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The California Citrus Variety Improvement Program after Twelve Years

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PREVIOUS REPORTS to the IOCV (7, 8) have outlined objectives and progress in the California program for establishing and maintaining virus-free, true-to-name sources of citrus propagative material. This paper summarizes briefly the background and present resources of this program and reports the current status of its technical progress, accomplishments, and problems; it includes some comments on future plans.

Background

During the past 40 years, virus diseases of citrus have emerged as problems of major importance in restraining vigor and productivity of orchards in regions of intensive commercial culture.

By the early 1950s, it was clear that many of the conclusions drawn from previous research and experience concerning orchard performance of various scions, stocks, and their combinations were invalid, or at least suspect, because of undetermined and random virus infections. Also, it was clear that the nearly universal commercial practice of using rootstocks widely different in genetic makeup from the scion had increased the virus hazard to such composite orchard trees as compared to those grown on their own or very similar roots. It followed that the whole subject of orchard performance of rootstock-scion combinations would have to be reinvestigated, using standard virus-free budwood sources developed specifically for this purpose.

Increased recognition of the depredations of virus diseases in commercial citrus orchards and a better understanding of their nature led to the formation, in 1957–58, of the Citrus Variety Improvement Program (CVIP), a joint effort of the departments of Plant Pathology and Horticultural Science of the Citrus Research Center (CRC) of the University of California at Riverside, planned in consultation with the Nursery Service of the California Department of Agriculture. The CVIP continues to operate in close cooperation and coordination with the citrus registration and certification program of the Nursery Service.

Broad policy of the CVIP is set by an 11-man committee chaired by the senior author and includes appropriate U.C. Agricultural Experiment Station, Extension Service, and United States Department of Agriculture personnel.

Resources and Personnel

The major portion of CVIP indexing is carried out at the university's Rubidoux facility in Riverside. This consists of 3,800 square feet of greenhouse, a small headhouse, 8,800 square feet of specially constructed screenhouse, and several large cabinets for environment control, including heat treatment. These facilities are about 2 miles from the nearest commercial citrus orchard and about 3 miles from CRC's experimental orchards.

The primary "foundation block" of 6 acres is located at the university's Lindcove Field Station in the San Joaquin Valley of central California. Three secondary foundation blocks are located at the Limoneira Ranch in Ventura County near Santa Paula (3 acres), at the university's South Coast Field Station in Orange County near Tustin (3 acres), and at the U.S. Department of Agriculture Date and Citrus Station in the Coachella Valley (2 acres).

Close planted trees for long-term indexing of cachexia virus and for performance trials on trifoliate orange rootstocks are maintained on 6 acres at Lindcove. Additional close plantings (8 acres total) for studies of virus tolerance and the spread of the stubborn pathogen are scheduled for 1971 at CRC, the South Coast Field Station, and Lindcove.

Supplementary holding blocks for promising hybrid and nucellar selections are located at Lindcove, Limoneira, and South Coast Field Station, totaling about 6 acres.

Thus, an aggregate of about 20 acres of permanent, widely spaced, orchard-type plantings and 14 acres of close plantings for field indexing and other studies are used or reserved for the program at 5 locations representing the principal climatic zones in which citrus is grown in California.

The equivalent of 6.5 men, 3 of whom are highly trained technical specialists, devote full time to this project. The time spent annually by committee members to guide and otherwise support the project amounts to about 0.5 professional man-years, with a proportional requirement in departmental overhead for travel and secretarial work.

The university has invested at least $600,000 in CVIP—excluding costs of physical facilities—during the past 11 years. Currently, salaries and support costs to maintain this program are estimated at between $60,000 and $70,000 annually, excluding administrative overhead. For the past 2 years, industry sources have contributed much of the support costs.

Technical Developments and Problems

The need of the CVIP to mount a large-scale indexing program generated specialized facilities and trained personnel. These resources have been used not only for service functions (producing and maintaining virus-free budwood sources), but also for research. Large-scale, routine experience with early indexing procedures revealed numerous inadequacies and defects in them. Use of CVIP resources for research has contributed materially not only to the solution of these problems, but also to the discovery of new viruses and to a better understanding of the components of certain virus complexes and their interactions.

During the past 10 years short-term indexing tests for ring spot, tatterleaf, and citrange-stunt viruses have been incorporated into routine indexing procedures by CVIP (5), but suitable short-term indexing procedures for cachexia, cristacortis, and impietratura viruses are not available. We must continue to rely on ponderous long-term tests to detect these potential menaces to the California citrus industry. Also, indexing procedures for stubborn and some other pathogens need simplification and improved speed and precision (9).

Some major improvements in indexing techniques developed in conjunction with the CVIP are the rapid Etrog citron test for exocortis virus and a much sharpened, but still somewhat cumbersome, short-term indexing procedure for the stubborn pathogen. Also, substantial advances have been made in techniques of propagation and inoculation of plants used for indexing and in providing optimum cultural and environmental conditions for symptom expression (9).

Indexing Results

The data in Table 1 summarize the indexing of a total of 315 selections of budlines (varietal lines originating from a selected, apparently healthy, well-identified, single parent plant) of domestic origin (growing in California) chosen by the CVIP committee for possible inclusion in the foundation or supplementary holding blocks. Details of the indexing procedures used recently for virus detection have been outlined elsewhere (5).

Of the 315 selections, 87 have been discarded to date because of virus infection and 11 for other reasons. The remaining 217 selections apparently are free of infection with known viruses and are now represented in the key foundation and supplemental holding blocks at the Lindcove Field Station.

Of the 240 scion selections indexed, 42 were of old-line origin, 168 of nucellar or hybrid origin, and 30 of unknown or uncertain origin. Only 16 of the 42 old-line selections were apparently free of known viruses, whereas 142 of 168 nucellar or hybrid selections and 18 of the 30 other selections were apparently free.

These data eloquently demon-

TABLE 1. INCIDENCE OF VIRUSES IN DOMESTIC SELECTIONS OR BUDLINES INDEXED IN THE CITRUS VARIETY IMPROVEMENT PROGRAM DURING 1958–69

Groups	Total no. budlines indexed	Number of budlines discarded for specified virus infections, or other reasons: Exocortis	Tristeza and/or seedling yellows	Vein enation	Psorosis and/or concave gum	Tatter-leaf	Cachexia	Stubborn	Other	Budlines virus-infected No.	%
Scions											
Navel orange	44	4	5	2	2	0	0	0	0	13	30
Sweet orange (others)	35	2	2	1	1	0	0	1	2	7	20
Mandarin and tangelo	54	5	5	1	0	0	0	0	0	11	20
Lemon and lime	46	8	0	4	4	2	0	0	5	18	39
Grapefruit and pummelo	27	2	0	0	0	0	1	0	1	3	11
Hybrids and misc.	34	2	2	0	0	0	0	0	0	4	12
Total scion selections	240	23	14	8	7	2	1	1	8	56	23
Rootstocks											
Selections	75	8	15	4	4	0	0	0	3	31	41
Totals	315	31	29	12	11	2	1	1	11	87	28

strate that in California, at least, it is not possible to secure an acceptable level of virus freedom by very careful selection based on visual inspection alone; rigorous indexing is absolutely essential. Even the exclusive use of nucellar budlines will not provide adequate security.

Exocortis, tristeza, vein-enation, and psorosis virus infections account for most of the discarded selections (Table 1), but the infections found are not an accurate index of the frequency of infection by each of the listed viruses because a selection was discarded and indexing discontinued as soon as any virus infection or important defect was detected. Results from detailed indexing of similar materials suggest that many infected budlines probably carried 2 or more viruses.

Additions have been made annually to the Lindcove foundation block since the first apparently virus-free selections were planted there in 1961. Eighty-eight trees representing 49 of the 217 selections remaining in the program have completed all long-term indexing tests, trueness-to-type examinations, and other requirements necessary for registration by the Nursery Service.

The 42 selections in the Lindcove foundation block from which a limited amount of budwood was available in the fall of 1969 for production of mother-block trees by cooperating nurserymen are listed in Table 2.

As of October 1969, 118 mother-block trees were registered or were eligible for registration under Nursery Service regulations (4) as budwood source trees for the production of certified nursery stock. In the spring of 1969, the first certified nursery trees were planted in commercial orchards.

Foreign Introductions

A cooperative program involving the University of California's Citrus Research Center and the U.S. Department of Agriculture was initiated in 1954 for the purpose of introducing citrus varieties deemed to be of potential commercial or scientific research value in the United States. In 1958, this foreign introduction program was combined with the CVIP. Details of the results obtained have been reported elsewhere (3, 11); hence, only a brief summary will be presented here.

During the past 15 years, 128 budwood importations originating in 20 countries were partially or completely indexed. Of these, only 19 selections were apparently free of all reported citrus viruses except cachexia and stubborn, which then required long-term indexing procedures. Thirteen of these 19 were deemed of sufficient potential value to warrant release from the quarantine facility at Riverside for the purpose of establishing them at Lindcove in a special observation block while awaiting the outcome of the long-term indexing tests.

Of special interest among these is a Valencia-type orange introduced from Portugal, which is now fruiting at Lindcove and appears to hold exceptionally well into the summer.

TABLE 2. SELECTIONS AVAILABLE FOR LIMITED[a] BUDWOOD DISTRIBUTION, FALL 1969

Citrus variety or group	CVIP number	Selection or budline	Date planted in foundation block	Date budwood first released
Navel orange	155	Atwood	1964	1967
	26	Washington, Frost nucellar	1961	1963
	179	Washington, Frost nucellar	1964	1969
	206	Washington, Nucellar, CRC 3419	1966	1969
	180	Thomson	1965	1968
	12	Washington, parent	1961	1963
Valencia orange	176	Campbell, old budline	1964	1969
	30	Cutter, nucellar	1961	1963
	181	Old budline	1965	1968
	62	Olinda, nucellar	1964	1967
	178	Olinda, nucellar	1965	1968
Mandarin	9	Clementine (Algerian)	1961	1963
	32	Dancy, Frost nucellar	1963	1965
	156	Encore	1966	1969
	133	Honey	1964	1967
	2	Kara	1961	1963
	1	Kinnow	1961	1963
	66	Wilking	1964	1967
Satsuma	33	Owari, nucellar	1963	1965
	61	Owari, nucellar	1964	1967
Tangelo	20	Minneola, old budline	1961	1963
	128	Pearl	1964	1967
Lemon	21	Eureka, Frost nucellar	1961	1963
	69	Eureka, UCLA 12N	1962	1964
	232	Lisbon, Foothill nucellar	1966	1969
	231	Lisbon, Frost nucellar	1966	1969
	68	Lisbon, Limoneira 8A	1962	1964
	113	Lisbon, Monroe nucellar	1964	1967
	73	Lisbon, Prior 14-18	1962	1964
Grapefruit	135	Marsh, Brown selection	1964	1967
	29	Marsh, Frost nucellar	1961	1963
	142	Marsh, Reed seedling	1964	1967
	148	Marsh, Whitney selection	1964	1968
	144	Redblush, USDCS nucellar	1964	1967
Rootstock selections	86	Troyer citrange	1965	1968
	97	Carrizo citrange	1964	1967
	84	Pomeroy trifoliate orange	1964	1967
	83	Rubidoux trifoliate orange	1964	1967
	164	Barnes trifoliate orange	1965	1968
	138	Siamelo	1964	1967
	150	Citremon, CRC 1449	1964	1967
	105	Citrumelo, CRC 1452	1964	1967

a. Limited to research needs of public institutions and to California nurserymen and growers participating in the long-range Citrus Registration and Certification Program of the Nursery Service of the California Department of Agriculture.

Also of interest are 2 very vigorous nucellar Shamouti budlines introduced from Israel. One of these produced fruit at Lindcove during the 1968–69 season and has now been entered into the domestic program for eventual inclusion in the foundation block. Shamouti, the principal export orange variety of Israel, ships exceptionally well and is popular in European markets. It seems to have a climatic requirement and season of maturity somewhat similar to the navel orange.

About 2 dozen introductions of well-known foreign varieties, though infected with non-vector-transmitted virus diseases such as psorosis, are being retained in the quarantine screenhouse and allowed to fruit for the purpose of observing fruit characters, obtaining seeds, and possible use in heat treatment, meristem tip micrografts, or nucellus culture techniques for virus removal or avoidance (1, 6, 10).

Seedlings from 7 varieties which had not been introduced previously and which showed some potential for California have been established in a block at the Lindcove Field Station (together with seedlings of many domestic varieties) for the purpose of establishing virus-free nucellar budlines for further evaluation. Among those now beginning to fruit are several major blood orange varieties from Spain and Italy. Some have produced very attractive fruit of good quality and may have promise in U.S. markets as specialty fruit.

Although the experience to date with the introduction of budwood of varieties of foreign origin has not been very encouraging, new techniques may soon make it worthwhile to again introduce vegetative propagative material of additional foreign budlines with a view to freeing them of virus disease. It is hoped that this would have the advantage of greatly shortening the time required to produce virus-free budlines as compared with the present nucellar method. For example, at present at least 10–12 years are required to produce from nucellar orange seedlings virus-free budlines sufficiently mature to risk commercial propagation.

The Future

During the past 11 years, CVIP has been undergoing fairly rapid evolutionary changes and improvements as new knowledge of citrus virus diseases—much of it stimulated by IOCV—has been made available and techniques have been refined (9). Substantial future progress in simplifying and shortening these current procedures may confidently be expected. It is hoped that still better chemical, serological, tissue culture, or other methods of virus detection will be developed to replace at least some of the current expensive, relatively cumbersome indexing methods involving field or greenhouse inoculation of test plants and the reading of symptoms.

Heat treatment (2) appears to be effective in the elimination of psorosis, vein-enation, and tristeza viruses from citrus. Hot water and moist hot air treatment of excised budwood

(10) appear promising for the elimination of tatterleaf and citrange-stunt viruses and the stubborn pathogen. A meristem tip micrograft technique is being investigated for producing virus-free citrus. Nucellus cultures (1, 6) have already provided virus-free clones of some mono-embryonic and other citrus varieties. A research and development program is in progress aimed at incorporating heat treatment and/or tip culture into the CVIP. It is possible that all selections ultimately will be heat treated before being used as primary budwood sources.

Some stubborn disease has been detected in primary source trees in the Lindcove Foundation Block. Also, some trees in the satellite blocks and in nurserymen's mother blocks appear to have been infected with the stubborn pathogen either in the nursery or after planting in the orchard. This troublesome problem is suspected to be caused by the stubborn pathogen spread by a vector as yet unidentified. Thus, future primary budwood source trees may have to be grown and maintained indefinitely under screen or glass to minimize the possibility of infection by vector-transmitted pathogens.

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