The University of California *Prunus domestica* Cultivar Development Program

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Abstract

The University of California Dried Plum/Prune Cultivar Development Program was founded in 1985 by Dr. Theodore DeJong of University California, Davis (UCD) and Jim Doyle of the UC Kearney Agricultural Center (KAC) in Parlier, CA. Over the last 27 years, the program has used traditional breeding methods to improve the germplasm for the development of new *Prunus domestica* cultivars for California. Dr. DeJong, Carolyn DeBuse and Sarah Castro currently manage the program at UC Davis. Annual hand pollinations involve >20,000 controlled crosses per season and from these, 1,000-2,000 seedlings are produced. Of the approximate 10,000 trees located in the seedling blocks at any one time, about twenty genotypes are selected for further study each year. Evaluations of advanced selections are conducted at two locations, one in the Sacramento Valley and the other in the central San Joaquin Valley. The prune industry in California is dependent on a single cultivar ('Improved French') and the primary goal of the program has been to develop new cultivars that can improve crop production/processing efficiency and extend the harvest season. To date the program has released two prune cultivars ('Muir Beauty' and 'Sutter') that ripen fourteen and seven days earlier (respectively) than 'Improved French'. However the industry has had difficulty in adapting these two cultivars to their handling and processing practices. The program has also released 'Tulare Giant', a large, early, fresh market plum cultivar that has been very successful. Program goals and desired characteristics of advanced selections have evolved over time as the California dried plum industry has experienced increased pressure for improving production efficiencies and cutting costs.

INTRODUCTION

The California dried plum (prune) industry involves about 30,000 ha of a single *Prunus domestica* cultivar, 'Improved French'. While 'Improved French' is an excellent cultivar that is adapted to the high heat common to the central valleys of California and to mechanical harvesting; dependence on a single cultivar leaves the California dried plum industry vulnerable to potential problems. This single cultivar system is subject to large variations in productivity due to possible non-optimal weather conditions during bloom, the need for all the fruit to be harvested over a very short period in the summer, and the potential for large losses if it were susceptible to an introduction of a new pest or disease. In addition, the California dried plum industry is constantly under pressure to increase its production and handling efficiency as a result of rising costs of labor and fuel. Due to the fragility of such a monoculture system, the California Dried Plum Board initiated funding for a breeding program at the University of California in 1985 with the goal of developing new cultivars for the Californian dried plum industry. The goal of this program is to create new cultivars that have processing characteristics similar to 'Improved French', spread bloom and harvest timing, and increase production and drying efficiency. Target characteristics for increasing production and drying efficiencies are traits that reduce pruning requirements and decrease fresh to dried fruit weight loss. Thus the program aims to aid prune growers by developing new cultivars that need less inputs than the

conventional ‘Improved French’ cultivar.

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 25 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 are made by emasculating flowers on maternal trees and hand pollinating with harvested pollen from paternal trees. Usually >20,000 flowers are emasculated and pollinated on several genotypes in a specific year. 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 cut Californian prune grower costs.

The major traits of current interest are:

- Good tree structure – to reduce pruning costs
- Decreased 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 health benefits of eating prunes
- Uniformity in fruit maturation – to insure 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.

Improving tree structure is important because it could reduce pruning costs for growers. Currently, pruning is the number one cultural cost related to cultivating dried plums. ‘Improved French’ is a vigorous cultivar that produces fruit on spurs attached to two-year-old (or older) shoots. ‘Improved French’ trees are pruned annually because of their vigorous growth and “wispy” growth habit. This cultivar produces long, wispy, spur-bearing “hangers” that produce fruit at the end of thin branches. These hangers dissipate shaker vibrations and impede efficiency of mechanical thinning and mechanical harvesting using tree shakers. Hand pruning of ‘Improved French’ is necessary to select and shorten hangers on each tree. One goal of the breeding program is to create a more spur bearing tree that does not need such intensive pruning. A tree with reduced vigor would also create less need for removing excessive vigorous shoots as well as reduce the need for ladders.

Another important objective for this program is reducing the ratio between fresh and dried product. The growers in California own their prunes until after they are dried and thus are charged for their drying costs. The rate paid depends on the fresh to dried

weight ratio of their fruit. Over half of a typical farmer's harvesting costs go into drying the fruit. Actually, ~40% of their total operating costs go to drying their fruit (Niederholzer et al., 2008). The dry away ratio for 'Improved French' is usually at or above 3.0. Thus it is very important to develop cultivars that have a dry away ratio below 3.0.

Widening the harvest and bloom time windows could also increase efficiency of the dried prune industry. Since there is only one cultivar currently being cultivated, there must be enough equipment available to harvest and dry the entire crop in just a few weeks. This makes the cost of equipment and equipment maintenance high. If the industry had multiple cultivars with varying harvest dates, fewer machines could be used multiple times over the course of the harvest season instead of only during a short harvest window each year. A similar concept applies with regard to the bloom window. With only one cultivar being grown, the chance of a crop disaster due to poor pollination is high (De Ceault and Polito, 2010). Multiple cultivars with varying bloom dates would spread the risk and increase the chances of producing a substantial crop each year that would allow the Californian industry to maintain a global market share every year.

Optimal sugar content in prunes is a relatively new objective for this program. We have recently determined that our germplasm expresses large variation in the sugar composition of the fruit. Dried plums are marketed for their digestive health benefits as well as for being a low glycemic index food. Both of these factors result from prunes having high concentrations of sorbitol. A goal of the program is to release new cultivars that have the same or better health benefits as "Improved French" for dried plum consumers. Therefore one objective of the program is to develop cultivars with high fruit sorbitol concentrations. Uniformity in fruit maturation is a trait that is very important because of the way the fruit is harvested. Unlike most fresh fruit, dried plums are harvested once per tree. Harvest timing is based on fruit firmness or the pressure the fruit flesh can withstand when punctured. So the more uniform the fruit pressures throughout the canopy of a tree, the easier it is to get all the fruit off the tree, and handle, transport, and uniformly dry it. In addition, it would be desirable to have mature fruit hang on the tree for an extended period of time. This would increase a cultivar's harvest window and allow grower flexibility for harvesting it. It may also be possible to decrease the dry away ratio by having the fruit hang on the tree long enough to lose appreciable water.

All seedlings that are candidates for selection are put through a rigorous testing process to insure that the fresh and dried characteristics are suitable for the industry. Fruit from over 1,000 seedling trees are evaluated each year for their quality. The fruit is tasted and evaluated in the field for its color, shape, flesh texture, pit size, pit adhesion to flesh, and presence of defects. If the seedling fruit passes this visual and sensory evaluation, 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 to evaluate its dried quality. If the dried fruit meets specified qualities, the genotype is grafted into 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 insure the fruit meets their standards. Subsequent to positive processing evaluations, the selection is 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 AND DISCUSSION

Much of the germplasm used in the 1980s that came from the eastern United States or Europe was not suited for California's hot weather conditions. A summary of

those historical varieties can be seen in Doyle et al. (2012). Over the last 25 years of breeding, the breeding population has been refined to parental selections that have many improved traits. In 1975, Hansche et al. determined that some important *P. domestica* genes are likely additive. Our experience over the past 25 years seems to have confirmed that there is a positive response to selection. Our improved germplasm now has selections bearing fruit with increased flavor, more standard positive traits and fewer negative traits while being able to tolerate California's hot climate. Many of the germplasm selections vary in bloom and harvest time. The precocity of the seedlings has also greatly improved. Fruit can now be seen in the 3rd leaf of seedling growth whereas initially it was unusual for most seedlings to bear fruit before the 5th year in the orchard.

The program released three cultivars, two in 2000 and one in 2004. 'Sutter Prune' and 'Tulare Giant' are described in DeJong et al. (2002). 'Muir Beauty' prune was released in 2004 as a pollinizer for 'Tulare Giant.' It is a result of a cross between 'Tulare Giant' and 'Improved French'. It is a pollen self-compatible, high quality dried plum that is not suitable for currently used commercial processing or pitting methods. It is best marketed as a whole natural product. It harvests about two weeks before 'Improved French' and blooms with 'Tulare Giant'.

In a typical year, the program plants 1,000-2,000 seedlings from the pollinations made the previous spring. Of the 1,000-2,000 seedlings evaluated each year, fruit from approximately 300 seedlings are brought to the lab for further testing, and fruit from about 100 of these trees are subsequently dried for analysis of their dried fruit qualities. Of those, 15-20 trees are grafted onto rootstocks in the selection blocks for further evaluation of tree and fruit characteristics in subsequent seasons. Table 1 provides a list of the seedlings that were grafted into the selection blocks in early 2012 as an example of the selections made in one year. Note the range of harvest dates as well as the variation in fruit sugar content (°Brix) and dry ratio (fresh fruit weight /dry fruit weight). Once grafted to a conventional rootstock, the selections are thoroughly evaluated before release. Table 2 shows the top selections of 2011. Notice that a majority of the selected items have low dry away ratios and high sugar contents. If the selections listed in Table 2 continue to show promise in the upcoming years, they will be candidates for evaluation by the industry's processors.

We have identified selections (Table 2) that have many of the major traits we referenced as objectives of this program however we are still in search of the "perfect plums" for the Californian dried plum industry.

CONCLUSION

This breeding program is over 27 years old and has greatly improved the available California *Prunus domestica* germplasm with traits suitable for drying. As far as we are aware, this program is the only breeding program in the western hemisphere that is solely focused on dried plum cultivar development. The program is largely funded by the Californian dried plum industry and this requires that the program focus on the specific needs of Californian growers. The program is primarily focused on fruit quality, tree structure and tree phenology. The initial germplasm base, 27 years ago, was of limited suitability for realistic development of new Californian cultivars. Now, genetic traits for substantial cultivar improvement are available and active in the improved germplasm. We anticipate the release of several new cultivars within the next decade.

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Tables

Table 1. Items chosen for grafting in the selection block in 2012.

Selection	Date tested in 2011	Days from French	°Brix	Dry ratio	Comments
G12S- 64	9-Aug	-32	20.3	3.6	Good skin quality suitable for processing
H1N- 40	12-Aug	-29	24.7	3.1	Very small pit
G35N- 10	15-Aug	-26	20.0	3.7	Good skin quality and dried characteristics
G21S- 20	25-Aug	-16	18.3	3.7	Very attractive fried fruit
G29N- 39	26-Aug	-15	19.6	3.6	Substantial skin especially suitable for processing
H1N-93	30-Aug	-9	20.0	3.9	Especially attractive dried fruit characteristics
H1S- 84	30-Aug	-9	19.8	3.3	Dense flesh and excellent dried characteristics
H1S- 31	30-Aug	-9	23.2	3.1	Excellent dried characteristics
H1S- 45	30-Aug	-9	22.6	3.1	Very small pit and good dried characteristics
G47S- 45	1-Sep	-7	26.7	2.7	Low dry away ratio, good dried flavor
G47S- 61	1-Sep	-7	18.9	3.8	Free pit, good flesh and skin characteristics for drying
G47S- 57	1-Sep	-7	20.9	3.4	Excellent dried characteristics
H11N- 96	7-Sep	-1	24.4	3.4	Exceptional flavor
H7S- 1	13-Sep	5	19.6	3.6	Excellent dried characteristics
G14S- 11	13-Sep	5	30.7	2.7	Thick skin, excellent flavor, low dry-away ratio
H11S-47	23-Aug	-18	21.6	Fresh	Large, high sugar

Table 2. A list of the program's top selections in 2011. Notice the low dry away ratios and high sugar content of most selections.

Selection number	Test date	Fruit fresh weight (g)	Sugar content (°Brix)	Dry ratio (fresh/dried)
F11S-38	8/15/11	20.4	36.2	2.0
G16N-19	9/16/11	32.3	29.9	2.5
F2N-32	8/29/11	29.0	27.1	2.6
G47S-45	9/1/11	19.7	26.7	2.7
G2N-44	9/12/11	42.2	25.7	2.9
G2S-8	9/12/11	42.2	25.4	2.9
G3N-16	8/22/11	35.2	21.1	3.0
French	9/6/11	26.7	27.0	3.4