

SURVEYS AND CERTIFICATION

Why Have Mandatory Citrus Certification Programs?

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ABSTRACT. Certification programs are fundamental to the control of graft-transmissible diseases of citrus and other vegetatively propagated crops. When properly implemented, certification programs can provide protection against further spread of graft-transmissible diseases already present and provide a safeguard against the introduction of exotic graft-transmissible diseases. Although the benefits of certification programs are readily acknowledged, there are relatively few certification programs in the countries growing citrus, and even fewer that are mandatory. The experience with citrus certification programs in Florida has been that voluntary certification programs, while helpful, are not adequate to protect the industry against the spread of debilitating, graft-transmissible diseases. This article reviews the increasingly complex disease situation developing in the Caribbean Basin due to the spread of the brown citrus aphid and the threat of other exotic pests. The history of the voluntary Florida budwood certification will be reviewed with respect to tristeza and other virus-like diseases, and how these diseases eventually resulted in the development of a mandatory citrus certification program which began in 1997. The essential components of citrus certification programs are discussed.

Index words. Certification, tristeza, Caribbean, aphid, huanglongbing (greening), citrus variegated chlorosis, Florida.

Impact of the BrCA in the Caribbean Basin. The brown citrus aphid (BrCA), *Toxoptera citricida*, is the most efficient vector of citrus tristeza virus (CTV) being up to 25 times more efficient at transmitting CTV when compared to *Aphis gossypii*, the next most efficient vector of CTV (52). The BrCA was introduced into the America's in the 1930s by the importation of infested citrus material from South Africa into Argentina and Brazil. Following this introduction, this efficient vector of CTV moved northward and was first reported in Venezuela in 1976 (40). The following sequence of events occurred in Venezuela following the introduction of the BrCA (36, 40):

CTV was first reported in Venezuela in 1960 in Mexican lime germplasm collections (22). When the BrCA first entered Venezuela in 1976, CTV was present but was not causing problems. Almost all the 6 million trees comprising the citrus industry were on sour orange rootstock. By 1979, the aphid had

spread throughout all citrus producing areas of Venezuela with the BrCA displacing indigenous aphids, such as *Toxoptera aurantii*, *Aphis spiraecola*, and *A. gossypii*. The first outbreak of CTV decline on sour orange occurred in the north-central region in 1980; by 1987, 6 million trees had been killed by CTV induced decline on sour orange. The farmers initially responded to the loss of their trees by planting new trees on sour orange rootstock. It soon became apparent that no trees could be grown on sour orange in the presence of CTV.

Farmers propagated new trees on CTV-tolerant rootstocks using budwood sources which had performed well on sour orange rootstock, then discovered that the budwood source had been contaminated with one or more viruses or viroids which, collectively, may render all CTV-tolerant rootstocks non-productive. Volkamer lemon was a commonly used rootstock, it produced trees which are vigorous and produce well. However, when the trees on

Volkamer lemon reached 4 to 6 yr of age, they were affected by a condition referred to as “sudden decline.” Closer study (35) revealed that “sudden decline” was the same as citrus blight in Florida (8, 49), except in the tropical climate of Venezuela, it is much more severe resulting in trees dying, a condition which is not common in Florida in younger trees. Citrus blight also severely affects *Poncirus trifoliata*, and citrange rootstocks. The presence of other viruses/viroids became apparent, depending on what CTV-tolerant rootstock was used. Cachexia viroid causes dwarfing and stem pitting on mandarin-type rootstocks. Citrus viroids cause dwarfing and low productivity in trees on citrange, citrumelo, or *P. trifoliata* rootstocks. Citrus tatterleaf, also known as citrange stunt, affects lemons and citrange, citrumelo, or *P. trifoliata* rootstocks. Woody gall, when present in budwood, produced galls on rough lemon and lemon-type rootstocks.

In Venezuela, as well as other countries where the BrCA has become established, the complexity and severity of CTV changes after the arrival of the BrCA (33, 36). Initially the isolates of CTV causing decline on trees on sour orange rootstocks are the most obvious because of the widespread use of sour orange rootstocks. However, when “CTV-tolerant” rootstocks are used, the presence of isolates of CTV which cause stem pitting begin to appear. The stem pitting may occur either on grapefruit or sweet orange, or on both hosts. These stem pitting isolates spread through the country rapidly because of movement of infected nursery material (36). Once the infected tree was planted in the field, the aphid vectors further spread the severe isolates locally. Stem pitting strains of CTV cause a loss of tree vigor, reduce yield, and reduce quality of fruit. From yield tests in South Africa (28), stem pit-

ting on grapefruit can reduce yields up to 45 percent. Thus, 15 yrs after the first report of the BrCA in Venezuela, 6 million trees (the entire industry) had been lost on sour orange rootstock, and stem pitting strains, which cannot be controlled by use of CTV tolerant rootstocks, were widespread in all citrus areas (36, 40).

The last phase of the increasing complexity of CTV after introduction of the BrCA is the appearance of very severe strains of CTV which causes stem pitting on “CTV-tolerant” rootstocks (34). The first report of a CTV isolate which could cause stem pitting on a “CTV-tolerant” rootstock was the Capão Bonito isolate reported in 1963 (29), named after the name of the town where the severe CTV strain had been found in Brazil. The Capão Bonito isolate of CTV causes severe stem pitting on Rangpur lime rootstock. In Brazil, the effects of the Capão Bonito isolate have been minimal because of a strict quarantine to prevent movement of citrus out of the region where the severe isolate was found (9). In Venezuela, CTV isolates have appeared and spread which cause very severe stem pitting on rough lemon and Volkamer lemon rootstocks, and even stem pitting on Cleopatra mandarin rootstocks (36, F. Ochoa and R. Lee, unpublished data). In Venezuela, the CTV isolates causing stem pitting on “CTV-tolerant” rootstocks have been spread through the industry through the movement of infected nursery material.

Following the establishment of the exotic insect pest, the BrCA, through the Caribbean Basin, similar scenarios of progressive tree losses due to CTV will occur in country after country unless timely measures are taken to implement mandatory citrus certification programs. The clock is already counting off the time. Table 1 summarizes the date of the first report of the pres-

TABLE 1
 DATES OF FIRST REPORT OF *TOXOPTERA CITRICIDA* (BrCA) AND DESTRUCTIVE CITRUS
 TRISTEZA VIRUS (CTV) OUTBREAK FOR CARIBBEAN BASIN AREA

Country	BrCA first reported	CTV outbreak recorded
Bahamas	1996	None
Belize	1996	None
Costa Rica	1989	None
Cuba	1993	None
Dominican Republic	1992	1998 (16)
Florida/U.S.A.	1995	CTV decline already endemic (6)
Haiti	1992	1997 ^z
Jamaica	1993	1997 (20)
Nicaragua	1991	None
Panama	1985	1995 ^y
Puerto Rico	1992	1996 (53)

^yD. D'Adeski and R. F. Lee, unpublished.

^zJ. Bernal, personal communication.

ence of the BrCA and the date of the first outbreak of CTV decline on sour orange in the Caribbean Basin.

Other exotic pests with vectors which threaten citrus in the Caribbean Basin. Citrus variegated chlorosis (CVC), caused by *Xylella fastidiosa*, was first reported in 1987 at one location in northern Sao Paulo State, Brazil (25). Presently this devastating disease is present in all citrus growing regions of Brazil, in Argentina and Paraguay. This disease is spread by xylem feeding leafhopper vectors, commonly called sharpshooters. These insects are widespread in Brazil (27), present in Florida (5, 51), and throughout the Caribbean. Once a tree is infected with CVC, it is rendered totally non-productive within 3 yr (1). Another virus disease, citrus leprosis, spread by mite vectors, invades groves abandoned because of low productivity due to CVC. Then a deadly disease complex is formed which has killed thousands of trees in northern São Paulo State, Brazil (21). A survey conducted by FUNDECITRUS in 1998 estimated that 29 percent of all citrus trees in São Paulo State were infected with CVC (21). The rapidity of spread of CVC through the Brazilian citrus industry, the

reduction of yield, and ability to form a disease complex with citrus leprosis which kills trees surely make CVC one of the deadliest citrus diseases known.

Citrus huanglongbing (HLB) (greening) has not been reported in the Western Hemisphere. In Asia and parts of Africa, HLB is considered to be one of the most debilitating diseases of citrus and a limiting factor of citrus production (3, 43). The Asian vector of HLB, *Diaphorina citri*, has been present in Brazil for many years. In June 1998, this psyllid was found in southern Florida, and surveys indicated it was established in four counties (S. Halbert, personal comm.). *D. citri* has been expanding its geographical range and has been reported to be present in the West Indies (10). This exotic vector of HLB may be present in other Caribbean countries but not found because its presence is not obvious. With the vector present, the risk of establishment and spread of HLB is much greater if this phloem inhabiting bacterial pathogen should be introduced.

There are additional exotic pests which could have an impact on citrus production in the Caribbean: citrus chlorotic dwarf (CCD), caused by a graft-transmissible virus-like

pathogen in Turkey which adversely affects many citrus varieties and is vectored by whitefly vectors (19). CCD affects a number of citrus hosts and has expanded its range in Turkey. Witches' broom disease of lime (WBDL), caused by a mollicute-like organism and having a leafhopper vector, causes death of acid lime, sweet lime, and some other varieties (2, 11). WBDL has eliminated production of acid limes along the northern coast of Oman and is present in neighboring countries as well as Iran and India (2).

Comparison of the Caribbean Basin to the Mediterranean area. The BrCA has already invaded and become established in most countries of the Caribbean Basin (Table 1). The scenario of events following the establishment of the BrCA (losing trees on sour orange rootstock, finding budwood sources are latently infected with viruses and/or viroids which will affect their productivity on CTV-tolerant rootstocks, increasing severity of CTV isolates) is already unfolding (36). A similar scenario could be repeated in the Mediterranean area. The BrCA was introduced to the Madeira Islands, west of Portugal and Morocco in the Atlantic, in 1994 (32, 33). Research has indicated the increasing complexity of the CTV strains present on the islands (32, 33). When the BrCA reaches the citrus areas surrounding the Mediterranean, a scenario similar to that in the Caribbean Basin could occur. HLB and both the African vector, *Trioza erytrae*, and the Asian vector, *D. citri*, are present in the Near East region and moving toward the Eastern Mediterranean countries (2, 3). Additionally, citrus stubborn, caused by *Spiroplasma citri*, and vectored by leaf hoppers, is present in some countries (2). Of the citrus producing countries in the region, only Spain has a mandatory citrus certification program (30).

Economic losses due to graft-transmissible diseases. Many of the chronic decline diseases of citrus caused by graft-transmissible agents do not kill the trees, but renders them unproductive. With pathogens spread by insect vectors, the presence of infected trees hastens the spread of the disease. Farmers are often reluctant to remove and replant declining trees, they always hope the decline is reversible with application of more fertilizer or better plant care. The economic impact on the farmers due to these chronic decline diseases is great. The economic loss due to a viroid, which does not have an insect vector, and due to HLB which has an insect vector has been estimated (43, 44).

Roistacher et al. (44) calculated the economic loss based on Valencia sweet orange on Rangpur lime rootstock groves with and without citrus exocortis viroid under the same management program in Belize. Because the budwood source was infected and viroids are easily transmitted by graft inoculation, almost all trees were infected. From an analysis of all costs associated with establishment and production, including initial capital, maintenance, pick and haul, and grove maintenance, the return on the 8-yr-old grove planted with virus-free certified budwood was US\$4,865 per acre with 100 trees per acre, compared to US\$-2,298 for the exocortis-infected grove under the same conditions and management.

The costs of living with a chronic decline disease of citrus having an insect vector, HLB, in Thailand has been reviewed by Roistacher (43). From the interpolation of data, a one acre (100 trees/acre) citrus grove in Thailand would yield a cumulative loss of US\$/ha of \$-3,701 and \$-1,634 for a grove life expectancy of 6 and 8 yr, respectively. A cumulative profit of \$1,510 and \$3,839 per acre would be realized if

the life expectancy of the grove were 10 yr and 12 yr, respectively. While the exact numbers will vary depending on local costs, this trend would occur anywhere. The longer the grove remains as a healthy block of trees, the greater the return on the investment. If a chronic disease, such as HLB, shortens the productive life span of the grove, the profitability will be marginal or maybe not realized at all.

Why are mandatory certification programs needed? Unquestionably, properly implemented citrus certification programs are effective in preventing the further spread of graft-transmissible pathogens. These programs provide the most cost effective way to control such pathogens, even with those pathogens having insect vectors, as the time and expense for indexing are concentrated on the source trees used for subsequent propagations (24). Many chronic decline diseases which affect citrus have insect vectors, for example: CTV; HLB; CVC; WBDL; CCD; and stubborn. With these graft-transmissible pathogens which have vectors, certification programs are effective only if they include all citrus propagations in the citrus industry, e.g. they must be mandatory.

Review of the voluntary Florida Budwood Registration Program (FBRP). A review of the Florida Budwood Registration Program (FBRP) provides a good case study of the benefits and limitations of a voluntary citrus certification program. The FBRP was started because of increased grower awareness of the destructive nature of graft-transmissible diseases. A resolution was passed in 1951 at the Florida State Horticultural Society meeting requesting the establishment of a budwood certification program (34). This resolution was the result of investigations by growers and nurserymen into programs being started in California and

Texas. By 1951 tristeza decline already had devastated citrus industries on sour orange rootstock in Argentina and Brazil and the graft-transmissible nature of psorosis, cachexia, and exocortis had been demonstrated (14, 34). Under the leadership of the Florida State Plant Board who worked with members of the Florida Citrus Industry, a Statement of Policy was developed under which the FBRP would operate. In early 1953 the FBRP began accepting applications on a volunteer basis (34). Within 10 yrs the FBRP was the world's largest registration program for citrus budwood (24). This volunteer program required initial indexing for CTV, psorosis, cachexia, and exocortis for registration of budwood source trees, although some registered sources were infected with exocortis and cachexia. Registered trees were observed annually to ensure freedom from Florida gummosis, blight, decline, leprosis, and bud mutations and for trueness-to-type. The funding for operation of the FBRP was mostly from the State of Florida's general revenue.

Almost concurrently with the start of the FBRP, CTV was first reported in Florida based on Mexican lime indexing by Grant (17) in 1952. However, it seems likely CTV was present in Florida long before this date. Swingle (50) in 1909 wrote that in the previous five yrs he had never seen a vigorous or productive Satsuma budded on sour orange. The Meyer lemon was introduced from the Orient into California, Texas, and Florida in 1908 (23). Indexing the clonal propagations from these introductions resulted in consistent recovery of seedling yellow strains of CTV, and it is generally accepted that the seedling yellows was present in the originally introduced material (23). Rhoads (39) in 1936 included classic descriptions of CTV-induced decline occurring in trees on sour orange

rootstock as well as describing classic symptoms of citrus blight on rough lemon rootstock. In the 1950s, citrus in the ridge area of Florida was principally on rough lemon rootstock and the other citrus areas to the north were mostly on sour orange (49).

While CTV was present in Florida in the 1950s, there were few tree losses. Knorr (18) monitored the spread of CTV by placing Mexican lime plants in various locations throughout the citrus area, then observed the "fire alarms" for symptoms. Few of these "fire alarm" trap plants became infected with CTV and most isolates produced mild to moderate symptoms on the Mexican lime plants. In 1956, tree losses due to CTV were reported in Orange Country and in the Fort Pierce area (7). In 1957, CTV losses were reported in Orange, Lake, and Seminole Counties (18). In the 1960s, only isolated losses due to CTV were reported except in the Fort Pierce area where natural spread of CTV decline occurred (4). However, mild isolates of CTV were spreading elsewhere because many of the registered bud source trees were becoming infected with CTV (12). Because of this increased spread of CTV during the early 1960s, trees were no longer removed from the list of registered bud sources if they were CTV infected beginning in 1964 out of the concern that there may not be enough CTV-free budwood to supply the Florida industry (4). At this time in the FBRP, all budwood source trees were planted in the field.

In 1975, a destructive outbreak of CTV loss was reported in western Orange and southern Lake Counties (13). A survey conducted in 1979 of registered bud source trees being propagated on sour orange rootstock revealed that 87 and 9 percent of the sweet orange and grapefruit bud source trees, respectively, were CTV-infected (15). However, upon biologi-

cal indexing, most strains recovered were mild and few seedling yellows strains were recovered (15; R. Lee, unpublished data). However, due to recurring severe freezes, the losses incurred by citrus blight, and desire for high fruit quality, the demand for trees on sour orange rootstock continued to increase, and bud source trees not previously propagated on sour orange rootstock were being used to meet this increased demand.

The prevalence and severity of CTV could no longer be ignored in the early 1980s. Many newly propagated trees on sour orange rootstock did not grow well, and epidemics of CTV decline on sour orange were occurring in many areas of the state (6). The long distance spread of decline isolates of CTV was by movement of nursery trees, often on CTV-tolerant rootstock, as many of the registered trees were infected with decline strains of CTV. In 1984, a voluntary indexing program was started whereby budsticks from bud source trees were collected under supervision of FBRP inspectors (54). Using sour orange liners donated by commercial nurseries, biological indexing of the bud source trees currently used for propagations was conducted. Ten sour orange liners were budded from each bud source tree, and all bud source trees for each clonal selection were indexed in one location. Virus-free and mild CTV infected bud sources of each clonal selection were included for controls in order to judge the amount of dwarfing due to CTV strains present. Budding was done in February/March, 1984, and the tree performance was judged by visual evaluation and caliper measurements of the stem diameter in September 1984. The presence of severe CTV was obvious in many of the budlings. In general, about one third of the budwood source trees indexed contained CTV strains which dwarfed tree growth to the

extent that the average stem diameter was less than 50 percent of the average for the control plants (54).

Presence and effect of other pathogens. Citrus canker: A citrus leaf spot disease, which was thought to be citrus canker, *Xanthomonas campestris* pv. *citri* (Hasse) Dye, was found in Florida in September 1984 (48). A strict quarantine was imposed on the movement of plant material to reduce the risk of transporting canker. As a result, many propagations were made in the next few years using buds from well-performing trees located near the nursery. These sources were often on CTV-tolerant rootstocks and unregistered. This practice probably contributed to additional spread of severe strains of CTV in Florida, as well as viroids, psorosis, and other graft-transmissible diseases.

Psorosis: Concern over psorosis had been one of the major reasons the growers wanted a citrus certification program in the 1950s (34). Beginning in 1961, it was unlawful to propagate psorosis in nine major commercial varieties which were then available psorosis-free (24). In 1967 an additional seven varieties were included as psorosis-free propagations.

Viroids: In 1967, it was realized that exocortis was spread by contaminated pruning tools, and recommendations were made to avoid this (14). Many of the older registered bud source trees in Florida contained viroids. Because some nurseries claimed their budwood sources were "as good as registered", viroid contaminations were overlooked and used for propagation on viroid-susceptible rootstocks, resulting in the removal of thousands of acres due to lack of productivity (45, 46).

Citrus blight: During the late 1960s and the 1970s, the Florida citrus industry moved southward and increased acreage in the Florida Flatwoods. Thousands of trees, mostly on rough lemon rootstock,

were planted within a few years in this warmer location (26). Citrus blight began removing these trees from production as they reached 5-7 yr of age, and tree losses due to citrus blight reached epidemic proportions by the mid to late 1970s (49). Epidemic losses due to blight began in the south, but moved northward in the early-mid 1980s, resulting in the loss of many productive groves on rough lemon rootstock, the favored rootstock in the Ridge area. Because of the field tolerance of sour orange to blight, sour orange was heavily propagated as a favored rootstock until about 1982 when Carrizo became a favored rootstock after the heavy losses on sour orange due to CTV. When the plantings on Carrizo became 5- to 7-yr-old, it became apparent that Carrizo rootstock was very susceptible to blight, and for the next 3 to 4 yr, sour orange was again heavily propagated. It was not until the mid 1980s that the impact of strains of CTV causing decline in trees on sour orange rootstock was so obvious that it could not be ignored, and CTV tolerant rootstocks, especially Swingle citrumelo and Cleopatra mandarin, became popular (46).

The situation in the final years of the voluntary FBRP. By the late 1980s, the FBRP was faced with the increasing reservoir of severe strains of CTV in bud sources which were being spread throughout the state by propagation on CTV-tolerant rootstocks. Tree losses due to CTV were over 50 percent per year in some locations in the Indian River and the Southwest Florida Flatwoods citrus areas (6). Fundamental changes were made in the operation of the FBRP in 1987 to prevent decline strains of CTV from getting into the propagation source material (47). Briefly, trees harboring severe strains of CTV which affect growth on sour orange were dropped as registered bud source trees. Foundation trees were main-

tained under protected conditions. Budwood increase nurseries were authorized for use for the first time in 1991. These budwood increase nurseries could be maintained for up to 24 mo for cutting buds; it was recommended that some trees in the nurseries be on sour orange to serve as a biological index for the presence of severe CTV. Nurserymen and scion grove owners began to establish their registered scion trees under protected conditions.

Sixteen million plants were propagated in the 1993-4 season, less than 4 million of these were registered (46). There were 44,636 registered scion trees in 70 scion blocks. The FBRP had resources to index 2,000 scion trees per yr (46). Many registered scion trees had never been re-indexed since they were first registered. Because all nurseries in Florida must be certified to be nematode-free (this requirement was mandatory for all nurseries, not just citrus), some nurseries claimed all the trees they propagated were registered, since there was a "registration fee" charged to pay for the cost of nematode certification (45). Many propagating sources were two to five generations removed from the registered bud source tree, yet sold under the claim that it was "as good as registered" material. Citrus viroids were often found in plantings on viroid susceptible rootstock, cachexia was found on occasion. Indexing for agents associated with Rio Grande Gummosis, prevalent on grapefruit in the Indian River area, indicated that 79 percent of the grapefruit trees in five different groves showed leaf symptoms similar to psorosis when indexed on sweet orange, and a follow up survey of registered Ruby Red grapefruit bud source trees indicated that about 15 percent also showed these psorosis-like symptoms (38). The presence of the psorosis-like agents was apparent only when indexing was done in temper-

ature controlled greenhouses; field observation of the spring flush for psorosis symptoms as required by the program was not adequate to detect the presence of this pathogen.

Value of the mandatory certification for freedom of nematodes. While the voluntary budwood certification program was falling short of its intended goals, the mandatory certification of all nurseries, not just citrus, for freedom of injurious nematodes was highly successful (26). The nematode control certification and control program began with the burrowing nematode, *Radopholus similis*, to control spreading decline, and became mandatory in 1958. The citrus nematode, *Tylenchulus semipenetrans*, and the coffee lesion nematode, *Pratylenchus coffeae*, were added as regulated nematodes later. The mandatory nematode certification program had several components: i) certification of nurseries as nematode-free, surveys to define infested areas; ii) eradication to remove spreading decline infected trees; and iii) a barrier program to prevent movement of nematodes to healthy trees. The implementation of this program in 1958 resulted in no further spread of the burrowing nematode, nor the other regulated nematodes which were added to the program later. Thus, the expansion of the Florida citrus industry into the warmer region in the south was done without contaminating this new citrus area with nematodes. At the present only about 25 percent of the Florida citrus area is nematode-infested, and this area was already infested when the program began in 1958. Considering the costs of operating the nematode certification program including the costs of surveys, eradication, and barrier programs from 1958 to 1994 and the resultant losses which have been documented on spreading decline infested trees, for every \$70,000 invested, there was a return of \$1 million.

Beginning in 1994, only the certification of nurseries to ensure freedom from nematodes has been mandatory, and the survey, eradication and barrier programs have been voluntary. For the crop year 1994 to 1995, for every \$1,403 invested in the administration of the mandatory nematode certification program, there was a return to growers of \$1 million. This does not take into account potential damage which could be caused from the coffee lesion and citrus nematodes.

The development of a mandatory citrus certification program in Florida. The mandatory citrus budwood program in Florida, officially called the Citrus Budwood Protection Program (CBPP), began in January 1997, although while the program was being developed, industry people referred to it as the Quality Tree Program. The mandatory program resulted from actions by the Florida Nurserymen's Association, the Florida Citrus Production Manager's Association, and a number of other citrus organizations (45, 46). The growers/nurserymen were concerned about the inadequacies of the voluntary program as previously reviewed, and the possible establishment of a number of exotic citrus pests all of which have vectors or a means of natural spread: CVC, naturally spread psorosis, HLB, stubborn disease, WBDL, CCD, and stem pitting strains of CTV which might become apparent following the introduction and establishment of the BrCA in Florida in 1995. The disruptive effects of recent introductions of exotic pests, such as citrus canker, Oriental leaf miner, Mediterranean fruit fly, won support from all members of the industry in Florida to support actions which will make these introductions less frequent.

Under the CBPP, graft-transmissible diseases will no longer be propagated. Severe strains of CTV will

not be propagated, presently the severe strains are identified by their reactivity with the monoclonal antibody MCA-13 (37). Testing for severe strains of CTV is required on a regular basis on registered scion trees and in multiplication nurseries. When newer methods which may be more accurate and/or sensitive have been tested, they will be utilized. Recurring indexing for CTV, psorosis, and viroids are required on all registered trees. The program is governed by a standing advisory committee composed of nurserymen, production managers, scientists and regulators; the scientists and regulators provide technical information and have no voting power. Provision was made for certification of all diagnostic laboratories to ensure they meet a minimum level of performance for detection of CTV and other graft-transmissible pathogens. Laboratory certification began in 1997 with CTV detection. Unlike the previous voluntary program, the CBPP financial support is partly derived from fees for services to the industry. The cost of indexing for CTV for privately-owned registered scion trees is paid by the owner. A fee is charged for registering each bud source and seed source tree. Beginning in 1998, the mandatory program was expanded to include all citrus propagations in the state, including dooryard propagations. The implementation of this expanded program has gone smoothly due to an advance education campaign to inform everyone who might be affected.

Benefits of the CBPP. A benefit which is often overlooked is the availability of yield and performance data generated from the trials for verification of horticultural trueness-to-type (46). This information has enabled Florida growers to make knowledgeable selection of clones considering rootstocks and yield of specific clonal varieties on specific rootstocks. The effect of the

availability of this information has been that the average productivity of citrus in Florida is about 10-15 percent greater on a per tree basis due to better producing clones being propagated as compared to production 15 to 20 yr ago. Additional benefits realized by a mandatory program are (41, 46): i) problems with graft-transmissible pathogens are kept localized; ii) losses due to current pathogens are reduced; iii) the risks of introduction of new pathogens are greatly reduced; and iv) the structure of the certification program makes it easier to introduce a new clonal selection into the industry.

Essential components of a model certification program. As pointed out earlier, a citrus certification program is composed of three distinct and different programs: i) quarantine; ii) clean stock; and iii) certification (26, 31). These three programs must be integrated to provide for a functional, effective certification program.

1) Quarantine Programs for safe introduction of selected horticultural germplasm.

It is often desirable to move citrus species and varieties between different citrus areas for commercial and/or scientific purposes. Uncontrolled introduction of such budwood carries a risk of introduction of new pests and pathogens. Provision has to be made to import such budwood safely to reduce the risk to the importing industry or country. This is usually accomplished by careful introduction through quarantine stations which perform procedures for the safe importation of the germplasm. Quarantine programs are usually operated under the jurisdiction of the ministry of agriculture of a country or the commissioner of agriculture in a state or province. The quarantine component emphasizes the testing for freedom of specific diseases existing in the country of origin of the plant material.

There are two main approaches to importing citrus budwood under quarantine conditions: the classic method of propagation of the imported material in an isolated condition until the material can be freed of graft-transmissible pathogens by thermotherapy and/or shoot-tip grafting, indexed to verify their pathogen-free status, and then released to the clean stock program for subsequent use in the citrus industry. The second method maintains the imported budwood in tubes. Imported budwood is immediately surface sterilized, placed in culture media in test tubes, buds are forced, shoot tip grafting is performed, and the resulting plants are then indexed to verify freedom from pathogens. This approach is now used in Spain and California, and offers the advantage of more rapid introduction. As an example, one budstick from Texas was introduced into Spain in January 1988, and in May 1989, 10,300 healthy buds were released to citrus nurseries (42).

2) Clean Stock Programs for identification and production of desirable sources, and their maintenance as pathogen-free propagating stock.

In a citrus certification scheme, it is desirable to recover healthy plants from the local varieties or cultivars. The local varieties may be best adapted for the local climate, soils, and market. Clean stock programs are usually carried out by research institutions with the joint participation of scientists in horticulture, virology, and tissue culture, and in close communication with the Ministry of Agriculture or Commissioner of Agriculture.

A clean stock program consists of six steps: i) selection of mother trees of local cultivars; ii) indexing of the mother trees; iii) recovery of pathogen-free plants by shoot tip grafting and/or thermotherapy; iv) indexing of the recovered plants; v) horticultural evaluation of the healthy

plants; and vi) maintenance of healthy plants under protected conditions with recurring indexing to ensure they have not become contaminated again. When selecting mother trees, selection of individual trees of the different cultivars should be made according to documented horticultural criteria, such as superior production, higher fruit color, early or late ripening, etc. The presence or absence of pathogens

should not be a deciding factor, the therapy treatment will rid the selection from the pathogens.

3) Certification Programs for maintenance and distribution of virus-free propagating materials for commercial use.

An additional purpose of a certification program is to guarantee the sanitary status and trueness-of-type of the propagating material during the process of commercial

PROPAGATION COMPONENTS OF A CITRUS CERTIFICATION SCHEME

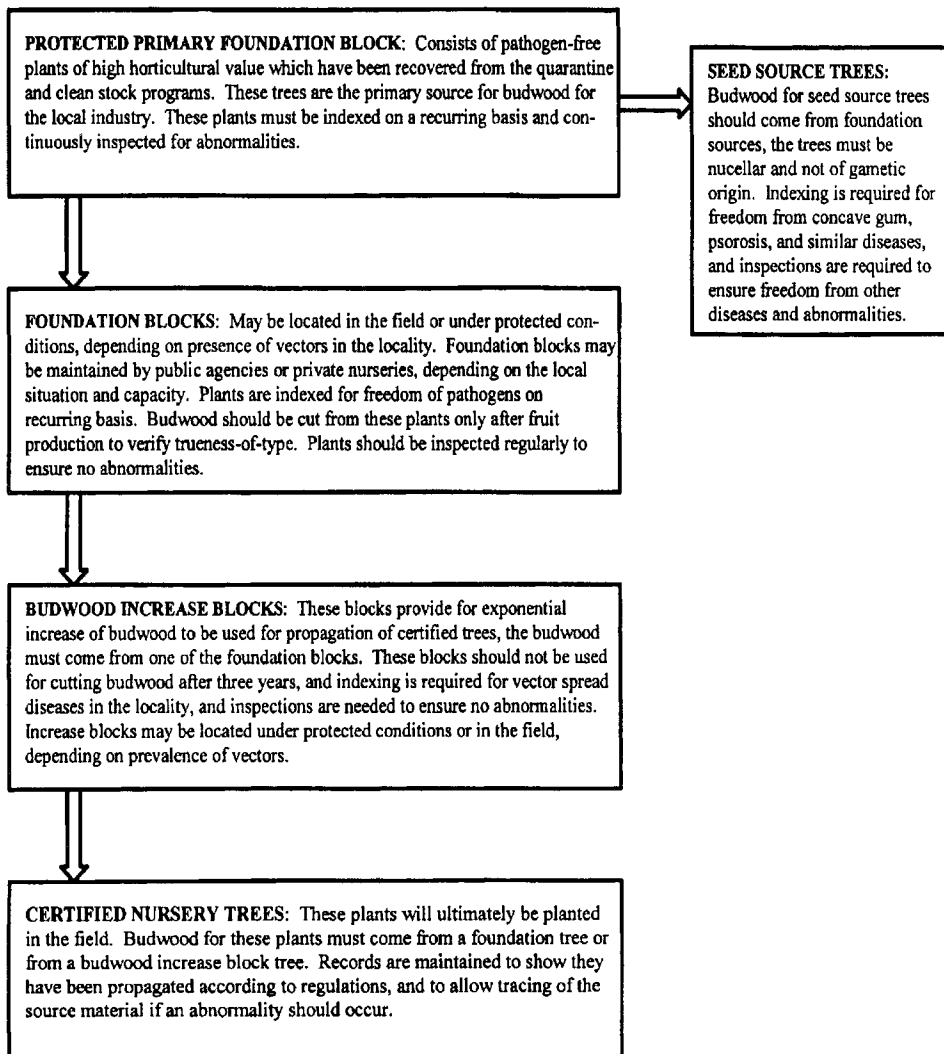


Fig. 1. Propagation components of a citrus certification scheme.

propagation through the nurseries. The program should also control the horticultural quality of nursery plants. These programs have legal regulations governing the different steps of nursery operations and require periodic indexing and inspection of trees of the different blocks used for nursery propagations. Usually they are operated by a state or provincial agency having legal authority to impose restrictions and to inspect nurseries. In most countries, all steps of the propagation occur in nurseries.

Certification programs have to be adapted to the specific situation of each citrus area. Organization of the citrus industry, pests and diseases present, and sustainable sources of funding are important considerations when developing a citrus certification scheme. Certification programs only give a guarantee for those pathogens which are actually included and tested for in the program.

Citrus certification schemes are necessary, even in areas with endemic vector-transmitted diseases. The indexing and enforcement of the regulations results in the farmers being able to buy nursery plants free from graft-transmis-

sible pathogens, even those diseases having insect vectors. If a problem develops, the "paper trail" allows the original source of the problem to be identified.

The propagation components of a citrus certification scheme are outlined in Fig. 1. This basic scheme allows for concentration of resources of the expensive and time consuming indexing for freedom of graft-transmissible pathogens, verification of horticultural trueness-of-type, and selection for highest horticultural quality to be focused on the foundation trees, yet the benefits of this effort is realized by all the resulting propagations. Certification programs must have the support of the growers and members of the industry, and funds must be available to sustain operation of the program.

These programs are the foundation on which to build any efforts to reducing damage caused by diseases and pests, and for the improvement and continued productivity of a citrus industry.

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