Prunus Vulnerability Statement
March 2017
Prunus Crop Germplasm Committee

EXECUTIVE SUMMARY

Prunus species are the basis of U.S. fruit and nut production worth more than $7 billion annually that encompasses the crops of almond and stone fruit (peach, nectarine, apricot, plum, prune, sweet cherry, and tart cherry). Within each crop, cultivated U.S. germplasm typically has a narrow genetic base, although diverse germplasm exists in other countries – Asia and Europe are the Centers of Diversity of most cultivated *Prunus* species. The National Clonal Germplasm Repository at Davis, CA holds approximately 2000 accessions covering more than 90 taxa of the several hundred known *Prunus* species, with most species represented by very few collection accessions. Only limited evaluation of performance characteristics and DNA profiles have been compiled for the collections, and thus their full genetic potential remains largely unknown.

Within the U.S. and Europe there has been an increase in demand for almonds and fresh stone fruit, although a decrease for processed stone fruit, in part due to a greater awareness of health benefits. Increased fruit and nut quality is needed to promote repeat sales and satisfy the increased demand for *Prunus* crop products. However, postharvest maintenance of quality and integrity is a problem in stone fruits because of their short market life and susceptibility to diseases. Stone fruit are genetically vulnerable to pests and diseases. At present, application of multiple pesticide sprays per year is common practice in *Prunus* crop production, but long-term genetic solutions are required. *Prunus* crops are also susceptible to a range of environmental stresses. Unfortunately, germplasm encompassing a wide range of climatic adaptability does not exist in the U.S. Large-scale *Prunus* crop production in California has ushered in the demise of germplasm adapted to other regions. *Prunus* crop production is becoming increasingly mechanized and orchards are planted at higher densities than in previous decades. Yet there are few cultivar choices ideally suited to such new production technologies, including a lack of dwarfing *Prunus* rootstocks.

Rapid changes in agricultural technology and global climate pest and disease threats, and increased appreciation of the contribution of fruit to a healthy diet warrant increased breeding attention to develop superior new cultivars that meet the demands of new production systems, ecological sustainability, and human health. Yet there continues to be a reduction in publicly funded breeding programs. Private breeding programs contribute substantially to U.S. cultivar development and production, but often lack immediate connections to publicly funded research programs and are less likely to use non-elite germplasm. Unlike public programs, and unlike private breeding in agronomic crops, private stone fruit breeding is only beginning to embrace new DNA-based technologies. These novel technologies have the potential to revolutionize tree fruit breeding by efficiently combining desirable attributes, and facilitating rapid introgression from non-elite germplasm. **To ensure sustainability of U.S. *Prunus* crop industries, sources of resistance or tolerance to pests, diseases, and storage disorders, adaptability to or avoidance of environmental stresses, new tree architectures, and superior and novel fruit quality are desperately needed in an available form for breeders to develop improved cultivars.**

I. Introduction

The National Plant Germplasm System of the USDA-ARS includes the National Clonal Germplasm Repository (NCGR) in Davis, CA, which was established 1981 and federalized in 1989 to preserve *Prunus* crop germplasm, except for tetraploid cherry (*P. cerasus* and other tetraploid cherry species) which are preserved at the Plant Genetic Resources Unit (PGRU) in Geneva, NY, and the ornamental *Prunus* which are housed at the National Arboretum in Washington, D.C.

Stone fruit and almond production in the U.S. is worth more than $7 billion (Table 1). About 80% of the processing peach crop is grown in California, which also produces about 50% of the fresh market peaches and 90% of the nectarines. South Carolina and Georgia produce another 25% of the fresh market peach crop, with the remaining crop being produced by another 30 states. Most Japanese plum and apricot production is in California. California is the major prune plum producer followed by Oregon, Washington, Idaho, and the Great Lakes region, with limited production in the Southeast. Fresh market sweet cherries are produced mainly in Washington and Oregon followed by California, with a significant amount produced for brining in the Great Lakes States. Most tart cherries are produced in Michigan, followed by New York, Oregon, Pennsylvania, and Utah. All commercial almonds are produced in California.

Within the U.S. and Europe there has been an increase in demand for fresh fruit and a decrease in demand for processed stone fruit. The increase in fresh fruit consumption is in part due to a greater awareness of the health benefits and availability of off-season production from the Southern hemisphere, but it is clear from consumer surveys that increased quality is needed to promote repeat sales and satisfy the increased demand for stone fruit.

Table 1. Stone fruit production in the U.S.

Crop	**2007**	**2009**	**2013**	**2014**	**2015**
Peach	499 M	595 M	548 M	630 M	606 M
Nectarine	86 M	134 M	125 M	178 M	150 M
Almond	2.32 Billion	1.78 Billion	6.38 Billion	7.38 Billion	5.32 Billion
Apricot	43 M	44 M	45M	53 M	41 M
Plum and Prune	211 M	262 M	238 M	377 M	331 M
Sweet Cherry	584 M	505 M	772 M	767 M	759 M
Tart Cherry	67 M	64 M	104 M	107 M	87 M

Source: Noncitrus fruits and nuts 2015 Summary (July 2016). USDA, National Agricultural Statistics Service.

II. Germplasm Utilization

Numerous public institutions are involved in *Prunus* crop breeding, although public investment is declining. These programs usually have working collections of material of interest to them, although often covering only elite material and therefore of relatively narrow diversity. There are a few arboretums that also have limited collections of *Prunus*.

Major *Prunus* breeding programs and/or *Prunus* collections in North America

Peach/Nectarine

Fayetteville/Clarksville, AR – John Clark, Margaret Worthington - University of Arkansas
Bakersfield, CA – Terry Bacon, Sun World, Inc.
Davis, CA – John Preece, Carolyn DeBuse - NCGR
Davis, CA – Tom Gradziel - University of California, Davis
Delano, CA – David Cain - International Fruit Genetics
Fresno, CA – John Slaughter, Burchell Nursery
Le Grand, CA – Glen Bradford, Jon Quisenberry – B Q Genetics
Modesto, CA – Floyd Zaiger, Gary Zaiger, Leith Zaiger, Grant Zaiger - Zaiger Genetics*
Parlier, CA – Craig Ledbetter - USDA-ARS Parlier*
Gainesville, FL – José Chaparro - University of Florida
Byron, GA – Tom Beckman and Chunxian Chen - USDA-ARS Byron*
Baton Rouge, LA – Charles Johnson - Louisiana State University
Calhoun, LA – Charles Graham - Louisiana Experiment Station
Benton Harbor, MI – Paul Friday - private breeder
Benton Harbor, MI – William Shane - Michigan State University
Coloma, MI – Annette and Randy Bjorge - Fruit Acres Farm
Raleigh/Jackson Springs, NC – Dennis Werner - North Carolina State University
Cream Ridge, NJ - Joseph Goffreda – Rutgers University
Clemson/Pontiac, SC – Ksenija Gasic and Greg Reighard - Clemson University*
College Station, TX – David Byrne - Texas A&M University
Prosser, WA – Ken Eastwell - Washington State University
Kearneysville, WV – Chris Dardick - USDA-ARS Kearneysville
Queretaro, Mexico – Salvador Perez and INIFAP
Vineland, Ontario, Canada – Neil Miles - University of Guelph

*Programs also conducting rootstock breeding

Almond

Davis, CA – John Preece, Malli Aradhya, Carolyn DeBuse - NCGR
Davis, CA – Tom Gradziel - University of California, Davis
Modesto, CA – Floyd Zaiger, Gary Zaiger, Leith Zaiger, Grant Zaiger - Zaiger Genetics
Parlier, CA – Craig Ledbetter – USDA-ARS Parlier

Apricot

Davis, CA – John Preece, Malli Aradhya, Carolyn DeBuse - NCGR
Le Grand, CA – Glen Bradford, Jon Quisenberry – B Q Genetics
Modesto, CA – Floyd Zaiger, Gary Zaiger, Leith Zaiger, Grant Zaiger - Zaiger Genetics
Parlier, CA – Craig Ledbetter - USDA-ARS Parlier
Byron, GA – Chunxian Chen - USDA-ARS
Cream Ridge, NJ – Joseph Goffreda - Rutgers University
College Station, TX – David Byrne - Texas A&M University
Queretaro, Mexico – Salvador Perez and INIFAP
Vineland, Ontario, Canada – Helen Fisher - University of Guelph
Gainesville, FL – José Chaparro- University of Florida

Plum/Prune
Bakersfield, CA – Terry Bacon, Sun World, Inc.
Davis, CA – John Preece, Malli Aradhya, Carolyn DeBuse - NCGR
Davis, CA – Ted DeJong, Jim Doyle (*P. domestica*)
Delano, CA – Tim Bourne - Marko Zaninovich (*P. domestica*)
Le Grand, CA – Glen Bradford, Jon Quisenberry - B Q Genetics
Modesto, CA – Floyd Zaiger, Gary Zaiger, Leith Zaiger, Grant Zaiger - Zaiger Genetics
Gainesville, FL – José Chaparro - University of Florida
Byron, GA – Chunxian Chen - USDA
Traverse City, MI – Nicki Rothwell - Michigan State University (*P. domestica*)
Geneva, NY – Courtney Weber - USDA-ARS Geneva (*P. domestica*)
College Station, TX – David Byrne - Texas A&M University
Prosser, WA – Ken Eastwell - Washington State University
River Falls, WI – Brian Smith - University of Wisconsin

Sweet Cherry
Davis, CA – John Preece, Malli Aradhya, Carolyn DeBuse - NCGR
Delano, CA – David Cain - International Fruit Genetics
Le Grand, CA – Glen Bradford, Jon Quisenberry - B Q Genetics
Lodi, CA – Marvin Nies - private breeder
Traverse City/Clarksville, MI – Amy Iezzoni - Michigan State University
Prosser, WA – Ken Eastwell - Washington State University
Prosser, WA – Cameron Peace (temporary) - Washington State University
Mt. Vernon, WA - Gary Moulton – Washington State University
Vineland, Ontario, Canada – Frank Eady - University of Guelph
Summerland, BC, Canada – Frank Kappel - AAFC

Tart Cherry
Davis, CA – John Preece, Malli Aradhya, Carolyn DeBuse – NCGR
East Lansing/Clarksville, MI – Amy Iezzoni - Michigan State University
Geneva, NY – Thomas Chao - PGRU

Species & Interspecific Hybrids
Davis, CA – John Preece, Malli Aradhya, Carolyn Debuse - NCGR
Davis, CA – Tom Gradziel - University of California, Davis
Modesto, CA – Floyd Zaiger, Gary Zaiger, Leith Zaiger, Grant Zaiger - Zaiger Genetics*
Parlier, CA – Craig Ledbetter - USDA-ARS Parlier
Washington D.C. – Richard Olsen U.S. National Arboretum (ornamental cherries)
Gainesville, FL – José Chaparro - University of Florida
Byron, GA - Chunxian Chen, Tom Beckman - USDA-ARS Byron
Calhoun, LA - Charles Graham - Louisiana State University
College Station, TX – David Byrne - Texas A&M University
Prosser, WA – Ken Eastwell - Washington State University
River Falls, WI – Brian Smith - University of Wisconsin

*Programs also conducting rootstock breeding

The American Horticultural Society has a list of Arboreta and Botanical Gardens containing *Prunus*.

North American organizations with an interest in *Prunus* germplasm and for which interaction is desirable for input into U.S. *Prunus* germplasm decisions

Almond Board of California
American Pomological Society
American Society for Horticultural Science - Fruit Breeding Working Group
American Society for Horticultural Science - Genetics and Germplasm Working Group
California Genetic Resources Conservation Program
California Rare Fruit Growers
California Tree Fruit Agreement
FPS - California Foundation Plant Material Service - UCD
Fruit Tree Clean Plant Network
National Peach Council
NC-140 - North Central Regional Rootstock Committee
North American Fruit Explorers: an organization of private and hobby fruit enthusiasts
Northern Nut Growers
Ontario Fruit Testing Association
Okanagan Plant Improvement Co. Summerland, B.C. Canada
PMC/NRCS-USDA (Plant Materials Centers)
Prunus Breeders Group (an informal organization of *Prunus* breeders from throughout the world, but mostly from the U.S., Canada and Mexico, that meet irregularly to exchange knowledge)
South Carolina Certification Board

European organizations with an interest in *Prunus* germplasm

Bioversity - *Prunus* Working Group has developed a database for *Prunus* held at 45 locations in Europe. They have also supported collection trips for *Prunus*
EUCARPIA - European Association for Research on Plant Breeding
International Society for Horticultural Science - Working Groups related to *Prunus*:
- Apricot Breeding and Culture
- Cherry Production
- Peach Culture
- Plum and Prune Genetics
- Nut Production (almond)
- Rootstock Breeding and Evaluation

N. I. Vavilov All-Russian Scientific Research Institute of Plant Industry
Nordic Gene Bank
Prunus Genetics Group of Europe
Rootstock Group of Europe
United Kingdom Plant Genetic Resources Group

III. Statement of Crop Vulnerability

To ensure sustainability of U.S. stone fruit industries, sources of resistance to pests, diseases, and storage disorders, adaptability to environmental stresses, new tree architectures, and superior and novel fruit quality are desperately needed in an available form for breeders to develop improved cultivars.

Within each crop, cultivated stone fruit in the U.S. typically has a narrow genetic base. Studies using isozymes and DNA markers to evaluate genetic diversity among *Prunus* have indicated that within U.S. germplasm there is low diversity among peaches, low to intermediate among apricots, and medium to high diversity among Japanese plum germplasm (Byrne, 1990).

A survey of RAPD markers in the peach/nectarine NCGR germplasm clearly indicated that the U.S. germplasm is narrow and can be grouped into three closely related clusters (Warburton and Bliss, 1996). In contrast, the few Chinese accessions in the study were grouped separately from U.S. germplasm and showed much more diversity among them than did U.S. accessions. This same trend is revealed in various other studies of isozyme and morphological polymorphisms among cultivated peaches (Arulsekar et al., 1986; Messeguer et al., 1987; Durham et al., 1989; Byrne, 1990; Mowrey et al., 1990; Werner, 1992; Ibanez et al., 1993; Perez et al., 1993). Inbreeding analyses of various populations of peaches (Eastern cultivars, Florida low chill cultivars, and California processing germplasm) and Japanese plum germplasm have shown that peaches share much common parentage within breeding germplasm pools (Scorza et al., 1985; 1988; Gradziel et al., 1993; Byrne and Bacon, 1999). For example, peach cultivars from the eastern U.S. have a handful of commonly used parents and high levels of inbreeding. Most nectarine cultivars trace back to just four cultivars. Recent high throughput next generation genotyping of 475 peach and peach related accessions in the NCGR collection confirmed narrow genetic background of peach and revealed errors in species designation for some wild relatives (Gasic t al 2015; FY 2012 – 2013 Prunus Award). GRIN database catalogued material as 85% *Prunus persica*, 8% wild relatives (*P. mira*, *P. davidiana*, *P. kansuensis* and *P. ferganensis*) and 7% categorized as hybrids between peach and other related species and *Prunus spp* (unknown). Population structure analyses revealed 7 groups among which *Prunus persica* accessions formed 5 clusters and remaining two clusters constituted of *P. mira* and admixed individuals, respectively. Data uncovered origin of accessions collected and catalogued as *P. kansuensis* and *P. ferganensis* to be *P. mira* × *P. persica* and *P. persica*, respectively. Accessions catalogued as *Prunus* spp. and/or unknown were successfully assigned to the related group, mostly *P. persica*, or remained unstructured together with other interspecific hybrids. Most of *P. davidiana* accessions showed some degree of hybridization with *P. persica* and *P. mira* and were unstructured.

Plums have a broader genetic base than other commercial *Prunus* species, but still the vast majority of commercial fresh market plums grown in the U.S. are Japanese types, which are grown in California but are not adapted to other growing regions. Japanese plum cultivars had coancestry and inbreeding coefficients half or less of those calculated for peaches (Byrne, 1990). Within Japanese plum germplasm, the higher level of diversity is believed to be due to introgression of disease resistance from related species into germplasm developed in the southeastern U.S. by Luther Burbank who crossed *P. salicina* with other diploid plum species. Unfortunately, among California plum germplasm, much less variability exists. This situation reflects the fact that these cultivars can be traced back to only a few introductions of *P. salicina* and one introduction of *P. simonii* from China (via Japan). A recent introduction of *P. salicina* from Taiwan is very distinct from other *P. salicina* introductions available in the USA, indicating that much more variability exists within this species in its center of diversity (Boonprakob, 1996). The prune cultivar French accounts for 96% of prune production on the West Coast. The European plum cultivar Stanley accounts for almost all the European plum production in the eastern U.S.

‘Bing’ accounts for 75% of the fresh market sweet cherry crop. For sweet cherry, just a few founding cultivars, such as ‘Black Heart’, ‘Emperor Francis’, ‘Empress Eugenie’, ‘Napoleon’, and ‘Windsor’, and their descendants, have been repeatedly used as parents in North American sweet cherry breeding programs (Choi and Kappel, 2004) and this has probably led to the reduction of genetic diversity in sweet cherry (Gerlach and Slosser 1998; Shimada et al., 1999; Zhou et al., 2002). Furthermore, the highly desirable attribute of self-compatibility found in many U.S. cultivars (sweet cherry is otherwise self-incompatible and an outbreeder) is from a single source, itself derived from ‘Emperor Francis’ and ‘Napoleon’. A survey of 66 sweet cherry cultivars (Choi and Kappel, 2004) released from four North American sweet cherry breeding programs including HRIO Vineland, Ontario, Canada, WSU-IAREC, Prosser WA, NYSAES, Geneva, NY and PARC, Summerland, BC, showed high levels of inbreeding in both self-incompatible and self-compatible cultivars. A lack of diversity could lead to inbreeding depression in future generations. A lack of diverse sweet cherry germplasm is expected to limit long-term genetic gain. The entire tart cherry industry is based on the 400 year-old ‘Montmorency’ cultivar which is considered an inferior cultivar in many European countries.

Apricots have such a limited amount of genetic variation in adaptive traits within commercial US cultivars that they can be grown commercially in only a few isolated regions of the U.S. for where they were selected. The introduction of new cultivars from foreign sources may often give disappointing results, with unpredictable variability depending on the environment therefore, cultivars must be bred for each producing area and for each marketing opportunity (Zhebentyayeva et al., 2015). Greater than 50% of the apricot production in California is from a few cultivars. Apricots grown for the fresh market in California and Michigan generally have one cultivar, ‘Perfection’ as a common parent.

‘Nonpareil’ accounts for more than 50% of the almonds produced in the U.S. Numerous *Prunus* species that may possess desirable traits are not available in the U.S. or are represented by only one or two *accessions.* Bailey’s Hortus Third (2) states there are *more than* 400 species in the genus *Prunus*, but fewer than 100 are listed in GRIN.

Compared to agronomic crops, stone fruit are much more genetically vulnerable to pests and diseases. At present, the application of multiple pesticide sprays per year is common practice in stone fruit production. Because of their high value, this intensive spray schedule is still economically feasible. The economic advantage of spraying is fast declining as available chemicals become limited and expensive, in response to the greater awareness of the ecological and safety risks involved in their use. Thus, susceptibility of stone fruits to brown rot, peach scab, mites, bacterial spot, bacterial canker, peach tree borers, and other pests needs to be countered with genetic resistance. Unfortunately, acceptable sources of resistance for these pests and diseases do not appear to exist in elite commercial germplasm. Many stone fruit crops could not be economically grown if specific chemicals were banned. The use of dibromochloropropene (DBCP) for post-plant nematode control in peaches and its subsequent banning is a classic example of dependence on chemical control because of genetic susceptibility. Now growers must also contend with the loss of methyl bromide and ethylene dibromide. Peaches, plums, cherries, and apricots are all susceptible to brown rot, mites, peach tree borers, and bacterial canker. There are also many diseases which attack specific *Prunus* species such as peach leaf curl and cherry leaf spot. Major diseases and pests are listed in Tables 4 and 5 (Appendix).

Stone fruit crops are susceptible to a range of environmental stresses such as freezing at bloom, mid-winter cold damage, fluctuating winter temperatures, and warm winter conditions, which limit the regions in which they can be cultivated (Table 6 - Appendix). China has *Prunus* species adapted to a wide range of environments from the severe winters of the north to the subtropical areas of the southern part of that country. Much of the breeding for low winter chilling requirement and cold hardiness has depended on a few Chinese germplasm introductions. Unfortunately, germplasm encompassing a wide range of climatic adaptability does not exist in the U.S., which has restricted the breeding efforts. This problem has been exacerbated by the production advantage of California over other U.S. production regions ushering in the demise of germplasm adapted to non-Californian conditions.

The Prunus wild relative portions of the collections have grown more rapidly than cultivar and breeders' lines portions. These wild relatives have potential to make an immediate contribution to Prunus production through use of their genetics in new, improved rootstocks. Wild relatives are much richer sources of disease and pest resistance than cultivated Prunus. If there is good graft compatibility, anchorage, and the new traits of interest, such as disease resistance are present, wild germplasm can be used directly as rootstock or as F1 interspecific hybrids with cultivated species. The backcrossing necessary to remove undesirable wild traits in the scion are typically not necessary on rootstocks. The new, wild germplasm is being exploited for rootstock development and this will continue.

Postharvest maintenance of fruit quality and integrity is even more of a problem in stone fruits than other fleshy-fruited tree crops because of their susceptibility to diseases and their short storage life (Table 7 - Appendix). Pervasive trends towards fresh fruit consumption and away from processed has amplified the problem of postharvest losses. Brown rot and Rhizopus rot are major problems and the cost of control and resultant losses are extensive. Storage disorders, such as internal browning, mealiness, and skin blemishes, which are accentuated by harvesting firm immature fruit and in the handling and storage process, cause large losses. Sources of resistance to brown rot, Rhizopus rot, storage disorders, and better firmness and shelf life need to be located and incorporated into commercial cultivars. Almonds are an exception because the seed is used instead of the fleshy pericarp.

Stone fruit production is becoming increasingly mechanized. Almost all tart cherries are mechanically harvested, as are all prune plums, almonds, and some canning peaches. Growers are planting all fruit crops at higher densities to obtain quicker returns on high capital investments, yet there are few dwarfing rootstocks in *Prunus*. Conceptually, fruit orchards are becoming more like factories, producing a constant supply of uniform products. This change in technology results either in old cultivars being forced into new roles for which they are not ideally suited and orchards being forced to less adaptable sites, or marginal areas are forced out of production. This situation necessitates the need for scions and rootstocks with new adaptability characteristics in addition to those of machine adaptation.

At a time when rapid changes in agricultural technology and global climate, and increased appreciation of the contribution of fruit to a healthy diet would seem to warrant increased breeding efforts to tailor cultivars to meet the demands of new production systems and ecological and health awareness, there continues to be a reduction in publicly funded breeding efforts. Private breeding programs contribute substantially to U.S. cultivar development and production, but often lack immediate connections to publicly funded research programs. Unlike public and private breeding programs in cereal and field crops, private and public stone fruit breeding programs have been slow in embracing new DNA-based technologies that hold the potential to revolutionize tree fruit breeding by efficiently combining desirable traits, particularly via introgression from non-elite germplasm. Many state and federal programs have been reduced due to inadequate budgets or have been eliminated entirely. The maintenance of public breeding programs is critical to *Prunus* germplasm preservation because since the closing of the USDA Plant Introduction Station at

Chico, CA in 1973, germplasm collections have been held by a few individual plant breeders in state and federal and private programs. These breeder collections are located in climates not suitable for all germplasm. Much of the Chico material was lost between 1973 and the formation of NCGR at Davis, CA in 1981 by the University of California Davis, before federalization. The extant Chico germplasm exists as one or two unhealthy specimens in individual collections. Often, these specimens are the only representatives of a species available in the U.S. Work should continue to obtain all of these specimens for the clonal *Prunus* collection at Davis.

Most U.S. cultivated germplasm has been imported, because Asia and Europe are the Centers of Diversity of most commercial *Prunus* species (Table 2). Historically, obtaining germplasm from these Centers of Diversity has been difficult because of some countries have closed their borders to germplasm exports, so when imported germplasm is lost, it is unlikely that it can be readily replaced. In addition to political obstacles to importation of new germplasm, much of the potential *Prunus* diversity is at risk of being lost because of deforestation and replacement of local varieties and landraces.

Table 2. Centers of Diversity of cultivated *Prunus* species

Crop	**Species of primary genepool[z]**	**Centers of Diversity**
Peach & Nectarine	*P. persica, P. davidiana, P. ferganensis, P. kansuensis, P. mira,* all species below for almond	China, central western Asia
Almond	*P. dulcis, P. argentea, P. bucharica, P. scoparia, P. webbii,* all species above for peach	China, central western Asia, Europe
Apricot	*P. armeniaca, P. mume, P. manshurica, P. sibirica*	China, Central Asia
Plum & Prune	*P. salicina, P. simonii,* diploid *P. cerasifera*, various North American species, *P. domestica,* hexaploid *P. spinosa,* hexaploid *P. cerasifera*	Asia, Europe, North America
Sweet Cherry	*P. avium, P. canescens*	Europe, Asia
Tart Cherry	*P. cerasus, P. fruticosa*	Europe, Asia

[z] The species of the crop and closely related species which are readily hybridized without breeding barriers other than timing of flowering

Native *Prunus* species exist in diverse climates ranging from subarctic regions to dry deserts where they are subjected to high and low temperatures, high and low moisture conditions, variable soil conditions and a host of insects and diseases. While little is known about the range of desirable characteristics possessed by wild *Prunus* species, many of these species are known to possess useful characteristics such as cold hardiness, drought tolerance and small tree size. For example, evergreen *Prunus* species exist, but very little is known about their characteristics and usefulness. These species now have limited value because they cannot be hybridized with commercial species. Varying levels of compatibility exist among *Prunus* species.

A partial listing of major genetic vulnerabilities in *Prunus* crop can be found in Tables 4-7 (Appendix). A more comprehensive treatment of specific diseases attacking these species can be found in Anderson (1956), USDA-ARS (1976), and Wilson and Ogawa (1979), Kester et al. (1990), Iezzoni et al. (1990), Mehlenbacher et al. (1990), and Ramming and Cociu (1990).

IV. Germplasm Needs

A. Germplasm Acquisition

1. Current holdings

Current *Prunus* germplasm collections in the United States are a limited representation of existing diversity. Species in China were mostly collected before 1940 and many of those introductions have been lost (Fogle and Winters, 1981). Overall North American species have not been adequately collected. However, recent collection of the North American Plums have improved plum diversity in collection (Chaparro et al FY 2011 – Prunus award)

The total number of accessions held in the National Clonal Germplasm Repository (Davis, CA) and Plant Genetic Resources Unit (Geneva, NY) has grown in the last two decades (Table 3). In addition to these USDA-ARS collections, the American Horticultural Society in 1975 had a list of 29 Arboreta in the U.S. listing 104 *Prunus* species in these collections.

Table 3. *Prunus* species and numbers of accessions held in the NCGR in Davis, CA

Crop	Species	Ploidy	1989	1999	2009	2017
Peach and Nectarine						
subgenus *Amygdalus*						
- section Amygdalus						
	P. persica	**2x**	**138**	**233**	**333**	**594**
	P. davidiana	2x	1	3	6	5
	P. ferganensis	2x	0	0	0	1
	P. kansuensis	2x	1	2	2	1
	P. mira	2x	0	3	4	5
Almond						
subgenus *Amygdalus*						
- section *Euamygdalus*						
-- group *Amygdalus*						
	P. dulcis	**2x**	**92**	**54**	**112**	**208**
	P. bucharica	2x	0	4	3	13
	P. fenzliana	2x	0	0	6	27
	P. webbii	2x	3	3	3	5
-- group *Orientalis*						
	P. argentea	2x	3	2	1	2
- section *Chameamygdalus*						
	P. petunnikowii		0	0	2	2
	P. tangutica		0	1	1	2
	P. tenella	2x	0	2	4	5
- section *Spartioides*						
	P. glucea		0	0	0	0

P. scoparia	2x	0	1	1	1
- section *Leptopus*					
P. pedunculata		0	0	0	2
- others, basal					
P. glandulosa		4	2	1	0
P. spinosissima		0	1	1	1
P. triloba		0	1	1	1
subgenus *Emplectocladus*					
P. fasciculata		31	4	0	6
P. havardii		0	0	0	0

Apricot

subgenus *Prunus*					
- section *Armeniaca* (Apricots)					
P. armeniaca	**2x**	**20**	**171**	**258**	**378**
P. ansu	2x	2	0	0	0
P. brigantiaca	2x				4
P. manshurica	2x	0	3	2	3
P. mume	2x	3	5	20 (3^{N})	20
P. sibirica	2x	0	1	0	1
P. × dasycarpa (= *P. cerasifera × P. armeniaca*)	2x	3	6	6	6

Plum

subgenus *Prunus*					
- section *Prunus* (Old World plums)					
-- European					
***P. domestica* (European plum)**	**6x**	**0**	**141**	**154**	**193**
P. bokhariensis		3	3	2	2
P. spinosa	2x, 3x, 4x, 5x, 6x	21	5	8	23
P. cerasifera	2x, 3x, 4x, 6x	14	32	45	66
P. cerasifera var. *divaricata*					27
P. insititia	3x, 6x	0	1	3	0
-- Asian					
***P. salicina* (Japanese plum)**	**2x**	**92(16^{N})**	**40**	**63** (1^{N})	**77**
P. salicina* var. *mandshurica					**1**
P. salicina* var. *salicina					**3**
***P. hybrid* (plumcot, aprium, pluot, peachcot, plum cherry)**			**59**		130
P. simonii	2x	2	3	3	8
- section *Prunocerasus* (New World Plums)					
-- American clade					
P. americana	2x	1	4		11
P. rivularis	2x	0	0	0	3
P. hortulana	2x	3	0	1	6
P. mexicana	2x	15	2	2	3
-- Beach clade					

P. maritima	2x	50	2	21 (1^{N})	3
P. geniculata		0	0	0	1
-- Chickasaw clade					
P. alleghaniensis	2x	0	3	2	0
P. angustifolia	2x	2	15	4	20
P. gracilis		0	0	0	0
P. munsoniana	2x	0	1	2	0
P. nigra	2x	0	1	0	1
P. umbellata	2x	0	0	0	7
-- Other					
P. subcordata	2x	26	12	7	12
P. texana		0	0	0	2
- section *Microcerasus* (other spp. assigned to this section may not be in subg. *Prunus*)					
P. bifrons		0	0	0	4
P. pumila	2x	1	0	1	0
P. pumula var. *besseyi*	2x	5	1	0	4
P. microcarpa		0	0	0	3
P. tomentosa		55	6	9	11
- section *Penarmeniaca* (dry-fruited)					
P. andersonii		0	3	0	4
P. fremontii		1	2	0	2
- section unassigned					
P. × cistena (*P. cerasifera × P. pumila*)		1	0	0	1

Cherry

subgenus *Cerasus*

- section *Cerasus*					
***P. avium* (sweet cherry)**	**2x**	**0**	**92**	**116**	**184**
***P. cerasus* (tart cherry)**	**4x**	**0**	**32 (65^{P})**	**36 (94^{P})**	**48**
P. campanulata		0	0	0	0
P. canescens	2x	0	0	(1^{P})	1
P. cerasoides		0	0	1 (1^{N})	1
P. conradinae		0	0	0	0
P. cyclamina		0	0	0	0
P. emarginata		1	1	0 (1^{N})	1
P. fruticosa	4x	36	3 (7^{P})	4 (12^{P})	6
P. maackii	4x	0	0	2 (3^{N},1^{P})	1
P. pleiocerasus		6	1	1	0
P. sargentii		0	0	0 (35^{N})	0
P. serrulata	2x, 3x	7	2	1	3
P. serrulata var. *lannesiana*		0	0	(6^{N},1^{P})	10
P. speciosa		0	0	0	1
P. takesimensis		0	0	0 (3^{N})	0
P. verecunda		0	0	0 (1^{N})	0
P. × dawyckensis (*P. canescens × P. dielsiana*)		0	0	0	0
P. × yedoensis		0	2	1 (4^{N})	7

- section *Pseudocerasus*					
P. pseudocerasus		1	1	3	7
P. mahaleb	2x	7	11	13	15
P. incisa	2x	0	0	0 (7^{N})	4
P. nipponica		0	0	0 (1^{N})	0
P. nipponica var. *kurilensis*		0	0	(7^{N},1^{P})	0
P. pensylvanica		0	0	(1^{P})	3
P. subhirtella	2x	0	0	0	4
P. subhirtella var. *ascendens*		0	0	0 (1^{N})	0
P. subhirtella var. *subhirtella*					1
- section *Phyllomahaleb*					
P. maximowiczii		0	0	0	1
- section *Lobopetalum*					
P. dielsiana		0	0	0	0
- section “*Microcerasus*”					
P. jacquemontii		0	1	0	1
P. japonica		1	1	1	0
P. prostrata		0	3	1	2
Basal relatives					
subgenus *Laurocerasus*					
P. buergeriana		0	0	0	0
P. caroliniana	4x	0	0	0	0
P. ilicifolia	4x	0	0	0	2
P. laurocerasus		1	0	1	53
P. lusitanica	2x	0	0	0	0
P. lyonii		0	0	0	0
subgenus *Padus*					
P. grayana		1	1	0 (1^{N})	0
P. padus	2x	38	5	1 (2^{N})	9
P. padus var. *commutate*					1
P. padus var. *pubescens*		0	0	0	0
P. serotina	4x	1	14	14	3
P. serotina var. *salicifolia*					3
P. virginiana		1	2	1 (1^{N})	0
P. virginiana var. *demissa*					2
- section unassigned					
P. × *kanzakura*		0	0	(1^{N})	1
Other hybrids		0	0	(9^{P})	4

[Z] Numbers within parenthesis indicate accessions at other locations: P = Plant Genetic Resources Unit, Geneva, NY (fruiting cherries), and N = National Arboretum, Washington, DC (ornamentals)

Taxonomic groups are according to Bortiri et al. (2002) and Wen et al. (2008), with additional taxonomic sections assigned according to GRIN

2. Recent acquisition efforts

The Davis Repository has been actively acquiring *Prunus* germplasm from the Caucasus and Central Asian regions, two important Centers of Diversity for *Prunus*. Recent explorations for Prunus crop wild relatives in The Republic of Georgia, Azerbaijan and Kyrgyzstan during 2009 -

2016 have resulted in the introduction of hundreds of new accessions to the existing collections. Many of these are still in quarantine by APHIS in Beltsville, MD, and others are in Davis in a field nursery for evaluation to select those individuals that show the greatest genotypic and phenotypic diversity to add to the permanent collection. The field collections at the Wolfskill Experimental Orchards (WEO) have grown considerably as result of planting many new germplasm accessions released from quarantine held during the previous years at the Davis location.

Bioversity has developed the European Cooperative Program for the conservation and exchange of Crop Genetic Resources (ECP/GR) for the conservation and exchange of *Prunus* germplasm. These holdings will not be beneficial to the U.S. unless the introduction of *Prunus* germplasm can be made more efficient by increasing the number of importations possible and decreasing the time it takes to test imported material in quarantine. In addition, field space is a major limitation in acquiring these importations as NCGR at Davis, CA is unable to expand beyond current footprint of Wolfskill.

<u>Funded *Prunus* collection expeditions</u>

- 1988 - Wm. Gustafson, Western China, Sinkiang Province - almond, wild *Prunus*
- 1988 - Thompson, Pakistan - apricots and almonds.
- 1990 - Thompson, Ramming, and Sperling - Central Asia/Russia, apricots
- 1995 - Weeks - west coast North American species
- 1995 - Parfitt and White, Turkmenistan (USAID) - almond relatives, wild *Prunus*, 15 apricot cultivars
- 1998 - Iezzoni, Lang, and Karle - *Prunus avium* in the Ukraine
- 1998 - Forsline, Iezzoni, and Karle - *Prunus* and *Malus* germplasm in Russia
- 2000 - Byrne, Ramming – *Prunus* germplasm China
- 2008 – Stover, Postman – Plum and other germplasm Armenia
- 2010 – Aradhya -- Multiple crops exploration Republic of Georgia
- 2010-2012 – Chaparro, Chavez – Wild Prunus from eastern USA
- 2011 – Preece, Postman - Crop wild relatives Albania
- 2012 – Aradhya - Multiple crops with focus on apricots Azerbaijan and Kyrgyzstan
- 2014 – Aradhya Multiple crops Republic of Georgia

3. Major gaps in the collection

<u>Summary</u>

- Wild peach and apricot from China, Uzbekistan, Kyrgyzstan, and Tajikistan (Fergana valley)
- Plum species native to Asia
- Almond cultivars and wild species from the almond germplasm bank of Zaragoza, Spain
- Wild sweet cherry and tart cherry from Asia. All the *P. avium* and *P. cerasus* collected by Amy Iezzoni was from Eastern Europe, and it is likely that this germplasm is a subset of what is available in the species due to a domestication bottleneck when cherry cultivation began in Europe

Species needed to maximize diversity are listed below for their priority for collection. These priorities are currently assigned by considering desirable traits expected to be provided by a species, conservation status in the wild, and assuming that the designation of a taxon as a species means it occupies a distinct genetic niche. The latter assumption requires systematic investigation to enable development of an objective rationale for strategic expansion (and contraction) of the USDA-ARS *Prunus* collection. Crop genepools (Harlan and de Wet, 1971) that consider crossability and fertility among species need to be described for each crop to inform potential users of the diversity available to them.

Species not represented or with minimal current representation receive higher priority for collection. Eight *Prunus* species listed as threatened by the Center for Plant Conservation (*P. alleghaniensis*, *P. alleghaniensis* var. *davisae*, *P. geniculata*, *P. harvardii*, *P. maritima* var. *gravesii*, *P. minutiflora*, *P. murrayana* and *P. texana*) are also high priority for collection. Species and named clones from Centers of Diversity need to be collected before these resources are lost due to destruction of native forests or to the planting of commercial cultivars in place of landraces.

<u>High Priority</u>

Peach

- *P. davidiana* - disease resistance (e.g., to plum pox virus), self-compatibility for almond
- *P. kansuensis* - not enough diversity, need for rootstocks

Almond

Few accessions are currently available for most almond species below.

- *P. argentea* - self-compatibility and frost resistance for almond
- *P. bucharica* - self-compatibility, growth habit, and frost resistance for almond
- *P. dulcis* - pest and disease resistance and novel fruit quality for peach
- *P. fenzliana*
- *P. petunnikowii* - pest and disease resistance for almond
- *P. tenella*
- *P. spinosissima* - get from Spain collection

Apricot

- *P. ansu* - source of lower chill and disease resistance
- *P. armeniaca* - need material from SW Asia, Northern Egypt, Iran, Pakistan, and the Fergana Valley
- *P. holosericea* - Tibet, Sichuan - possibly endangered
- *P. manshurica* - need more diversity from north east China
- *P.* × *dasycarpa* - collect as for *armeniaca*

Plum

- *P. alleghaniensis* - resistance to crown gall, threatened species
- *P. alleghaniensis* var. *davisae* - threatened
- *P. geniculata* - native to Florida, endangered, drought tolerant
- *P. harvardii* - threatened species, collected by Stephen Rieger
- *P. hortulana* - resistance to bacterial spot. Being lost
- *P. maritima* - clate bloom, high heat threshold. Being lost. Get NJ116 and clone from IR-2
- *P. maritima* var. *gravesii* - threatened
- *P. minutiflora* - threatened species
- *P. munsoniana* - good fruit quality, productive, Being lost
- *P. murrayana* - threatened species, a plant at Dallas, Texas Agricultural Research and Extension Center
- *P. salicina* - excellent fruit quality, very winter hardy. Target Chinese native species (*P. consociiflora, P. gymnodonta*)
- *P. simonii* - firmness and acidity

P. texana - threatened species
P. japonica - not enough diversity, need for rootstocks

Cherry
P. bifrons
P. canescens - disease resistance
P. glandulosa - need to collect wild types
P. fruticosa - need for dwarfing rootstocks, cold hardiness, and late bloom time
P. maackii - need for disease resistance
P. maximowiczii - collect more, esp. low chill
P. pleiocerasus
P. serotina - need large-fruited types for disease resistance, cold hardiness, and medium chill adaptation

<u>Medium Priority</u>
Almond
P. fasciculata - need additional diversity
P. webbii - self-compatibility and growth habit for almond
Apricot
P. mume - need to collect fruiting hybrids (with apricot) from Taiwan, China, and Japan
P. sibirica - collect seed
Plum
P. americana - very winter hardy, tough skin. Charlie Graham, Dick Okie, Tom Beckman, and Brian Smith have accessions
P. angustifolia - resistance to bacterial spot, limited tolerance to plum leaf scald. Charlie Graham, David Byrne, Tom Beckman, and Dick Okie have collections
P. besseyi - late bloom, high heat threshold, very winter hardy, resistance to crown gall
P. cerasifera - earliness, nematode resistance, cold-hardiness, maybe self-fertility. European collection for diversity
P. fremontii
P. gracilis
P. orthosepala - complex American hybrid, collect a few, get from Wayne Sherman
P. pumila
P. spinosa - need more diversity
P. subcordata - drought tolerance, high chill requirement. Collect more
P. tomentosa - collect more from China.
Cherry
P. padus - collect more
P. subhirtella- need more variability
<u>Low Priority</u>
Plum
P. andersonii - need, but not being lost, some available commercially
P. nigra - very winter hardy, not threatened

P. umbellata - resistance to crown gall. Get from Wayne Sherman, Charlie Graham and Tom Beckman

Cherry

P. avium - medium chill, self-fertile types from Mediterranean region
P. cerasus - gaps being filled with Amy Iezzoni's material from PI
P. emarginata - need, but not being lost
P. pennsylvanica - collect, but not being lost
P. virginiana - get a few, get one with yellow fruit, also some from Soil Conservation Service

4. Plant quarantine

The greatest problem once clonal acquisitions have been made from outside the U.S. is getting material through plant quarantine. With new facilities, a new streamlined pathogen testing procedure, and other changes, performance of the quarantine service has improved dramatically. The flow of materials from various working collections into the Repository collections has been slow because of California quarantine regulations which do not allow *Prunus* budwood entry from many U.S. regions. Importation of seeds are much easier internationally and nationally, as they are far less likely to be infected. Seeds are ideal for collecting and representing the diversity in *Prunus* wild relatives. Crop wild relatives have been the focus of recent collections because they bring more genotypic and phenotypic diversity into the collections than cultivars. Where Clonal representations of specific named cultivars or unique trees are not essential, representation by seed is recommended.

5. Regular review of collection holdings

The Prunus CGC regularly reviews material in the National Clonal Repository at Davis, CA. These reviews have led to specific recommendations on composition of the collection and elimination of duplicates. The germplasm system must be responsive to opportunities to add to collections and must be ready to acquire vulnerable germplasm should continuity of existing collections become threatened or opportunity to add from world collections becomes available. Curators should bear prime responsibility for acquisition, but the CGC needs to supply the information that alerts the curator to opportunities and needs.

B. Germplasm Maintenance

Peach and nectarine: The peach and nectarine collection was repropagated in 2013 and planted at Wolfskill Experimental Orchard in 2014. The wild peaches were separated from the cultivated and breeders' lines of peaches to allow more space per tree for the more vigorous wild peaches. The collection is healthy, vigorous and even aged and was phenotyped in 2014 – 2016. The old peach block was removed.

Apricot: The apricot collection was repropagated by budding in 2015 and 2016 and in late 2016, the new trees, representing 91% of the collection was planted at Wolfskill Experimental Orchard. The remaining 9% of the collection and any trees that failed to successfully overwinter are being repropagated in spring 2017 for fall planting.

Almond: The almond collection is being repropagated earlier than originally planned because of an *Armillaria* infestation in the old collection. Persimmons are being planted in the old almond block to free up space for the repropagated almonds.

Cherry and plum: The cherry and plum collections were in much better health and vigor than the old peach and apricot collections, and with the exceptions of some weak accessions, have not been repropagated, but will be in the next 5 years.

General: The *Prunus* collection is not backed up within the National Plant Germplasm System. The NCGR-Davis has been collaborating with the USDA-ARS National Center for Genetic Resources Preservation, Fort Collins, CO on cryopreservation studies on *Prunus* green shoots, dormant buds, seeds, and pollen. These remain in the research phase; however, the literature indicates successful cryopreservation of *Prunus* seeds and pollen, so are beginning backups of wild *Prunus* accessions.

Types of plant material with storage potential

1. Live plants: can be stored in the field, and in tissue culture. Backing up collections in containers in the Repository nursery is costly, inefficient, and unreliable.
2. Cryopreservation: budwood, seeds and pollen of *Prunus* wild relatives in liquid nitrogen. It may be useful to store cultivar pollen under cryopreservation because much of the use of the collections is for breeding.
3. DNA: stocks of DNA provide a valuable resource for accessions that have been lost or as interim representation of material in the accessioning pipeline. Also, with rapidly advancing DNA-based technologies, requests for DNA are increasing. In some cases, such as lost accessions, or never-accessioned ancestors of modern cultivars, DNA is all that is needed to advance genetic knowledge and increase utilization of descendants.

C. Germplasm Evaluation

Evaluations of the collections is largely dependent on externally funded research, by interests of individual scientists and visiting scholars. In recent years, the *Prunus* collections have been evaluated for viral pathogens, phenotype, and genotype. The newly repropagated peach and nectarine collection was phenotyped for vegetative growth and fruit characteristics to combine these data with genotyping by sequencing done on this entire collection. The apricot and cherry collections are in process of being genotyped by sequencing. The spotted winged Drosophila populations were studied in the cherry collection, and the plums in the collection that were used as parents by Luther Burbank or were the products of his breeding program are being genotyped.

Sanitary status of material entering and leaving the repository is important. Concerns are:

1. The need to exclude new and exotic pest diseases when introducing plant material exists, but the introduction of material needs to be expedited. New pest disease detection and elimination procedures are essential.
2. Virus status of material needs to be known so dangerous diseases are not spread.
3. A balance between liberal and restricted distribution policies on virus status need to be established so the repository is able to distribute plant material in a reasonable manner without duplicating existing virus detection and clean stock programs.
4. Research to date has shown that the viruses and viroids in the *Prunus* collections are common and ubiquitous and therefore not a threat. However, the collection needs constant vigilance as new pests and pathogens are introduced.

D. Germplasm Enhancement
All active breeding programs listed earlier are conducting germplasm enhancement to some extent. Enhancement does need to be continued with cooperative programs between breeding programs. There is a need for improved scion and rootstocks. Additional effort needs to be placed on collecting and establishing germplasm at the repository so it is available to enhancement programs. Enhancement programs have already impacted the industry and they will continue to do so. One priority is the increased eating quality of our fresh fruit so consumers want to buy fruit a second time. The need for pest and disease resistance is high priority given the increasing restrictions placed on the use of pesticides.

V. Recommendations

Immediate attention

1. Collect wild germplasm from native forests in China, Asia, Europe, and North America before they are destroyed.

2. Address and remove remaining obstacles for the introduction of plant material into and within the United States.

3. Adequate resource support for the National Clonal Germplasm Repository at Davis to maintain, evaluate, enhance, and distribute the *Prunus* collection accessions. Establishment of a back-up collection is required. Routine performance evaluation of accessions that match CGC priorities is required to encourage utilization of these wide genepools in breeding.

4. Determine genetic relationships among all *Prunus* species and taxa, and systematically evaluate desirable attributes that each species potentially provides, to provide an objective rationale for strategic expansion of the collection.

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VII. Appendix

Table 4: Major diseases of stone fruit and species affected

Table 5: Major pests of stone fruit and species affected

Table 6: Major environmental hazards of stone fruit and species affected

Table 7: Tree and fruit characteristics of stone fruit and species affected

Table 4.

MAJOR DISEASES OF STONE FRUIT		**SPECIES AFFECTED**					
						Cherry	
Disease	**Causal Organism**	**Almonds**	**Peach**	**Plum**	**Apricot**	**Sweet**	**Tart**
Crown Gall	*Agrobacterium tumefaciens*	X	X	X	X	X	X
Bacterial Canker	*Pseudomonas syringae*	X	X+	X+	X+	X	X+
Bacterial Spot	*Xanthomonas pruni*/ or *compestris* cv *pruni*	X	X+	X+	X+		
Brown Rot	*Monilinia* spp.		X		X	X	X
Peach Blight	*Coryneum*	X	X	X	X	X	X
Peach Twig Blight	*Glomerella cingulata*		X				
Crown Rot	*Phytophthora* spp.	X	X	X+	X	X	X
Peach Mildew	*Sphaerotheca*		X		X	X	X
Cytospora Canker	*Leucostoma*		X	X	X	X	X
Anthracnose	*Glomerella cingulata*	X	X	X			
Peach Leaf Curl	*Taphrina deformans*	X+	X+	X+	X-		
Verticillium Wilt	*Verticillium* spp.	X	X				
Cherry Leaf Spot	*Coccomyces* spp.			X		X+	X
Black Knot	*Dibotryon morbosum*			X			
Peach Scab	*Cladosporium carpophilum*		X		X		
Oak Root Rot	*Armillaria spp*	X	X	X+	X	X	X
Clitocybe Root Rot	*Clitocybe*						
Cotton Root Rot	*Phymatotrichum omnivorum*	X	X	X	X	X	X
Gummosis	*Botryosphaeria* spp.		X				
Rust	*Tranzschelia discolor*		X				
Rhizopus Rot	*Rhizopus nigricans*	X	X	X	X	X	X
Phony peach/plum leaf scald	*Xylella fastidiosa*	X	X	X+	X		
Viruses	Prune dwarf		X	X	X	X	X
	Green ring mottle		X	X	X	X	X
	Tomato ring spot	X	X	X	X		
	Plum pox		X	X+	X+	X	X
	Peach yellows	X	X	X	X	+	+
	Peach Rosette		X	X	X	X	X
	Little Peach	X	X	X	X	+	+
	Peach Mosaic	x	X	X	X	+	+
	Albino Cherry					X	X
	X-disease (mycoplasma)	X	X	X	X	X	X
	Prunus Necrotic Ring Spot		X	X	X	X	X

Table 5.

MAJOR PESTS OF STONE FRUIT	**SPECIES AFFECTED**					
Pests	**Almonds**	**Peach**	**Plum**	**Apricot**	**Cherry**	
					Sweet	**Tart**
Plum Curculio		X	X	X		
Tarnished Plant Bug		X	X	X		
Stink Bug		X	X	X		
Thrips		X				
Oriental Fruit Moth	X	X	X	X		
Codling Moth		X	X	X		
Japanese Beetle		X	X	X	X	X
Green June Beetle		X	X	X	X	X
Twig Borer	X					
Peach Tree Borer	X	X	X	X	X	X
Lesser Peach Tree Borer	X	X	X	X	X	X
Shot Hole Borer	X	X	X	X	X	X
Ambrosia Beetle		X	X	X		
Aphids	X	X	X	X	X	X
Mites	X	X	X	X	X	X
Scales	X	X	X	X	X	X
Navel Orangeworm	X					
Fruit Flies		X	X	X	X	X
Nematodes	X	X	X	X	X	X

Table 6.

MAJOR ENVIRONMENTAL HAZARDS OF STONE FRUIT — SPECIES AFFECTED

Environmental Condition	Peach	Plum	Apricot	Sweet Cherry	Tart Cherry
Freeze and frost injury	X	X	X	X	X
Drought tolerance	X	X	X	X	X
Water logging	X	X	X	X	X
Soil pH - high and low	X	X	X	X	X
Mineral uptake efficiency	X	X	X	X	X
Heat stress	X	X	X	X	X
Salinity (Sodium and calcium salts)	X	X	X	X	X
Chilling requirement	X	X	X	X	X
Soil hardpans	X	X	X	X	X
Air pollutants	X	X	X	X	X

Table 7.

TREE AND FRUIT CHARACTERISTICS OF STONE FRUIT — SPECIES AFFECTED

Characteristic	Almonds	Peach	Plum	Apricot	Sweet Cherry	Tart Cherry
Extension of maturity season	X	X	X	X	X	X
Cracking resistance	X	X	X	X	X	X
Fruit size	X	X	X	X	X	X
Fruit quality	X	X	X	X	X	X
Fruit firmness		X	X	X	X	X
Uniform ripening	X	X	X	X	X	X
Tree vigor and structure	X	X	X	X	X	X
Adaptation to mechanization	X	X	X	X	X	X
Tree longevity	X	X	X	X	X	X
Shipping and storage		X	X	X	X	X