Short title: History of the budwood scheme in Australia

History and evolution of the citrus budwood and seed scheme in Australia

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Abstract

The Australian citrus budwood and seed scheme is one of the oldest in the world and has been instrumental in maintaining the health, productivity, and uniformity of Australian citrus plantings. The scheme is run as a non-profit company under the trading name of Auscitrus, with most facilities at Dareton in far southwest New South Wales (NSW). In this paper, we provide a brief history of the citrus industry in Australia, including key events that led to the creation of a seed and budwood scheme in NSW in 1928. The emergence of plant diseases such as Phytophthora gummosis, citrus tristeza and exocortis compelled the industry to adopt new propagation and cultural practices. Industry and government continue to support and strengthen Auscitrus and Australian citrus biosecurity in the areas of diagnostics and surveillance, germplasm management, public education, policy and strategy. Auscitrus is a key component for the Australian citrus industry to manage endemic and respond to exotic graft-transmissible diseases such as huánglóngbìng.

Keywords: graft-transmissible pathogen, propagation, rootstock, scion, nursery industry, George Suttor, Charles Moore, James Pye, Reginald Benton, Lillian Fraser

Introduction

This historical review describes the foundations of the Australian citrus industry, the impact of plant diseases and biosecurity on industry development, and the importance of propagation schemes to prevent and manage graft-transmissible diseases.

The Australian citrus industry dates to the foundation of Sydney in January 1788, with seeds and young trees of orange and lemon acquired by the First Fleet in Rio de Janeiro, Brazil, during the long voyage to the new colony (Collins 1798). Reverend Richard Johnson, chaplain of the First Fleet, is thought to have grown the very first fruit-bearing orange trees in Australia, in the garden of a cottage that once stood facing Bridge Street in the centre of Sydney (Suttor 1828; Lowery 1927). George Suttor (Fig. 1) was provided a land grant of 186 acres (75 ha) at Baulkham Hills in March 1802, and he claimed to have grown the first commercial crop of oranges (Parsons 1967; Orchard 2018; Suttor 1828). Suttor started his orchard with three orange trees that were gifted to him by Colonel William Paterson, a friend of his father who had acquired the plants in San Salvador in Central America. While waiting for his orchard to come into bearing, Suttor began a nursery and on 20 May 1804, advertised the sale of a variety of young fruit trees including lemons, which were grown from seed (Suttor 1804; Mackaness 1977).

Fig. 1. George Suttor (1774–1858), pioneer citrus grower and nurseryman in Australia

Source: Maiden, J.H. (1909) *Sir Joseph Banks: The 'Father of Australia*' Govt Printer, Sydney, p. 211. Artist unknown.

For the first half century or more, the Australian citrus industry was based in the Greater Sydney region and was largely pest and pathogen free. Suttor noted that the only pest of significance in 1843 was the sap-sucking 'turtle-bug', a likely reference to the black scale (*Saissetia oleae* (Olivier)) (Suttor 1843). Vegetative propagation techniques such as grafting were advocated as early as 1807, and the 'Spanish' lemon (*Citrus* × *limon* var. *limon* (L.) Burm f.) and citron (*Citrus medica* L.) were preferred rootstocks (Anonymous 1807; Anonymous 1841; Suttor 1843). The primary motivation for grafting and other vegetative propagation practices such as layering and cuttings appeared to be early bearing, as root diseases were unheard of at the time.

In about 1860, a new and devastating disease emerged in the Sydney orange orchards, characterised by bark decay at ground level, the oozing of red gum from the trunk, and rotting of the small roots (Anonymous 1862). The disease was worst on oranges grafted on lemon rootstocks. The description of symptoms now points to the emergence of Phytophthora gummosis. A Select Committee 'to report ... upon the Disease in Fruit Trees' was appointed by the New South Wales (NSW) Legislative Assembly on 31 October 1865. The committee was unable to find a cause of the disease but concluded that it was associated with cold and wet soil, and poor drainage (Tunks 1866). Charles Moore, Director of the Botanic Gardens in Sydney, did a study tour of Spain and Portugal in 1867–68. In his official report he noted that the same bark decay disease was widespread in southern Europe and that sweet orange (*Citrus* × *aurantium* var. *sinensis* L.) trees grafted onto the bitter orange that grew around Seville in Spain ('Seville' orange; *Citrus* × *aurantium* L. var. *aurantium*) were resistant to the disease (Moore 1868).

James Pye from 'Rocky Hall Estate' (Fig. 2) in north Parramatta owned the largest citrus nursery in Australia during the mid-nineteenth century, and he was quick to start experimenting with 'Seville' orange rootstock, raising several thousand seedlings for grafting in 1871 (Anonymous 1871). However, from 1868 onwards, many experienced orange growers from the Sydney region questioned the wisdom of using 'Seville' orange as a rootstock, as they had experienced problems with plant longevity using this propagation

practice (Anonymous, 1868). Viruses were unknown as a lifeform until the 1890s, and tree decline was attributed to problems with transplanting nursery plants into the field because 'Seville' orange was considered to have a lack of fibre in the stems (Anonymous 1882). Quick decline of sweet orange and grapefruit (*Citrus* × *aurantium* var. *paradisi* ined.) grafted onto 'Seville' orange rootstocks is now known to be caused by citrus tristeza virus (CTV, species *Closterovirus tristezae*; Moreno et al. 2008), and the adverse experiences of the orange growers in Sydney provides indirect evidence for the early presence of this virus.

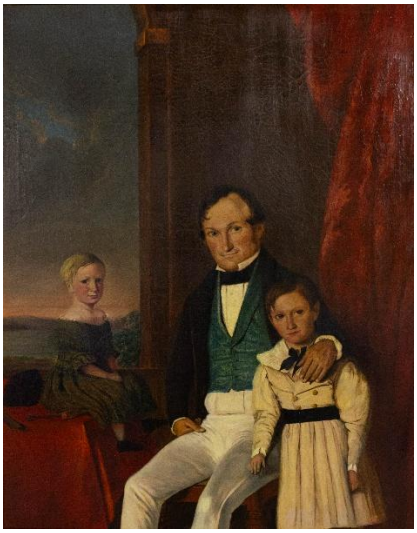
a.  b. 

Fig. 2. Portrait of James Pye and his two sons (panel a) and his orangery in Parramatta, New South Wales, before 1880 (panel b). Sources: City of Parramatta Cultural Collections / Artwork attributed to Joseph Backler, circa 1844, 2016.008, and https://mhnsw.au/collections/state-archives-collection/ Digital ID: 15344_a044_000040.

In 1887, 'irrigation colonies' were established at Mildura and Renmark on the Murray River by the Chaffey Brothers, Ltd (Peake and Venus 2019; Fig. 3). The Earl of Ranfurly from the County of Tyrone in Northern Ireland, and Gerald Percy Vivian Aylmer of Walford Castle in Darlington, England, were early investors in Mildura, and they purchased 160 acres (65 ha) from the Chaffey Brothers in June 1888. At the beginning of 1889, Ranfurly visited Riverside and other irrigation centres in California, where he secured plants of 'Ruby', 'Washington' navel and 'Dancy's Tangerine' orange (Anonymous 1891). These plants were taken back to Mildura, where they were multiplied in the nurseries of the Chaffey Brothers. In 1912, the Murrumbidgee Irrigation Area (MIA) was formally established, centred around Griffith and Leeton in NSW. The MIA was settled by returned soldiers from World War I (Fry 1985), and then by many Italian immigrants after soldier settlement wound down (Pich 1975).

Fig. 3. Planting citrus trees in the newly developed irrigation area 1890, Mildura VIC, Australia. Source: State Library of Victoria accession number H96.160/1915, photographer JW Lindt.

The industry expansions in the Murray-Darling River basin created strong demand for citrus planting material, particularly in NSW where an estimated 76% of the citrus plantings were located (Forsyth 2002). Given the short supply of buds, there was unregulated cutting of buds without regard for the health or trueness to type of the source trees, and these practises led to concerns about fruit quality and yield, varietal variations, and tree health.

Introduction of citrus propagation schemes

The need to regulate the citrus nursery industry in Australia came to the fore during the early 1920s. Settler blocks at Leeton and Griffith in the MIA were planted with navel trees that were propagated using budwood that was sourced from the Yanco Experiment Farm, a facility that was owned and operated by the NSW Department of Agriculture. The settlers were under the impression they had purchased an improved 'Washington' navel selection but later learnt, when the trees started to bear fruit, that the trees were mainly 'Thompson' navel interspersed with a scattering of other varieties (Anonymous 1924; 'Poncirus' 1928). 'Thompson' navel had a very poor reputation in the Sydney markets as when the fruit was left too long on the tree, the flesh of the fruit became coarse and dry and virtually unsaleable (Anonymous 1922). This situation caused widespread furore and calls for the state government to pay for the topworking of the trees to establish a new variety (Anonymous 1923). At the instigation of the MIA Research Bureau, a meeting was held on 1 December 1924, in which the issue of formulating a scheme for selection of citrus budwood from high class trees was discussed for the first time (Anonymous 1925a, b). Then, visits were made to Sydney and the central coast of NSW in 1925 to source budwood from superior trees in the old, established orchards, and the selected budwood was grafted onto rootstocks at the Irrigation Commission's nursery for breeding purposes.

In about January 1927, a conference was held between representatives of the NSW Department of Agriculture, the NSW Fruitgrowers' Federation, the Central Citrus Association, and the NSW Association of Nurserymen, culminating in a mutual decision to form the Cooperative Bud Selection Society, Ltd. This non-profit trading cooperative, registered under the *Co-operation, Community Settlement, and Credit Act 1923* (NSW), began operations on 8 June 1928 with the help of government start-up funding (Forsyth 1985). Directors of the Society were selected from each of the foundation member organisations, and the directorate hosted at the Fruitgrowers' Federation premises at Cathcart House, Castlereagh Street, Sydney (Anonymous 1928). Reginald James Benton, departmental instructor in citrus culture, assisted the Bud Selection Committee of the Society, and orchard

inspectors helped find suitable trees (Benton 1928). Highly productive and true-to-type trees on private orchards were systematically and regularly monitored for four years before the best trees were leased by the Society for budwood production (Benton 1934). In 1938, a certificate system was introduced to identify trees propagated using the Society's ratified budwood (Herrmann 2005).

The problem of erratic budwood quality was not confined to NSW. In December 1926, the Citrus Sectional Group Committee in Queensland requested that the Department of Agriculture and Stock prepare a regulation that made it 'compulsory for nurserymen to use only good seed and good budwood for propagation purposes' (Anonymous 1926). In Queensland, government officials took a greater role than industry in oversight of its scheme, which included 'paying more attention to the root system of the tree' (Anonymous 1934). In 1931, a citrus plot was established in the Gayndah district in central Queensland by the Department to plant the best trees in the state for budwood selection (Anonymous 1931; Barnes and Prest 1938). In December 1933, new regulations were issued by the Minister of Agriculture, which divided the varieties into two categories. Category A contained the most economically important varieties such as 'Washington' navel orange and 'Emperor' mandarin (*Citrus reticulata* Blanco) (Barnes and Prest 1938). 'A' grade varieties could only be sold in Queensland on the condition that departmental staff had supervised collection of the budwood to ensure health, vigour, productivity and fruit quality of the maternal tree. The same condition applied to the collection of seed for the propagation of rootstock seedlings. Fears raised by NSW nurserymen that these new regulations could block interstate trade led to ministerial discussions to harmonise regulations across Australia (Anonymous 1934). As early as 1929, there were calls for creation of a federal bud selection committee (Penang 1929).

The State Viticultural Nursery at Narara, located to the north of Gosford on the central coast of NSW, played an important role in the supply of high quality citrus budwood in the early years. This nursery was established in August 1913 with the express purpose of propagating grapevines on phylloxera-resistant rootstocks (Anonymous 1914). However, towards the end of the 1920s, the demand for grapevine planting material declined sharply, and the focus of the nursery shifted to plant breeding work in citrus, pome, and stone fruits (Anonymous 1929). Recording the performance of citrus trees at Narara commenced in 1926 (Anonymous 1933). In 1929, 1,000 selected rough lemon (*Citrus* × *limonia* var. *jambhiri* ined.) seedlings were grafted with buds from highly productive trees of 'Washington' navel and 'Valencia Late' orange, 'Eureka' lemon, and a selection of grapefruit varieties, and over 1931–32, an additional 3,500 citrus plants were propagated (Anonymous 1933). An experimental block of citrus was established, and the trees monitored to test the stability of varieties, and to propagate new plants for use in varietal trials in other parts of the state such as Leeton and Griffith. Additionally, small volumes of several varieties on different rootstocks were distributed to commercial citrus growers in the main citrus production areas. In 1947, approval was given by the NSW Government for the creation of a citrus research facility, and in 1948, two more properties were purchased at Somersby, a 239-acre property called 'Tenambi' and a second 35-acre property. Together with Narara, these properties became part of the 'Gosford Citrus Experiment Station' (Anonymous 1947; Anonymous 1948; Anonymous 1950).

Further formalisation of the budwood scheme came after regulations (the 'Horticultural Stock and Nursery Regulations') were introduced in 1973 under authority of the *Horticultural Stock and Nurseries Act 1969* (NSW). These regulations compelled sellers of proclaimed nursery stock to label plants with (i) the name and address of the nurseryman; (ii) the kind and variety of scion and the kind of rootstock, if used; (iii) the name and address of the seller, where the seller is not the propagator; and (iv) the number of pieces of stock to which the label relates

(Crawford 1973). Furthermore, citrus nurseries had to declare whether the plants were 'Propagated from approved material obtained from the NSW Horticultural Propagation Co-operative Society Limited' or 'not propagated from approved material'. These regulations came into effect in 1974 after citrus was declared a proclaimed nursery stock (Crawford 1974). In 1975, the Cooperative Bud Selection Society accepted responsibility for the supply of propagation material of citrus and other commodities and became the NSW Horticultural Propagation Society (NSW HPS). In 1976, the NSW HPS agreed to supply citrus budwood to Victoria.

The impact of plant disease on evolution of the citrus industry

After three unusually wet winters in the MIA, a disease epidemic was observed in 1941 across navel and Valencia oranges that were grafted on rough lemon or sweet orange rootstocks. Drs Bertram Thomas Dickson and James Arthur Prescott from the Council of Scientific and Industrial Research presented a report on the problem and they estimated that 19.4–40.0% of navel orange trees in the Leeton area suffered severe decline (Glover 1941). Blame was apportioned to the Irrigation Commission for originally establishing orchards on land unfit for horticulture, to defective drainage and run-off from rice paddocks, and to the influence of waterlogged sand-drifts. The newly appointed citrus pathologist in the NSW Department of Agriculture, Lillian Fraser, began working on the problem and she determined that the disease was caused by *Phytophthora citrophthora* (Fraser 1942; Fig. 4).

a.  b. 

Fig. 4. Images from the Phytophthora epidemic in citrus during the early 1940s in the Murrumbidgee Irrigation Area, New South Wales. Panel (a) 12-year-old grapefruit on rough lemon rootstock showing severe decline (note the healthy tree on 'Seville' orange rootstock in the background); panel (b), root decay observed on a rough lemon rootstock. Source: NSW DPIRD, photographers panel (a) LR Fraser and panel (b) unknown.

RJ Benton had been studying trifoliate (*Citrus* (syn. *Poncirus*) *trifoliata* L.) rootstock for many years as he had an interest in the effect it had on the juice content of the fruit (Anonymous 1939; Benton 1944). He observed that trifoliate rootstock gave 'splendid results' when the ground was overly wet, whereas rough lemon rootstock failed (Anonymous

1943). However, trifoliate had a worldwide reputation of being an unreliable rootstock due to variable growth rates of the scion, with severe dwarfing sometimes observed, most obviously on ‘Washington’ navel orange and grapefruit than with Valencia orange and mandarin (Fraser and Broadbent 1980; Fig. 5). Initially this problem was thought to be due to graft incompatibility.

a.  b.  c. 

Fig. 5. ‘Washington’ navel trees grafted onto trifoliate rootstock showing severe (panel a) and moderate (panel b) stunting, contrasted with an asymptomatic tree of the same type (panel c). All trees were 33 years-old at the time the photographs were taken, in 1943, and were growing at Kyabram, Victoria. Source: NSW DPIRD, photographer LR Fraser.

In 1943, a ‘Trifoliata Improvement Committee’ (later renamed the ‘Citrus Improvement Committee’) was formed, comprising Benton, Fraser, and two other departmental fruit specialists, to do statewide surveys of trifoliate stocks to identify superior types. It was observed that below the graft union of severely dwarfed trees, the butt was clothed with hard, persistent scales and some large trees also showed scaling (Fig. 6), giving rise to the name ‘scaly butt’ for the disorder (Benton 1944; Fraser and Broadbent 1980). The importance of scion selection in development of scaly butt first became apparent when severely dwarfed ‘Washington’ navel trees in the field were inarched with trifoliate seedlings, and scaly bark symptoms developed on the seedlings after about 4–5 years (Benton et al. 1949, 1950). Follow up experiments provided strong evidence that the disorder was caused by a graft-transmissible pathogen, which was thought to be a virus at the time (Fraser and Levitt 1957), but three decades later was revealed to be citrus exocortis viroid (CEVd, species *Pospiviroid exocortiscitri*; Visvader et al. 1982). When buds from diseased trees were grafted onto trifoliate seedlings or used to inoculate healthy trees, it sometimes took six to eight years for the disease symptoms to appear, and the severity of scaling was variable, leading to the hypothesis that different strains of the pathogen existed (Fraser and Levitt 1957).

a.  b. 

Fig. 6. Scaly butt symptoms on a 3-year-old Washington navel tree on trifoliate rootstock, Springfield, New South Wales in 1948 (panel a) and on a 28-year-old Bellamy navel tree on trifoliate rootstock, Dareton, New South Wales in 2017 which was inoculated with citrus exocortis viroid as part of a field trial (panel b). Source: NSW DPIRD, photographers panel (a) LR Fraser and panel (b) NJ Donovan.

The emergence of scaly butt meant that candidate trees for budwood collection could only be properly assessed for health status after observation of performance of the tree on trifoliate rootstock for at least 8–10 years (Broadbent and Fraser 1976). This new selection criterion created a shortage of budwood source trees. To address this shortage, and to help overcome difficulties in supplying smaller orders, the Parent Tree Registration Scheme was established in 1953 (Anonymous 1953; Anonymous 1954). This scheme made more parent trees on private properties available for supply of certified budwood, and applications to have trees registered under the scheme could be initiated by either the grower or the nurseryman. Registrations were granted subject to annual inspections and payment of a fee to cover expenses. The scheme provided two classes of registration: trees that were free from scaly butt symptoms, and trees on rootstocks other than trifoliate that could not be guaranteed to be free of the disease (Broadbent and Dephoff 1992). Trees nominated for inclusion in the scheme were screened for citrus psorosis virus (CPsV, species *Ophiovirus citri*) using sweet orange seedlings as indicator plants, and for xyloporosis (cachexia strains of hop stunt viroid HSVd, species *Hostuviroid impedihumuli*) using ‘Orlando’ tangelo seedlings (Broadbent and Fraser 1976). The CPsV testing was done in the glasshouse, but the xyloporosis testing was done in field plots at the citrus experiment station in Somersby.

Apart from scaly butt, budwood supply was affected when the incidence of Australian citrus dieback increased in the early 1970s. This condition was first recorded in 1942, sporadically up to 1968 and rarely since those peak years, with the causal agent yet to be identified (Broadbent et al. 1976).

CTV was slow to establish in the Murray and Murrumbidgee irrigation areas, and 'Seville' orange rootstock had gained local popularity due to its resistance to Phytophthora gummosis and root decay (Fraser 1958). Several excellent orchards were established using this rootstock. However, quick decline of sweet orange on 'Seville' orange rootstock was observed for the first time in the Mildura district in 1941, and the disease quickly spread in the pursuing years (Baulch 1948; Fig. 7a). Also, the epidemic of CTV extended to grapefruit, which was affected by a new disease in the late 1930s, variously referred to as stunt bush, dimple, or stem-pitting (Anonymous 1950; Anonymous 1951; Fig. 7b). Productive trees survived in grapefruit orchards where other trees had succumbed, and biological indexing using West Indian lime indicator plants suggested that these trees were infected with a mild strain of CTV (Fraser 1958). Field trials were established at Somersby and Dareton, and grapefruit trees inoculated with the mild strain were shown to avoid development of more severe stem-pitting disease over an observation period of more than 30 years (Broadbent et al. 1991). A CTV isolate, labelled PB61, was recovered from a single, productive, 'Marsh' grapefruit tree in an orchard in Griffith, and this mild isolate is commercially used today to protect trees against severe stem pitting isolates (Fraser and Broadbent 1979; Jackson et al. 2026).

a.  b. 

Fig. 7. Two diseases caused by citrus tristeza virus in Australia: quick decline of sweet orange on Seville orange rootstock (panel a) and grapefruit stem pitting (panel b). Source: NSW DPIRD, photographer(s) panel (a) unknown and panel (b) NJ Donovan.

Until the end of the twentieth century, stem pitting caused by CTV was recorded only in grapefruit and rarely in 'Seville' orange and 'Bengal' citron in Australia (Fraser 1958). However, in 1990, stem pitting of sweet orange was found in 'Washington' navel orange and 'Ortanique' tangor trees in the Central Burnett area of Queensland (Broadbent et al. 1992). This discovery quickly led to the introduction of domestic quarantine regulations that prohibited the export of all citrus plants and plant parts out of Queensland, except for fruit and rootstock seed (Armstrong 1992). Attempts to find a mild strain of CTV suitable for commercial use in cross-protection against orange stem pitting were unsuccessful (Zhou et al. 2002).

Creation of Auscitrus

A problem with the Parent Tree Registration Scheme was that when a property changed hands, consent to collect budwood from a registered tree in the orchard had to be freshly granted by the new owner, and this was not always provided (Broadbent and Fraser 1976). Concerns over budwood supply and growers not wanting to lose fruiting wood when buds

were removed from the trees, led to the planting of budwood multiplication blocks at the NSW Department of Agriculture research station at Dareton in the Mildura irrigation area in 1967, with the last buds cut from trees at Narara in 1973.

From 1971 to 1991, the Fruit Variety Foundation (FVF) was the government program responsible for maintaining high health status and true-to-type trees of selected citrus varieties and other horticultural commodities such as pome and stone fruit, grape and avocado. The foundation block of citrus was established at the Department of Agriculture Dareton Research Station in 1977 (Forsyth 1985), and trees were maintained in an insect-proof greenhouse at the Department of Agriculture's Biological and Chemical Research Institute in Rydalmere in Sydney. In 1997, trees were moved from Rydalmere to insect-proof screenhouses at the Department of Agriculture's Elizabeth Macarthur Agricultural Institute (EMAI) at Menangle in Sydney. Prior to entry to the FVF, clones (as opposed to varieties) were pathogen tested by biological indexing with symptom expression monitored in the inoculated indicator plants for all important viruses known to infect that species (Smith 1983). The collection of virus-tested and true-to-type mother trees became known as the Citrus Foundation Repository.

In 1986, the ability to import new citrus germplasm was re-established after it had been banned for more than 20 years. This expanded the industry from largely Valencia juicing oranges to include fresh fruit for domestic and export markets and provided an avenue for niche fruit varieties. It also enabled the importation of culturally significant varieties to reduce the risk of illegal imports.

In 1991, government funding was withdrawn from the FVF. Subsequently, the Australian Citrus Improvement Association (ACIA) was formed to coordinate crop improvement and multiplication. This involved deciding which cultivars to import, virus screening, and evaluation of scion and rootstock varieties. In 1993, the Australian Citrus Propagation Association Inc. (ACPA) formed, becoming the main supplier of budwood to all Australian states, although South Australia continued to serve as a supplementary source of rootstock seed and budwood, tested by ACPA. On the 31 December 2000, the *Horticultural Stock and Nurseries Act 1969* (NSW) was repealed, and most regulations pertaining to the supply of nursery trees abolished. However, the government did retain powers to make orders and proclamations to prevent the spread of pests and diseases under the *Plant Diseases Act* 1924 (NSW). Also, the South Australian arm ceased budwood supply due to limited capacity to test the trees.

In 2001, the ACPA and ACIA merged and began trading as "Auscitrus" to maintain the foundation trees in the Citrus Repository Program and to continue to supply high health status and true-to-type budwood and rootstock seed to industry from budwood multiplication trees (daughter trees of the foundation trees). In 2006, Auscitrus purchased their own property and established an independent facility and plantings near Dareton, not far from the Dareton Research Station. They continued to operate from both sites during a changeover period, but from 2016, the bulk of the budwood began to be sourced from the Auscitrus property. In 2025, Auscitrus stopped sourcing material from trees on departmental land and now operates autonomously. However, the NSW Government provides an independent pathogen diagnostic and elimination service at EMAI.

In the current system, Australian and imported selections of new citrus varieties are tested and demonstrated to be free of graft-transmissible pathogens (endemic and exotic) before release to industry. Pathogen testing and elimination of imported varieties is performed by the post-entry quarantine arm of the federal government and this process for Australian selections is undertaken at EMAI by Auscitrus. Originally, pathogen elimination was achieved by nucellar selection, but this practice has been replaced by shoot-tip grafting, which is a more

effective technique for clean-up of germplasm (Navarro et al. 1975). Prior to grafting, the source trees may also be heat-treated to reduce the load of pathogens in the shoot tips. After treatment, foundation trees of new varieties are placed in the biosecure environment of the National Citrus Repository. At least one tree of each variety is held in screen houses in two locations; the Auscitrus property at Dareton (in the Sunraysia citrus growing region) and at EMAI located on the outskirts of southwestern Sydney (not in a citrus growing region). The repository contains both public and privately owned citrus scion and rootstock varieties from imported and local sources.

Budwood multiplication trees and rootstock seed supply trees are propagated from high health foundation trees, and these daughter trees are used to supply propagation material to industry. The National Citrus Repository house at EMAI also serves as an offshore plant quarantine facility for New Zealand (NZ), accredited by the NZ Ministry of Primary Industries. In addition to high-health status foundation trees, daughter trees of selected varieties are inoculated with the mild CTV isolate, PB61, to protect against stem pitting isolates of CTV. Grapefruit budwood multiplication trees are propagated from the inoculated repository trees so that Auscitrus supplies inoculated grapefruit budwood to industry.

Foundation, budwood and rootstock seed source trees are regularly tested for graft-transmissible citrus pathogens as per a schedule based on the risk of infection and transmission, and the potential economic impact of pathogen infection. Endemic graft-transmissible pathogens of citrus in Australia include CTV, citrus leaf blotch virus (species *Citrivirus citri*; Donovan et al. 2018), apple stem grooving virus (syn. citrus tatter leaf virus; species *Capillovirus mali*; Fraser and Broadbent 1979), CPsV (Donovan et al. 2025), citrus virus A (species *Coguvirus eburi*; Donovan et al. 2022), citrus concave gum-associated virus (species *Coguvirus citri*; Donovan et al. 2022), citrus vein enation virus (*Enamovirus CVEV*; Fraser 1958), citrus variegation virus (*Ilarvirus CVV*; Donovan et al. 2018), citrus-associated rhabdovirus (species *Betacytorhabdovirus caricae*; Chambers et al. 2025a), CEVd, citrus bent leaf viroid (species *Apscaviroid curvifoliumcitri*), hop stunt viroid, citrus dwarfing viroid (species *Apscaviroid nanocitri*) (Gillings et al. 1991), and citrus viroids V (species *Apscaviroid epsiloncitri*), VI (species *Apscaviroid zetacitri*) (Chambers et al. 2020) and VII (species *Apscaviroid etacitri*) (Chambers et al. 2018). Citrus bark cracking viroid (species *Cocaviroid rimocitri*) was reported previously (Osman et al. 2017) but the viroid was not detected in recent surveys of nearly 700 citrus trees in Australian orchards and gardens (Chambers et al. 2025b). All these citrus pathogens can be spread in infected budwood but only CTV can be transmitted by insect vectors.

All budwood is cut to order, trimmed of leaves in the field, sealed in plastic bags and stored at 8–10 ºC until dispatch, usually within one week. Seeds are mechanically extracted, hot water treated at 52 ºC for ten minutes, cooled, treated in sodium hypochlorite 0.5% ai for two minutes, then rinsed. The seed is dried, treated with fungicide, then stored in plastic bags at 2 ºC for up to several months.

Auscitrus commercial funding is obtained from the sale of rootstock seed and budwood, and the handling of private varieties in the Australian Citrus Variety Testing Program. This includes eliminating pathogens from new Australian selections so they can be commercialised and maintaining foundation trees in the repository. Industry funding supports the maintenance and testing of foundation trees of publicly owned citrus varieties in the repository. In preparation for an incursion of other graft-transmissible pathogens vectored by insects, such as the devastating bacterial disease huánglóngbìng (HLB), new greenhouses were constructed. This co-investment by Auscitrus and industry has allowed budwood production to shift from field trees to screen-protected, potted trees (Fig. 8).

At the 2024 Annual General Meeting of the Australian Citrus Propagation Association, members voted unanimously to transition the Association from an Incorporated NSW Association to a Company Limited by Guarantee. Auscitrus Limited was registered on 26 March 2025 and the Association was subsequently cancelled, making Auscitrus a truly national organisation. The use of high health status propagation material from Auscitrus is not mandatory but there is consensus to move in this direction to reduce disease impact in the event of an incursion of HLB. A Nursery Stock Standard is under development that will include recognition of the use of budwood and rootstock seed from pathogen-tested sources.

Fig. 8. Aerial view of the Auscitrus property at Dareton, New South Wales, photographed in August 2025. Photographer: D Arnold.

Supporting research

Industry and government have worked collectively in Australia from the inception of the budwood scheme, facilitated by structured committees and funding pathways. There has been a consistent focus on citrus varietal improvement and germplasm management driven by disease challenges. The Trifoliata Improvement Committee evolved into the Citrus Improvement Committee in 1952 as its scope was expanded to include other disorders as well as scaly butt. The Citrus Research Committee formed in 1979 to continue support for horticultural evaluation and virus indexing of citrus varieties (Forsyth 2002). The research model evolved with the introduction of levies, collected from the citrus growers and supported by co-contributions from the federal government, to fund research and extension activities which align with government and industry priorities.

Australia also has a long history of working on international aid projects to support on and offshore citrus research. Whilst the focus of these projects, predominantly in developing nations across Asia and the Pacific, is on poverty alleviation, the knowledge exchange facilitates biosecurity preparedness and industry development in Australia as well as in the partner countries. A consistent theme of this work has been to promote the use of propagation material from health-tested and true-to-type sources.

Collaborative activities continue in the areas of diagnostics and surveillance, germplasm management, public education, policy and strategy. In addition to the support received for the maintenance and testing of public varieties in the National Citrus Repository, work is

continuing to better define and raise community awareness of the smuggling risks and ensure healthy, true-to-type budwood is available for culturally significant varieties. Research programs are ongoing to evaluate the field performance of new commercial citrus scion and rootstock varieties, including assessment of trueness to type. An established diagnostic program continues to develop new or validate existing published pathogen detection assays. This ensures Auscitrus and national diagnostic laboratories are using the best methods available, giving greater confidence in the health status of propagation material. Long running government surveillance programs, such as the Northern Australia Quarantine Strategy, are complemented by industry-led surveillance and awareness campaigns, such as CitrusWatch. Australia heavily invests in building and improving our plant biosecurity framework, including quarantine and preparedness activities aiming to prevent the entry and minimise the spread of high priority pests, such as the Asiatic citrus psyllid (*Diaphorina citri*) and '*Candidatus* Liberibacter asiaticus' associated with HLB.

Conclusions

Plant diseases have an immediate impact on crop yield and the cost of production, but in the long term, can also drive industry change. The impetus for development of a citrus budwood and seed scheme in Australia was a desire to ensure that planting material was uniform, productive, and guaranteed to be the variety it was claimed to be, but at the same time, high health status planting material was selected even before many pathogens had been identified. A strong partnership between industry and government, utilising the latest science, local experience and innovative thinking, has led to the establishment and evolution of the Auscitrus propagation scheme which can trace its beginnings to 100 years ago. The very early adoption of a clean planting material scheme has ensured that the Australian citrus industry has one of the highest health statuses in the world.

Acknowledgements

The authors gratefully acknowledge funding from Hort Innovation, using the citrus industry research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture. Bernie Dominiak and Krista Plett reviewed a pre-submission version of the manuscript.

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