

# Present Status and Future Outlook for Germplasm Reserves in Citrus

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Maintenance and research studies of citrus collections are presently being carried out in the U.S.A. by about 12 university and U.S. Department of Agriculture working groups in six states and Puerto Rico. The United States Department of Agriculture supports research in California, Florida and Texas; in those states, as well as Arizona, Hawaii and Louisiana, state-financed studies are also established. Clonal registration programs supervised by state regulatory agencies are also in operation in at least three states. Since all common *Citrus* cultivars require a nearly frost-free environment, plantings are not feasible in the central and northern states, nor has it been practical to maintain or evaluate citrus at any of the four Federal Regional Plant Introduction Stations. (The Federal "Port of Entry" at Miami does have a frost-free climate.) Foreign imports of citrus budwood are temporarily maintained in limited numbers in greenhouses at Federal Plant Quarantine headquarters, Glenn Dale, Maryland.

## Locations of Research Groups

The locations of 12 working groups and data on their citrus collections are listed in Table 1. A wide range of forms covering most of the economically important species, including oranges, lemons, grapefruits, mandarins, and their named hybrids are planted at several of the locations, and limited numbers are maintained at the others. Cultivars important as rootstocks, and in some cases *Citrus* rela-

tives are included. The USDA maintains some 200 to 300 genetically distinct clones at each of its three locations, and the University of Arizona holds a similar number at Tempe and Yuma. The largest collection is headquartered at the University of California, Riverside, where about 850 different clones (including relatives) are established. In the larger collections about 60 to 75% of the entries are scion types, while the remainder are potential or actual rootstock clones. Citrus in the U.S.A. is grown almost entirely on rootstocks, and rootstock needs and problems are of primary importance.

## Nucellar Embryony and Juvenility

Asexual (nucellar) embryony regularly occurs in many citrus forms and in *Poncirus* and *Fortunella*, making these genera highly unusual among fruit and nut crops. Most of the economically important cultivars of oranges and grapefruits reproduce largely by this means, as do lemons to a lesser extent. Mandarins are much more variable. Nucellar embryony is highly valuable for production of genetically uniform rootstock plants from seed, and most of the important rootstock cultivars are "highly nucellar." Although nucellar embryony is a major obstacle in breeding programs, it is also valuable for reproducing scion cultivars. Most citrus viruses are seldom transmitted by seed so that such reproduction usually provides initially virus-free clones. Reinfection, however, is a constant and serious problem.

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The major disadvantage of clonal reproduction by seed is the long juvenile period of *Citrus*. In addition to a 5- to 8-year period before fruiting, thorniness and early alternate bearing are common, and inferior fruit characters hamper evaluation of young seedling lines. Nevertheless, after a "settling down" period many such budlines have become very important clonal sources, and they have been widely produced throughout the world in the last 20 years. Certain cultivars, however, including many mandarins and mandarin hybrids, are normally strictly sexual and until recently could be maintained only by vegetative propagation.

#### Disease Problems and Registration Programs

Citrus is subject to a number of serious maladies including virus diseases, a mycoplasma, root rots, nematodes, and injury by various insects. Many of these troubles occur worldwide, but with varying severity in different regions. The virus disease tris-

teza, for example, which is dependent on rootstock-scion interaction, has in the past destroyed large numbers of trees in California, and in other parts of the world. Citrus is also subject to frequent somatic mutations, most of which are unfavorable, and a system for maintenance of true-to-type propagating material is essential.

Between 10 and 20 years ago, these considerations led to the establishment of citrus registration programs in Florida, California, and Arizona. The regulatory phases of these programs are administered by the respective state Departments of Agriculture or Commissions, in cooperation with University and USDA scientists. The primary purpose of these programs is to provide, to growers and others, citrus scion and rootstock material as free as possible from diseases and genetically true-to-type. A large number of commercially important cultivars and new hybrids have been tested, and selected clones are maintained in foundation plantings in each state. In the California program, with which

Table 1. Citrus cultivar collections and breeding and selection programs in the U.S.A.\*

Location of research groups	Genetically different clones in cultivar collections			Approximate number of trees in progeny plantings
	Estimated number	% scions	% rootstocks	
<b>U.S.D.A.</b>				
California	210	62	38	8,000
Florida	300	70	30	30,000
Texas	200	70	30	few
<b>State</b>				
Arizona	220	75	25	1,000
California	850	70	30	10,000
California	160	90	10	—
Florida	250	95	5	11,000
Florida	75	40	60	few
Hawaii	110	90	10	few
Louisiana	40	80	20	2,000
Texas	400	75	25	1,500
<b>Puerto Rico</b>				
Rio Piedras	45	75	25	few

\*These data were provided by members of the listed research groups. Their cooperation is acknowledged with thanks.

I am most familiar, indexing for diseases is done mostly in quarantine greenhouses. Indicator plants for various viruses are budded from the candidate source, and extensive readings for symptoms are later taken. Clones which pass these tests are repropagated in a key foundation block in the San Joaquin Valley. There they are grown under rigorous inspection and brought to fruiting for repeated observations on disease, yield and trueness-to-type. A primary bud source of each accepted clone is also retained in insect-proof screenhouses. Since not all diseases can be immediately eliminated, some cultivars are retained when partially disease-free. In the case of a disease such as stubborn, repeated examination of foundation field trees is necessary to verify a disease-free status.

These programs are important for conservation and improvement of the quality of citrus cultivars, but they do not afford preservation of nearly all the citrus germplasm of value to breeders. Much of this germplasm, as indicated by Table 1, is held in separate collections. The taxa are widely used within states but quarantine restrictions seriously hamper nationwide exchange. In addition, the entries are sometimes subject to arbitrary reduction or even complete elimination. A more comprehensive, nationally integrated system would be beneficial.

#### Genetic Vulnerability of Citrus

Citrus is genetically vulnerable in a variety of ways. Most of my correspondents from the citrus working groups indicated that there are cultivars of major importance to their areas which could not be satisfactorily replaced if some cultivar-specific disease eliminated them. Thus the 'Washington Navel' orange in California, the 'Lisbon' lemon in Arizona, the 'Tahiti' lime in south Florida, and the 'Marsh' grapefruit in many areas, have no

commercially suitable substitutes. In the case of the grapefruits, the genetic base is very narrow, since both pigmented and white forms all apparently trace by bud or nucellar seedling mutations to a recent common ancestor. With mandarins, a wider range of genotypes is available, and substitutions would be less difficult.

There are apparently few potentially important forms of *Citrus* or its close relatives growing in the wild which have not been recorded and brought into collections. *Citrus* is an old world plant and Southeast Asia, especially eastern India, is considered the center of origin. Its evolutionary spread has been projected (in theory) in China, the Malay peninsula, and the southwest Pacific islands; a few related genera occur in Africa. Over the last century botanists have classified many forms, including the cultivated ones. Since World War II, a few new explorations have been made, with limited results. Importations into the United States of many of the most successful cultivars from other commercial citrus regions have also been made, but most accessions have been carrying diseases and few or none have so far been outstanding as scions in our environments. For rootstocks, the possibilities are somewhat better among the less common species and related genera, and many of these are presently being examined. One, *C. macrophylla*, is becoming important as a rootstock for lemons.

*Citrus* and its related genera are almost exclusively diploid ( $x = 9$ ) and polyploidy has played no apparent part in their evolutionary development. Spontaneous tetraploids are often found among nucellar seedlings but this ploidy level is physiologically unfavorable and most  $4x$  taxa would not persist in the wild. Triploidy is much more favorable, but it is an endpoint rather than a reservoir of germplasm.

Thus the germplasm in present collections may represent nearly all that will be available. Fortunately, the common citrus species, and some related genera, are largely interfertile and many gene loci seem heterozygous, providing a wide range of variability for the breeder.

Among my correspondents from the citrus groups, nearly all stated that costs of maintenance of their collections are becoming a serious problem, even though in most cases they expect numbers of clonal entries to remain about the same. Availability of research personnel is not yet considered limiting by most, but the existence and use of the collections will certainly depend upon the financial support available.

Need continues to exist for breeding to obtain a wider range of scion forms adapted to various climatic areas and ripening dates. With some present cultivars problems of fruit size, internal quality, and various other fruit characters are of concern in many locations. The need for additional superior rootstocks is acute. Most correspondents indicated that better resistance especially to *Phytophthora*, nematodes, tristeza, and soil salinity is very necessary.

### **Possible Nationally Integrated Repositories**

The need for more permanent, nationally integrated repositories for citrus is recognized by most of the citrus groups, even though quarantine problems will still be difficult to manage. Certain newly developed techniques, including heat therapy, and micrografting of shoot tips, are very promis-

ing for freeing clones of certain diseases and thus making extensive interchange of propagating material more feasible. It is my own opinion that two official repositories, each with quarantine greenhouses, facilities for indexing and field foundation blocks, would be desirable. Records of source and identity of clones, and monitoring of disease status and trueness-to-type would be necessary. Evaluations of yield behavior and fruit quality would be desirable. In many respects, the most useful locations for these would be in Florida and California. These states are the centers of the largest portions of the citrus industry. They also include climates which are different and yet favorable for citrus growth, so that characters such as yield, trueness-to-type, and fruit quality could be satisfactorily evaluated. In Florida the geographical location of choice would probably be somewhere in the center of the state. In California, a favorable location would be the southern San Joaquin Valley, in the general area of the state's present citrus foundation block. Some citrus centers in the United States are less promising for repositories because of extremes of one sort or another. Thus south Florida, south Texas and south Louisiana are all somewhat isolated and have limited citrus acreages. Arizona and the Coachella Valley of southern California are subjected to intense summer heat and some important citrus cultivars do not grow or yield well there.

Citrus repositories, especially if organized together with those of other subtropical fruit or nut species, might be made administratively an extension of one of the present Federal Regional Plant Introduction Stations.