

ANALYSIS AND RECOMMENDATIONS IN SUPPORT OF CITRUS GENETIC RESOURCES IN CALIFORNIA

THE CALIFORNIA CITRUS GENETIC RESOURCES CONSERVATION AND UTILIZATION SYSTEM

THE THREE PRIMARY COMPONENTS of the California system for maintaining and providing citrus genetic resources are the UC Citrus Variety Collection (CVC), the UC Citrus Clonal Protection Program (CCPP), and the National Clonal Germplasm Repository for Citrus and Dates (NCGRCD). Each unit has a different history and origin and the interrelationships among them have been ad hoc. However, this situation has been functioning well in service to the California citrus industry and citrus researchers providing one of the largest and most diverse assemblages of citrus genetic resources in the world.

Each of these three components has distinctly different organizational and administrative structures. The CCPP is managed within the Department of Plant Pathology, while the CVC is managed within the Department of Botany and Plant Sciences, both within College of Natural and Agricultural Sciences, UC Riverside. The NCGRCD is managed for the NPGS by ARS staff reporting to the Pacific West Area office in Albany, California. Each unit may also have responsibilities in addition to the focus on genetic resources for California. For example, academic priorities may redirect staff activities for the two UC units. For the NCGRCD, its role in the NPGS gives it national responsibilities and its mission also includes another crop entirely—dates (*Phoenix* spp.).

While this document focuses primarily on live tree conservation, it is becoming increasingly apparent that citrus genetic resource management will need to expand to include such resources as DNA libraries (both cDNA and genomic DNA libraries), molecular probes, and clones. It is not clear what unit in the California citrus genetic resources system should initiate such collections, but concern for such material is put forward here as a recommendation.

The remainder of this chapter consists of an analysis for the CVC of the operational aspects of a genetic resources operation and recommendations to enhance and facilitate the continued success of the CVC in conserving citrus genetic resources for California.

Recommendation 1. *No changes in the management structure of the CVC, the CCPP, or the NCGRCD are advocated. The continued close collaboration among the three units is essential to the functioning of a citrus genetic resources conservation and utilization system for California.*

Recommendation 2. *The establishment of a California Citrus Genetic Resources Advisory Committee (CACGRAC) is recommended. This committee, composed of research and extension workers, agency and University administrators, growers, processors, marketers, consumers, and others, will provide guidance to the staffs of the units that comprise the California citrus genetic resources conservation and utilization system to assure the acquisition of critical genetic resources and their long-term conservation and efficient distribution.*

Recommendation 3. *The dependence of the NCGRCD on the CVC for seed and field evaluation facilities should be officially recognized by the parent organization of each unit and enhanced by a long-term commitment of support for the CVC by the USDA NPGS.*

Recommendation 4. *Citrus genetic resource management for California should expand to include resources such as DNA libraries, probes, and clones. The appropriate unit and adequate funding for the effort should be topics for consideration by the proposed California Citrus Genetic Resources Advisory Committee. (Rec. 2 above).*

THE CITRUS VARIETY COLLECTION Activities

Acquisition. With no budget directed to this activity, the addition of new accessions into the CVC is slow, depending upon research collaborations and serendipity. There is recognition that acquisition should be a continuing activity, but there is no strategy in place for evaluating the collection for underrepresented taxa, genotypes, or geographic origins and actively seeking out acquisitions. Even with some new accessions, the collection has grown smaller overall since its peak size of some 1,200 accessions in the early 1980s. This was primarily due to attrition loss and selective removal of duplicates.

Recommendation 5. *There should be continued and enhanced linkages with other national and international citrus genetic resources collections.*

Recommendation 6. *Acquisition of new accessions, both from within and outside California and of wild or naturally occurring citrus relatives from their native habitats, is an important function for the CVC. Acquisitions should be guided by a plan developed with assistance of the recommended advisory committee. Every effort should be made to acquire accessions for the CVC that are not currently available in California, taking full advantage of the California system that allows importation of citrus genetic resources.*

Documentation and database management. Each accession in the CVC generates data beginning with the passport data from the acquisition stage and ultimately including evaluation and characterization data accumulated as the accession is utilized. Maps and records of the varieties present in the CEBs are maintained separately from those of the accessions in the CVC. Prior to 1996, records for the CVC were kept solely on 4 × 6-inch cards. This procedure, maintaining a card for each accession, had been followed since the inception of the collection. In 1996, the information was transferred to a computer database which permits easy updating of information and manipulation of the data for record keeping (see Appendix). From 1996 to 1998, the CVC received funding to update and expand its database and to develop links between the CVC and other databases increasing its usefulness to a wider range of researchers and other interested parties. CVC accessions are also entered in the USDA Genetic Resources Information Network (GRIN) database (<http://www.ars-grin.gov>).

Recommendation 7. *The CVC database should be enhanced to include digital representations of important accession characteristics such as photographs of flower, leaf, and fruit morphology, gels of biochemical and molecular genetic analyses, and disease susceptibility or resistance symptoms.*

Recommendation 8. *There should be continued exchange of information between the CVC and the USDA NPGS GRIN databases.*

Maintenance. The CVC maintains at least two trees per accession for each of the 865 accessions currently in the collection. The cultural practices required for the trees include: irrigation, fertilizer applications, pest control, weed control, pruning, fruit reduction, tree care, and frost control. Minimizing pesticide use in the collection orchards is essential for a collection that is often used by researchers and visitors who may consume fruit samples as a means of evaluating new and commercial cultivars in the collection. Full implementation of integrated pest management techniques by which release and maintenance of beneficial insects and predatory snails is em-

phasized and pesticide usage kept to a minimum is a long-term goal for the CVC, but progress is slow with available funding.

Care for the trees in the 22.3 acre portion of the CVC located at UCR is done by UCR Agricultural Operations personnel. The Agricultural Operations office estimated the annual costs of its services for the CVC at about \$24,000. In addition during 1997–98, the staff of the CVC obtained voluntary assistance from the Riverside County UC Cooperative Extension Master Gardeners in fruit reduction and pruning in the CVC. The estimated annual costs for these services without volunteer assistance are \$2,000 for pruning and \$7,000 for fruit reduction.

Care for the three CEBs and the collection of citrus relatives at SCREC is conducted by the staff at the respective location. The number of hours needed to maintain the trees and funds for their care at LREC and SCREC are allocated by the Research Advisory Committees for each center. If the amount of care needed exceeds the amount of funds allocated, the excess cost is charged to the CVC budget and funded projects associated with the CEBs.

Rootstock status. When an accession is represented by two trees (which is the case with most of the 865 accessions), two different rootstocks are used: one instance of the accession would be on Carrizo citrange and the other would be on C-35 citrange or another appropriate rootstock.

Irrigation. All trees in the CVC will be on a low volume micro-sprinkler irrigation system such as is used by most commercial citrus operations in California. Although furrow irrigation provides adequate water (Figure 20), a low-volume irrigation system offers many advantages: it can save water and labor and allows fertilizers to be injected into the irrigation water when needed (STATE-WIDE INTEGRATED PEST MANAGEMENT PROJECT 1991). During 1998, one-third of the trees were converted to such a system with financial support (\$1,000) from CVC funds in combination with a donation of available irrigation supplies and 285 hours of labor from UCR Agricultural Operations. The remaining two-thirds of the trees are being converted with funds from a one-year grant awarded in 2000 from the California Citrus Nursery Advisory Board.

Recommendation 9. *Full implementation of integrated pest management techniques should be deployed in the CVC plantings which, along with the full installation of the low-volume irrigation system, would not only increase the efficiency of tree cultivation in the CVC, but would also enhance the unit as a showcase for California citrus.*

Recommendation 10. *The CVC needs to monitor information about citrus pathogens and keep in contact with citrus specialists to anticipate disease threats to the collection.*

Evaluation, characterization, and research. Evaluation and characterization of CVC accessions is driven by objectives of externally funded research projects, often crisis driven. For example, evaluation of a portion of the accessions for resistance to a specific disease could only be accomplished in conjunction with a funded project to work on that characteristic. Several of the research projects described below are of this nature. Ideally, maintenance of a field collection needs to be coupled with periodic evaluations of accessions for trueness-to-type and characterizations for traits of value to researchers and the citrus industry. Information on traits such as disease resistance/susceptibility, monoembryonic or polyembryonic seed production, pollen viability, self-compatibility, cross-incompatibility relationships, and rootstock-scion incompatibilities would be valuable for researchers, citrus growers, nurserymen and other industry



Figure 20. Headstand of furrow irrigation system once used at the CVC, now replaced by the more efficient low volume micro-sprinkler irrigation system, typical of most commercial citrus operations. *Photo credit: Michael J. Elderman.*

representatives in advance of crisis-driven needs. Information for such characteristics is available in the literature for some of the CVC accessions, but further confirmation and characterization is increasingly necessary as the range of techniques available to manipulate citrus genetic resources increases.

The CVC serves as a resource for a myriad of research projects from scion and rootstock breeding for the improvement of commercial varieties to the study of the biological activities of citrus limonoids as anticancer agents. Since 1997, 38 different projects have used CVC materials, conducted by researchers at UC Riverside, University of Arizona, Auburn University, University of Florida, and USDA (Table 4). These projects covered a range of topics: eight focused on scion and rootstock breeding; 11 involved characterization of accessions for commercially important traits such as disease resistance/susceptibility and anticarcinogenic activity of citrus limonoids; eight focused on isolating, mapping, and transferring specific genes; four investigated the phylogeny and genetic diversity of citrus and citrus relatives; two focused on cryopreservation; and five others involved research on pathogens of citrus, stress reactions, or biochemistry of citrus extracts. The CVC staff directly conducts research: two projects utilize accessions in the CVC and the CEBs and the third is a mandarin variety trial for the California desert, being conducted at CVARS.

Recommendation 11. *Users of the CVC should be encouraged to contribute to the maintenance of its collections.*

Dissemination of information. The CVC is used extensively as a resource for educational extension activities on the UC Riverside campus. California citrus growers, nurserymen, and other industry representatives as well as students from University of California and California State University campuses visit the CVC each year to evaluate potential commercial citrus varieties and learn about citrus diversity. Many visitors from other states and countries also tour the CVC since it is internationally renowned for citrus diversity. In addition to tours of the CVC, since 1995, the staff has provided numerous fruit displays and oral presentations to disseminate information on the performance of various citrus cultivars and on citrus diversity.

From March 1999 to March 2000, the staff conducted twenty-five off-campus presentations including four oral presentations to growers groups sponsored by the Citrus Research Board, fruit displays for the Sunkist Annual Meeting, the Tulare Farm Equipment Show, and the for members of the US Congress and their aides in Washington DC, field days at the three evaluation blocks, and poster presentations at the Orange Show and a two-day citrus diversity fruit display and poster session at the Riverside Orange Blossom Festival where over 150,000 visitors to the Festival had the opportunity to ask questions about and taste 30 different types of citrus

Table 4. Research projects utilizing accessions in the CVC (1997–2001).

Project description	Investigator	Institution/Department
Citrus variety evaluation for trueness-to-type and commercial potential.	T.L. Kahn, M.L. Roose	UCR Botany & Plant Sciences
Preliminary evaluation of parthenocarpy of new Clementine mandarin selections.	T.L. Kahn	UCR Botany & Plant Sciences
Evaluation of new citrus selections–Sensory evaluation.	T.L. Kahn, M.L. Arpaia	UCR Botany & Plant Sciences
Characterization of lime accessions	T.L. Kahn, M. Harris	UCR Botany & Plant Sciences
Development of a detailed genetic map of citrus, including genes for resistance to citrus tristeza virus, <i>Phytophthora</i> tolerance, apomixis, and fruit acidity.	M.L. Roose	UCR Botany & Plant Sciences
Identification and cloning of a gene that controls citric acid accumulation in citrus fruit.	M.L. Roose	UCR Botany & Plant Sciences
Inheritance and molecular genetic analysis of apomixis (nucellar embryony) in citrus.	M.L. Roose	UCR Botany & Plant Sciences
Positional cloning of a trifoliolate orange gene that confers immunity to citrus tristeza virus.	M.L. Roose	UCR Botany & Plant Sciences
Use of molecular markers including RFLPs, RAPDs, ISSRs, and SSRs to understand phylogeny and genetic diversity of citrus. Current work emphasizes lemons.	M.L. Roose	UCR Botany & Plant Sciences
A project initiated to identify a core collection of about 100 accessions, which represent a large proportion of the genetic diversity present in citrus. First phase will involve screening the entire germplasm collection for SSR (single sequence repeat or microsatellite) markers.	M.L. Roose; R.R. Krueger	UCR Botany & Plant Sciences; USDA-ARS-NCGRCD, Riverside CA
Development of improved methods for genetic transformation of citrus and their application to develop cultivars resistant to citrus tristeza virus.	M.L. Roose	UCR Botany & Plant Sciences
Development of new, early maturing grapefruit cultivars and seedless mandarins by hybridization and mutation breeding.	M.L. Roose	UCR Botany & Plant Sciences
Development of new rootstock cultivars which reduce tree size, have improved disease resistance, broader soil adaptation, and desirable effects on fruit quality.	M.L. Roose	UCR Botany & Plant Sciences
Development of citrus cultivars with enhanced characters using the tools of molecular genetics. Current efforts focus on reducing seed set and enhancing tolerance to pathogens and pests.	L. Walling	UCR Botany & Plant Sciences
Regulation of flowering in sweet oranges	L. Pillitteri, C. Lovatt, L. Walling	UCR Botany & Plant Sciences
Explorations of stress proteins as indicators of freeze damage in oranges.	T.J. Close	UCR Botany & Plant Sciences
Screening of citrus lines for susceptibility to <i>Agrobacterium</i> rhizogenes.	O. Becker	UCR Nematology
Detection and characterization of citrus tristeza virus strains in Field 12B, with emphasis on severe strains.	A. Dodds, D. Matthews	UCR Plant Pathology
Characterization of basic morphological and fruit quality factors for the entire NCGRCD collection.	R.R. Krueger	USDA-ARS-NCGRCD, Riverside CA
Characterization of trifoliolate accessions for basic morphological characteristics and seasonal growth characteristics.	R.R. Krueger	USDA-ARS-NCGRCD, Riverside CA
Screening sour orange hybrids and newer accessions for CTV tolerance and other characteristics.	R.R. Krueger	USDA-ARS-NCGRCD, Riverside CA
Screening rootstocks for micronutrient and salt uptake.	R.R. Krueger	USDA-ARS-NCGRCD, Riverside CA
Pathogen screening of CVC accessions.	R.R. Krueger	USDA-ARS-NCGRCD, Riverside CA
Development of efficient genetic transformation procedures for one or several commercially important citrus cultivars in California.	A. Dandekar, D. Burger	UCD Pomology
Development of new rootstock cultivars for the desert citrus growing areas that are suitable for lemons.	G. Wright; K. Bowman	Univ. of Arizona, Tucson AZ; USDA-ARS-USHRL, FL
Development of hybrid mandarin cultivars for the desert with excellent fruit quality, yield, size, and consumer acceptance.	G. Wright	Univ. of Arizona, Tucson AZ
Revision of the taxonomy of the subfamily Aurantioideae of the Rutaceae based upon analysis of the chloroplast and nuclear genomes.	C. Morton	Auburn Univ., Auburn AL
Genetic improvement of lemon cultivars for fresh and processed use.	B. Nielsen, B. Castle	Univ. of Florida, Lake Alfred FL
Evaluation of unique lime oils for commercial utilization.	M. Morris	A.M. Todd Company, Jefferson OR
Project initiated to increase the diversity of germplasm used in breeding <i>Citrus</i> scions.	J. Chaparro	USDA-ARS-USHRL, FL
Development of new rootstock cultivars.	K. Bowman	USDA-ARS-USHRL, FL
Studies on <i>Citrus</i> genetics	K. Bowman	USDA-ARS-USHRL, FL

Table 4. Continued.

Project description	Investigator	Institution/Department
Creation of transgenic citrus trees that have fruits free from limonoid bitterness and increased concentrations of limonoid glucosides that have pharmacological activity.	S. Hasegawa G. Manners	USDA-ARS, Western Regional Research Center, Albany CA
Isolation and characterization of new limonoids from the Rutaceae plant family.	S. Hasegawa G. Manners	USDA-ARS, Western Regional Research Center, Albany CA
Evaluation of <i>Citrus</i> and its closely related genera using limonoids as chemotaxonomic markers.	S. Hasegawa G. Manners	USDA-ARS, Western Regional Research Center, Albany CA
Evaluation and isolation of natural products from citrus seeds which inhibit <i>Aspergillus</i> growth and aflatoxin production.	G. Takeoka	USDA-ARS Western Regional Research Center, Albany CA
Anticarcinogenic activity of citrus limonoids.	S. Hasegawa G. Manners	USDA-ARS Western Regional Research Center, Albany CA
Evaluation of the cyropreservation of seeds of <i>Citrus</i> and <i>Citrus</i> relatives.	C. Walters	USDA-ARS, National Seed Storage Laboratory, Fort Collins CO
Evaluation of the cyropreservation of vegetative materials of <i>Poncirus trifoliata</i> .	L. Towill	USDA-ARS National Seed Storage Laboratory, Fort Collins CO

and citrus relatives. Increasing demand for oral presentations and fruit displays, especially labor-intensive displays such as the Riverside Orange Blossom Festival have necessitated hiring students as well as assembling a group of volunteers from the Riverside County UC Cooperative Extension Master Gardeners program to help conduct large fruit displays. Volunteers provided over 100 person-hours collecting and washing fruit in addition to hours spent setting up and taking down tents and tables, cleaning the booth, and providing questions and answers to the general public.

The staff of the CVC also receives numerous phone calls, letters, and email messages from local and international growers, nurserymen, industry representatives, state officials, and the general public requesting access to its database on characteristics, genetic identity, and history of specific cultivars and strains of citrus and citrus relatives. The staff also provides fruits, and other materials to UC faculty, specialists, and advisors as a source of demonstration materials for their activities. In March of 2000, the staff of the CVC provided support for a two-day Citrus Celebration, which culminated in a reception and dinner which honored 23 UCR researchers and two programs, the CCPP and the CVC, for their commitment to furthering science and the advancement of California's Citrus Industry.

A website (<http://cnas.ucr.edu/~citrus/index.htm>) has been established through the auspices of the UCR CNAS and consists of multiple pages of basic information about the CVC including, history, goals, research projects utilizing the collection (Table 4, this

document), photographs of common citrus varieties, and a list of the CVC accessions (Appendix, this document).

Recommendation 12. *The CVC website is a potentially valuable distribution point for CVC collection characterization and evaluation data. It may need relocation from its current status on the UCR College of Natural and Agricultural Sciences server. The website should include contact information for the staff.*

Personnel

The current curator of the CVC and the three CEBs is employed as a Senior Museum Scientist (67% time) in the Dept. of Botany and Plant Sciences. This position is currently held by T.L. Kahn.

The other members of the CVC staff are a Staff Research Associate (100% time) and work-study students who are employed 5 to 10 hours a week during the school year and full time during the summer. The numbers of students employed varies from year to year. The Staff Research Associate position (held by O. Bier) has been supported on a yearly basis since 1992 by grants from the CRB. Grants were to M.L. Roose from 1992 to 1995, since then, grants have been to T.L. Kahn and M.L. Roose. The on-going objective of these grants is to evaluate trueness-to-type and commercial potential of citrus varieties distributed by the CCPP, therefore, the SRA position only supports the CVC to the extent the duties of evaluation coincide with CVC objectives. The major evaluation emphasis of the CRB-supported work is on fruit quality traits of varieties in the major production

regions of the state. The short-term nature of work-study employment (and subsequent high turnover) and the indirect service of the SRA position are not optimal arrangements for technical support for the CVC.

Recommendation 13. *Positions and staffing levels needed are a full-time curator, full-time technical assistant/assistant curator, part-time seasonal assistants, and a part-time database/website specialist.*

Facilities and equipment

Computers accessible for work of the CVC are one Pentium 100MHz computer at the curator's desk that must serve her other activities as well and a Pentium 133MHz computer in the laboratory space provided to the CVC by the Dept. of Botany and Plant Sciences. Each machine has a copy of the CVC database on it, but each is maintained separately. Currently the CVC web page is housed on a server belonging to the UCR CNAS and staff of the CVC do not have direct access to it.

Recommendation 14. *The CVC should have at least two up-to-date, networked computers and at least one laser-quality printer, devoted to such activities as accessioning, data analysis and exchange, equipment and budget monitoring, and preparation of outreach materials.*

Laboratory facilities for the CVC are provided by the Dept. of Botany and Plant Sciences. Equipment comes from the Dept. or was purchased by T.L. Kahn with research start-up funds. However, some CVC activities require other arrangements for equipment. For example, for evaluations of pollen viability (Figure 21), CVC staff currently borrows a Zeiss epifluorescent microscope from the Dept. of Botany and Plant Sciences that is otherwise used for teaching courses in the department. If there were funds, a vertical illuminator could be purchased that would update the standard microscope in the CVC laboratory for use in fluorescence microscopy.

The main CVC field plantings are physically located about 2 miles (and 5 minutes by vehicle) from the offices of the curator and technical assistant and the lab facilities used by them in the Dept. of Botany and Plant Sciences. The secondary sites (2 acres each) at Irvine and Thermal are 1 and 1.5 hours away, respectively. Any tools and field equipment must be stored in the laboratory and carried to the field for each use. The laboratory size is 288 sq. ft. and not much storage is possible.

Recommendation 15. *Facilities and equipment needs include research equipment, a vehicle, and a greenhouse/headhouse structure on or near the orchard site to facilitate propagation of new or replacement accessions and field evaluation activities, house equipment and tools, and offer a reception point for CVC visitors and tours.*

Financial resources

Office space, laboratory, greenhouse space, screenhouse, administrative support, and a budget of \$3,000 per year for operating expenses for the CVC are provided by the Dept. of Botany and Plant Sciences, UC Riverside. Miscellaneous administrative expenses such as phone calls, photocopying, and FAX charges are paid by the CVC by recharge. Vehicles needed for travel to and from the lab, CVC, greenhouses, and CEBs are rented by the CVC from the Dept. of Botany and Plant Sciences. These vehicles are expensive and only available on a first-come-first served basis limiting planned use. The modest operating expense budget limits the quality of maintenance and the scope of evaluation and extension activities that can be undertaken each year.

For most of its existence, the CVC was supported almost entirely by the host institution, the University of California. In the past, there were small amounts of additional indirect support from research grants to E. Nauer, D.J. Gumpf, and M.L. Roose from the CRB for projects that utilized the CVC. Since T.L. Kahn became curator of the CVC and the CEBs, the University of California has provided direct support to the CVC as salary (to T.L. Kahn, now as a 67% time Senior Museum Scientist), as operating expenses, as office and laboratory facilities, as administrative services, as tree maintenance services via the UCR Agricultural Operations and the field stations, and as funds to update and expand the

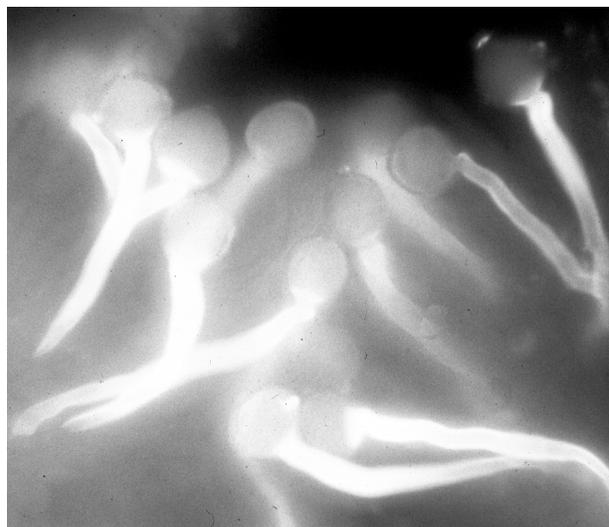


Figure 21. The squashed, softened stigma, one day after pollination, reveals germinating viable pollen grains. Pollen tube growth can be used as a measure of pollen viability. Abnormal growth of the pollen tube structure would be indicative of pollen-stigma incompatibility. The pollen tubes are stained with aniline blue that is specific for the callose which lines the walls of pollen tubes. They are visualized with fluorescence microscopy, a technique for which the CVC should be equipped. *Photo credit: Tracy L. Kahn.*

computer database of CVC accessions (\$1,500) via a 1997–98 award from the UC Genetic Resources Conservation Program.

In addition, direct extramural support for CVC activities has come from funds awarded to T.L. Kahn from USDA ARS as a Specific Cooperative Agreement with the NCGRCD (1997: \$10,000; 1998: \$4,000) to assist in the conservation and evaluation activities of CVC and from the California Citrus Nursery Advisory Board (a one-year grant in 2000 to complete conversion of the CVC main plantings to a low-volume irrigation system and to provide remedial fruit removal and pruning and development of a brochure in preparation for an endowment fund-raising campaign). The absence of other direct extramural support is primarily a reflection of the fact that there are not funding sources whose mission entails support of genetic resources acquisition and maintenance directly on a time scale that facilitates long-term conservation.

Other extramural funds indirectly support activities of the CVC. The CRB awards that support the SRA position for evaluation of accessions were described above. For the 1998–99 season (\$12,010) and 1999–00 season (\$16,841), T.L. Kahn and M.L. Arpaia received CRB funding for a related project that provides a sensory evaluation of a selection of new varieties (see Table 4). The CVC serves as one source of fruit for these taste panels. The CVC is also the site of research conducted by T.L. Kahn to evaluate factors controlling seedlessness in new Clementine mandarin selections (see Table 4). This project which is funded by the California Citrus Nursery Advisory Board (1998–99: \$3,365, 1999–00: \$4,125, 2000–01: \$4,215) provides funding for work-study students who are members of the CVC staff. Another cooperative CRB-funded mandarin variety trial, being conducted by T.L. Kahn and P. Mauk to provide the industry with information on tree growth, fruit quality characteristics, and timing of legal maturity for selected mandarin varieties in the California desert, also indirectly supports the CVC.

Finally, a UC Riverside Foundation account for the CVC was established in the 1980s and has received donations in support of the CVC. For example, participation by

T.L. Kahn and O. Bier to provide ideas and review of plans developed by the Walt Disney Imagineering staff produced \$1,000 for CVC activities. A donation of \$8,000 (1999–01) from the A.M. Todd Company was received in support of the CVC's research program on the characterization of lime varieties. While the fund currently has only \$7,378, it could serve as seed money for an endowment fund in support of the CVC.

Recommendation 16. *The CVC needs an annual budget for operating expenses and outreach that reflects the full costs of these activities including maintenance on facilities and equipment and depreciation on equipment (Table 5).*

Recommendation 17. *The CVC needs funding for first-time and one-time expenses to bring its physical facilities to a level adequate to meet its needs as a California repository of citrus genetic resources (Table 5).*

Table 5. Costs of personnel, equipment, and facility requirements for the CVC.

Category	Initial and replacement cost (dollars)	Annual cost (dollars)
Personnel		
Curator (1.0 FTE)		65,000 ^{a,b}
Technical Assistant (1.0 FTE)		40,000 ^{a,b}
Database/website specialist (0.5 FTE)		21,000 ^{a,c}
Temporary assistance		10,000 ^{a,d}
Supplies		
Nursery and lab supplies		5,000
Acquisition, research, & evaluation		
		25,000 ^e
Equipment		
Vehicle: minivan	20,000	
Vertical illuminator and filter sets (Zeiss)	5,000	
Computers (2)	5,000	
Printer	600	
Electric cart	5,000	
Services received		
Annual tree maintenance ^f		24,000
Annual tree pruning		2,000
Annual fruit reduction		7,000
Annual vehicle maintenance		2,000
Facility		
Greenhouse (36'x60')/headhouse (20'x36')	200,000	
Utilities for field facilities		2,000
Subtotal	235,600	203,000
Contingency fund reserve		
12% of annual budget		24,360
Total	235,600	227,360

^aincludes benefits;

^bestimate, actual amount will depend on job title;

^cbased on Computer Resource Specialist II title, entry level;

^dWork-study and summer students;

^eReserved for supplies, travel, and staffing

^fPerformed currently by UCR Agricultural Operations, does not include pruning.

Recommendation 18. *Funding to enhance and sustain the CVC's role in conservation and utilization of citrus genetic resources for California properly involves the US Government, the State of California, the University of California, and the citrus industry.*

Recommendation 19. *An endowment fund should be established with interest earned being dedicated to meet annual operations costs of the CVC. The fund should be organized under the auspices of the UC Riverside campus with contributions from the diverse enterprises comprising the California citrus industry and individual donors. A committee composed of representatives of USDA NPGS, UC, CDFR, and CRB and individuals having strong interest in the preservation of citrus varieties and diversity should be convened to develop this fund.*

Administration

The CVC is administered by a curator employed by the Department of Botany and Plant Sciences in the UC Riverside College of Natural and Agricultural Sciences. The curator has direct responsibility for the CVC collections. Close collaboration with the curators of the CCPP and the NCGRCD provides mutual guidance for genetic resource management issues, however, a more formal advisory arrangement would benefit the curator.

The curator's responsibilities include:

- ◆ Organizing, applying for, and reporting on the project support that allows for the physical maintenance of trees in the CVC and CEB acreage on the UCR cam-

pus, at the Research and Extension Centers (South Coast and Lindcove), and at the Coachella Valley Agricultural Research Station. For the UCR campus, grant requests for land, labor, and facilities, and progress reports must be submitted annually. For the Research and Extension Centers, research project proposals must be submitted for each collection at three-year intervals and project review reports must be submitted annually.

- ◆ Providing the general direction and guidance for the physical maintenance of CVC trees and accessions maintained in portions of two greenhouses on the UCR campus.
- ◆ Providing the curation, accessioning, and guidance for the physical maintenance of the CEBs.
- ◆ Facilitating research projects which utilize accessions from the CVC.
- ◆ Conducting research directly.
- ◆ Coordinating and, in most cases, conducting outreach activities related to the collection and citrus genetic diversity in general. The time required from the curator necessitated by this task has significantly increased in recent years.

Recommendation 20. *The relationship of the management of the CEBs to management of the CVC should be formalized and the extent of the effort required by the CVC curator to manage the CEBs needs to be defined to ensure that these activities do not come at the expense of CVC activities.*