (DeBuse et al., 2005). Controlled hybrid crosses were originally made by emasculating flowers on maternal trees and hand pollinating with harvested pollen from paternal trees. Usually >20,000 flowers were emasculated and pollinated on several genotypes in a specific year. Because the fruit set on emasculated flowers was often very low (<1%) in recent years we have produced crosses by caging whole trees and placing cut flowering branches of male parent genotypes in the cages with small hives of bumble bees as pollinators. The seedlings produced from crosses are evaluated using the program's evolving objectives.

The objectives of this program have evolved to not only continue increasing the standard positive fruit characteristics and minimizing the negative ones such as those mentioned previously, but also to create an easily processed prune that will reduce Californian prune grower costs. The major traits of current interest are:

- Good tree structure – to reduce pruning costs;
- Low fresh to dry fruit weight loss – to reduce drying costs;

- Widening the harvest window – to increase harvest and drying efficiency;
- Widening bloom time – to reduce risk of state-wide crop failure due to poor weather conditions during bloom;
- Optimal sugar profile in fruit – to maintain dietary health benefits of prunes;
- Uniformity in fruit maturation – to ensure all fruit can be mechanically removed with one tree shake;
- Slow fruit softening near harvest time – to increase the ability for ripe fruit to hang on the tree over a prolonged period to increase flexibility in harvest timing.

All seedlings that are candidates for selection are put through a rigorous testing process to ensure that the fresh and dried characteristics are suitable for the industry. Fruits from over 2,000 seedling trees are evaluated each year for their quality. The fruit are tasted and evaluated in the field for their color, shape, flesh texture, pit size, pit adhesion to flesh, and presence of defects. If the fruit from seedlings pass initial visual and sensory evaluations, they are then harvested and evaluated in the laboratory for internal flesh pressure, soluble solid content, and average fresh weight. If the lab tests are positive, a sample of the seedling fruit is then dried in a semi-commercial dehydrator to evaluate fruit dried quality. If the dried fruit meets specified qualities, the genotype is grafted onto a commercial rootstock in the selection block. Once chosen as a selection, the potential cultivar is then evaluated for its fruit, as well as for tree structure and whole tree characteristics. After grafting onto a conventional rootstock, the fruit attributes can change; therefore, the grafted selection is thoroughly tested over multiple years. If the multiple years of testing remain positive, the selection is evaluated by the industry's processors to ensure the fruit meets their standards. Subsequent to initial, positive processing evaluations, the selection is planted in larger grower trials and if subsequent results remain positive, they are released as a cultivar for commercial production. Although the primary goal of the program is to select for dried plum cultivars, genotypes with exceptionally large fruit and outstanding fresh market potential are maintained for evaluation by potential fresh fruit producers. It is then the choice of those producers to promote the release of such fresh market items.

RESULTS

The importance of bloom data has grown in the past two decades because of the changing weather patterns that California has experienced. It has become more common to have warm spells in March that often have temperatures near 27°C. Historically, if that occurs the result has been low fruit set across the state. Variation for time of bloom is naturally found within the breeding program's germplasm. Introducing new cultivars to the California prune industry that have bloom times earlier or later than 'Improved French' could reduce the risk of having the entire crop reliant on good weather conditions occurring during 'Improved French' bloom. The need for a spread in bloom timing is essential for industry-wide success in maintaining crop security from year to year. Additionally, because early blooming is often associated with lower winter chilling requirements we have chosen to emphasize selecting for early blooming in the program. Bloom data, including date of full bloom (90% flowers open), amount of bloom, and the first and final day of bloom have been recorded for all advanced selections since 2003. Table 1 shows the number of days each top selection bloomed in 2019, days before or after 'Improved French' full bloom as well as the number of days in bloom, the 90% full bloom date and the average bloom date relative to 'Improved French' over the last 2-5 years when known.

General breeding progress on other major selection criteria has also been substantial. For example, in 2019 we made 35 seedling selections from the seedling blocks (Table 2). Harvest dates for those selections ranged from July 25 to September 16 (42 days before and 10 days after our standard cultivar, 'Improved French'). Fresh fruit sugar contents of those same selections at harvest ranged from 23.1 to 34.0 °Brix. Fresh fruit weights ranged from 16.4 to 54.3 g (mean = 26.6 g (the goal for dried prunes is a small to medium size fresh fruit)). Fruit fresh to dry weight ratios ranged from 2.03 to 3.02 (mean = 2.64).

Table 1. Bloom data at the Winters selection orchard for the 2019 top selections.

Item name	Full bloom date (90%)	Days in bloom	Days from Improved French	Average days from Improved French
J2N-127	March 23	13	-13	-10.5
F11S-38	March 25	15	-11	-9.0
I12S-6	March 26	17	-10	-10.0
H15S-71	March 26	17	-10	-8.5
H13S-58	March 28	16	-8	-5.0
I11N-63	March 29	17	-6	-4.5
I11N-9	March 31	20	-5	-3.5
I5S-72	April 2	13	-3	-2.0
G37S-45	April 4	14	-1	-6.0
I14N-25	April 5	19	0	-0.5
Improved French	April 5	16	0	0.0
H9N-36	April 6	22	1	*

*2019 first year of bloom.

Table 2. Harvest data for seedling selections made in 2019. The harvest date for the California industry standard cultivar ('Improved French') was September 6, 2019.

2019 test date	ITEM ID	Days +/- Improved French	Fresh weight (g fruit^{-1})	Sugar (°Brix)	Dry count (kg^{-1})	Fresh/dry ratio
July 25	J15S-22	-42	20.0	25.9	155.2	2.79
August 1	J16N-95	-37	34.3	24.2	80.9	2.87
August 1	J18S-109	-37	23.4	25.3	130.7	2.92
August 1	J2S-34	-37	28.4	23.6	123.9	3.02
August 1	J8S-92	-37	22.9	25.6	138.6	2.81
August 6	J4N-135	-31	30.4	25.8	94.7	2.88
August 6	J4N-146	-31	26.9	30.0	87.2	2.50
August 6	J6N-132	-31	24.0	27.5	118.1	2.76
August 8	J4N-107	-29	28.8	27.5	97.8	2.65
August 8	J3N-145	-29	31.9	28.4	84.9	2.57
August 8	J3S-27	-29	20.0	27.4	145.4	2.67
August 13	J2S-39	-24	40.0	23.1	/	/
August 13	J2S-38	-24	32.8	28.9	104.0	2.87
August 13	J1N-160	-24	31.2	30.8	92.0	2.58
August 13	J1S-18	-24	32.8	25.2	91.2	2.87
August 13	J4N-119	-24	27.3	34.0	100.5	2.03
August 13	J5N-134	-24	35.7	26.2	90.2	2.97
August 13	J6S-90	-24	24.3	29.7	112.8	2.80
August 20	J6S-98	-17	26.7	24.1	108.7	2.74
August 22	J15N-184	-15	24.4	30.9	99.4	2.42
August 22	J16N-104	-15	16.4	33.5	155.5	2.16
August 22	J17S-30	-15	52.3	27.6	60.6	2.96
August 26	J17S-57	-11	27.6	26.8	111.5	2.99
August 26	J17S-11	-11	42.0	30.5	93.0	2.63
August 28	J15N-137	-9	17.6	28.6	143.6	2.30
August 28	J14N-160	-9	24.8	30.0	114.2	2.45
August 29	J8S-57	-8	29.4	26.0	101.7	2.60
August 29	J7N-111	-8	24.0	29.4	112.2	2.62
August 29	J2N-114	-8	29.9	33.5	75.0	2.32
August 29	J3N-109	-8	24.3	28.4	122.5	2.82
September 10	J1S-46	4	22.3	/	126.5	2.42
September 10	J2S-62	4	23.2	28.5	126.4	2.69
September 10	J6S-49	4	27.5	29.3	93.3	2.38
September 10	J7N-130	4	24.4	30.0	105.4	2.40
September 16	J6S-87	10	22.8	28.4	130.8	2.59

There are currently six advanced selections in the breeding program that we are considering for release to the California dried fruit industry. All of these selections have superior dried fruit flavor; exceptionally firm fruit that can begin to dry on the tree prior to harvest; and durable fruit that can withstand rough handling during mechanical harvesting, commercial dehydrating, mechanical sizing, pitting and packaging. Three of these selections have yellow fruit when on the tree and a mahogany/brown color when dried that changes to dark brown after extended storage. Three additional selections are more traditional pink to purple/blue in color that turn dark brown during drying. The following is a brief description of these selections.

G2S-8

This is a prune tree that has yellow fruit that can begin to dry on the tree before there is substantial fruit drop. The tree blooms approximately 4 days before 'Improved French' and in ready for harvest approximately 10 days after 'Improved French'. The fresh fruit is oval shaped and maintains an oval shape when dried. Fresh fruit weight ranges from 32.9 to 50.3 g and dried fruit ranges from 9.8 to 11.9 g. Fresh to dry fruit ratios range from 2.5 to 3.1 depending on sugar content and fruit maturity. Fruit sugar contents range from 20 to 26.3 °Brix and fruit sugar content appears to more affected by over-cropping than fruit size. The tree grows fairly upright and bears primarily on spurs and short shoots but is more precocious than 'Improved French'.

F11S-38

This prune tree also has yellow fruit that will begin to dry on the tree before it begins to drop fruit. It blooms approximately 10 days before 'Improved French' and can be harvested approximately 20 days before 'Improved French'. The fresh and dried fruit is an oval-round shape and smaller than G2S-8. Fresh fruit size ranges between 18.6 and 26.7 g while dried fruit ranges from 8.3 to 10.2 g. Fruit sugar contents are higher than G2S-8 (27.6-38.8 °Brix) and sugar contents are less affected by over-cropping than is fruit size. Fresh to dry fruit ratios can range from 1.7 to 2.7 depending on fruit maturity. Unusually low fresh to dry fruit ratios can be achieved by letting the fruit begin to dry (shrink) on the tree. The dried fruit is distinguished by its sweetness and strong fruity flavors that are more tangey than G2S-8. The tree growth is fairly upright and sets fruit primarily on short shoots and spurs. The trees are fairly precocious and tend to have heavy bloom and can be over-cropped. If over-cropped they tend to go into biennial bearing.

H13S-58

This prune tree also has yellow fruit that can begin to dry on the tree before substantial fruit drop. It blooms approximately 4 days before 'Improved French' and can be harvested approximately 7 days after 'Improved French'. The fresh and dried fruit is oval shaped and fresh fruit size ranges between 21.8 and 29.9 g while dried fruit ranges from 8.5 to 11.2 g. Fruit sugar contents range from 24.0 to 30.3 °Brix. Fresh to dry fruit ratios can range from 1.7 to 2.7 depending on fruit maturity. Low fresh to dry fruit ratios can be achieved by letting the fruit begin to dry (shrink) on the tree. The fresh fruit can be slightly astringent but that disappears after the fruit is dried. The tree is very precocious and sets fruit on previous season shoots so the young trees must be heavily pruned to prevent excess branch bending due to fruiting on new shoots.

I12S-6

This prune tree has purple fruit that can begin to dry on the tree before substantial fruit drop occurs. It blooms 10 days before 'Improved French' and has a wide harvest window that extends from approximately 7 days before 'Improved French' until 4 days after 'Improved French'. The fresh and dried fruit is an oval shape and the fresh fruit ranges between 24.1 to 32.9 g while the dried fruit ranges from 9.0 to 10.4 g. Fruit sugar contents range from 27.5 to 35.8 °Brix. Fresh to dry ratios can range from 2.3 to 2.8. This fruit is unique in the fact that the dry away ratio is not greatly changed by harvest date. Within the appropriate harvest window,

(approximately 3 weeks) the fruit fresh to dry weight ratio does not change appreciatively over that time. This tree is very precocious and will produce flowers on previous year shoots.

I14N-25

This prune trees produces light purple fruit. It blooms 6 days before 'Improved French' and harvests with or up to 7 days after Improved French. The fresh fruit is oval, and the dried fruit strongly resembles 'Improved French' in shape and appearance. The fresh fruit ranges from 25.0 to 27.3 g and the dried fruit ranges from 9.9 to 12.4 g. Fruit sugar contents range from 25.2 to 27.9 °Brix. The fruit fresh to dry weight ratio can range from 2.5 to 2.7. The tree produces flowers in early years of tree development and the fruit reliably resembles 'Improved French' in its dried fruit characteristics.

J2N-127

This prune tree produces purple fruit that can begin to dry on the tree before any substantial drop. It harvests about 4 days after 'Improved French' but blooms about 10 days before 'Improved French'. The fresh fruit size is about 15.8-25.5 g and the dried fruit weight ranges from 7.3 to 9.5 g. Fruit sugar contents range from 27.1 to 37.4 °Brix. The fresh to dry ratios ranges from 1.9 to 2.9. To obtain the lowest possible fruit fresh to dry ratios, the fruit need to remain on the tree at least a week after 'Improved French' is harvested. This item combines the convenience of a really low fruit fresh to dry weight ratio while also having good dried fruit quality.

CONCLUSIONS

It is essential that the fruit of any prune cultivar released for the California prune industry is able to be mechanically harvested and withstand industrial processes used in fruit drying, pre-processing storage, sorting, pitting, packaging and post-processing storage before they are recommended for widespread plantings. All six of the above selections are currently undergoing expanded field trials in commercial grower orchards before final decisions are made about their suitability for use in the California dried prune industry.

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