RESEARCH RESULTS FOR THE YEAR 2012 'FASTRACK' - A REVOLUTIONARY APPROACH TO LONG-GENERATION CYCLE SPECIALTY CROP BREEDING

Ralph Scorza, Ann Callahan, Chris Dardick, Doug Raines, Ted DeJong, Albert Abbott and Jayson Harper

OBJECTIVES

The objectives of the project are the development of a practical rapid cycling breeding system for plum, the development of improved plum germplasm and varieties, and the demonstration of FasTrack breeding as a model for the rapid breeding of other long breeding cycle crops, in particular tree fruits.

PROPOSED RESEARCH AND DEVELOPMENT

The American tree fruit industry is facing challenges of climate change, reductions in available labor, the need for reduced chemical inputs, the spread of exotic pests and pathogens, and consumer demands for improved fruit quality and healthful attributes. To meet these challenges the development of improved varieties is more vital than ever. Yet, fruit tree breeding remains a slow, arduous process that has changed little over the centuries. Limitations include long juvenility periods (3-10+ years), large land areas with significant field costs, and yearly limitations on flowering and fruiting related to chill and heat requirements. Recently, research has focused on marker assisted selection (MAS), germplasm characterization, and genetic engineering (GE) as means to advance tree fruit breeding. However, these strategies are all still limited by the inherently slow generation cycles of tree fruits. To address this need, a system has been developed to shorten the breeding cycle of tree fruits and other long breeding cycle crops. We have overcome the juvenility and environmental limitations of flowering and fruiting by incorporating a flowering-related gene from poplar (FT) to induce trees to flower early and continually and to produce viable fruits and seeds within one year. In plum (*Prunus domestica*), the normal generation cycle is 3-6 years. We are using the early flowering trait to develop a rapid breeding system-'FasTrack'. The system will allow for the rapid incorporation of important traits into plums and other long-generation-cycle crops and then in the final generation, when substantial improvements are clearly evident, the FT gene construct would then be selected against in segregating seedlings and the resulting "null segregants" (those seedlings not containing the early flowering transgene, or any transgene sequences) would not be genetically engineered. This improved germplasm may be used directly as new varieties or improved lines for further conventional breeding. Such an approach would provide breeders of long-generation-cycle crops the ability to respond to new market demands, climatic changes, introductions of exotic diseases and pests in a way never before possible with these species.
The FasTrack proposal, funded by the USDA Specialty Crops Research Initiative and supported in-kind by the California Dried Plum Board, UC, Davis, Clemson University, Andres Bello University, International Food Information Council (IFIC) and Penn State University began in the fall of 2009. The research team includes from USDA-ARS Kearneysville, WV, Ralph Scorza, Chinnathambi Srinivasan, Ann Callahan, Chris Dardick-, and Doug Raines; from UC, Davis, Ted DeJong; from Clemson University, Albert Abbott; and from Penn State University, Jayson Harper.
Project goals cover the areas of research, extension, and outreach. Progress in these areas in 2012 is briefly summarized below.

SUMMARY OF SIGNIFICANT ACCOMPLISHMENTS 2012

- FasTrack breeding parameters were optimized
- The gene for PPV resistance from 'HoneySweet' Plum has been combined with the early flowering (FT) trait.
- The early flowering gene has been combined with 'Improved French' types from the UC Davis prune breeding program
- Third generation plants that contain genes for early flowering combined with the 'HoneySweet' plum PPV resistance gene and 'Improved French' genetic background have been germinated and these will then be available for backcross breeding to combine PPV resistance with 'Improved French' traits.
- Additional molecular markers for 'French Prune' and 'HoneySweet' plums have been developed
- 'Improved French' and 'HoneySweet' genomes have been sequenced and this will generate additional molecular markers for backcross breeding selection.

2012 RESULTS NARRATIVE

Research Component Progress

Third generation seedlings are being grown out. Considering that we are beginning the fourth year of the project and that a typical generation cycle for *P. domestica* plum is on average 4 years, the timeline for FasTrack breeding is extremely rapid. To reach this stage in the breeding program would normally require around 10 years.

All seedlings from crosses of the genetically engineered Plum pox virus resistant plum variety 'HoneySweet' by FT (early flowering) elite lines have been screened for the presence of the PPV resistance construct and the presence of the FT construct using molecular markers. All seedlings from California germplasm by FT elite lines have been screened for the presence of the FT construct.

In order to incorporate molecular markers as a selection tool, parental lines from California germplasm and from Kearneysville germplasm, including the elite FT lines have been screened with markers derived from 'HoneySweet' sequence and from 'Improved French' sequence that were designed to differentiate the germplasm.

Since FasTrack breeding is greenhouse-based, comparisons of fruit quality in the greenhouse and field are important. Our studies continue to suggest that fruit grown in the greenhouse and field are similar in size, brix, color and other phenotypic traits. Additional years and genotypes will be sampled and additional phenotypic traits will be evaluated

Fertilization trials have been conducted to maximize fruit yield.

Grafting studies have shown that while grafting early flowering plant onto standard plum rootstock increases vegetative growth of the early flowering plants flowering and fruiting is reduced. While fruit production is reduced on grafted plants fruit phenotype is nearly identical on early flowering plants grafted onto non-GE rootstocks and self-rooted early flowering plants indicating that fruit qualities of seedling early flowering trees will remain stable when trees are grafted onto standard rootstocks.

Temperature control in the greenhouse has been improved and we have used a cooler temperature setting to increase flower and fruit production.

Early flowering plum trees in the field have continued to produce flowers and fruit throughout spring and early summer with flowering resuming in the fall. The prolonged flowering period in spring/summer can allow for the escape from spring frost events and this year while an early spring freeze event destroyed the flowers and developing stone fruits in our orchard the early flowering lines were able to produce flowers and fruit as the season continued. Field grown early flowering trees may provide additional hybridization opportunities for FasTrack breeding and also novel production potentials. These opportunities are under investigation.

Extension Component Progress

Breeding for PPV resistance using 'HoneySweet' plum as a parent is an important goal for providing the California dried plum industry with PPV resistant germplasm and varieties should PPV spread to California. We are advancing the generations and combining PPV resistance from 'HoneySweet' plum with California germplasm to develop PPV resistant 'Improved French' types. Breeding for alternative ratios of sugars in plums for taste and health benefits is one goal of the FasTrack breeding project. We are working on this goal through the phenotyping of seedlings, selections, and cultivars in the breeding program and through the isolation of sugar-related molecular markers. This will be a longer term goal for germplasm development and will continue beyond the time frame of this project. The approach is to develop basic information on individual sugars and sugar ratios in plum germplasm and to build the technology for rapidly breeding and selecting sugar ratios that the industry may require in the future.

Outreach Component Progress

It is important to liaison with the plum industry, fruit breeders, consumers, and regulators, in order to obtain scientific and societal input into this novel technology for plant improvement. We have developed a FasTrack website **http://ucanr.org/sites/fastrack/** and we plan to continue to work with this website to reach out to other scientists, industry and the general public. Additional outreach activities in 2012 include presentations at professional meetings in the U.S., Canada and Europe on the FasTrack approach to breeding. We have maintained communication with the dried plum industry and participate in the CDPB annual meetings.