Breeding with Indigenous *Citrus* Species©

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INTRODUCTION

Genetic variability is the foundation for breeding new cultivars. Wild relatives and undomesticated types of exploited crop plants are often extremely important sources of genetic variability and Zagaja (1983) lists examples where these have been of unquestionable value in fruit improvement.

Although the history of planned genetic improvement of cultivated citrus is short, wild types and relatives have been valuable in breeding new cultivars, particularly rootstocks. Carrizo and Troyer citranges are important rootstocks selected from a cross between *Citrus sinensis* 'Washington' × *Poncirus trifoliata*. Similarly, Swingle citrumelo, another rootstock, was selected from hybrids of *Citrus* ×*paradisi* (grapefruit) × *P. trifoliata*.

Australian *Citrus* species still exist in their natural habitat. This paper describes plant-breeding activities in which *Citrus* species indigenous to Australia have been used to develop unique, new cultivars.

AUSTRALIA'S INDIGENOUS *CITRUS*

The genus *Citrus* was classified in the tribe *Citreae* within the sub-family *Aurantioideae* as part of the family *Rutaceae* by Swingle and Reece (1967). Swingle and Reece (1967) included five other genera, viz. *Poncirus*, *Fortunella*, *Eremocitrus*, *Microcitrus*, and *Clymenia* within the *Citreae,* which they considered as the true citrus-types. The genera names *Eremocitrus* and *Microcitrus* survived until Mabberley (1998) argued that they should be re-classified as *Citrus,* which is now a widely held opinion and will be used in this paper. Australia is the unique home to *Citrus glauca* (syn. *Eremocitrus glauca*), desert lime or desert kumquat; *C. australasica* (syn. *Microcitrus australasica*), finger lime; *C. australis*, Australian round lime or dooja; *C. inodora*, Russell River lime; *C. maideniana*, Maiden's Australian wild lime; and *C. garrawayae*, Mount White lime (Swingle and Reece, 1967; Armstrong, 1975). Although *Citrus gracilis,* Humpty Doo lime, is also considered indigenous to Australia, *C. glauca, C. australasica*, and *C. australis* have been of greatest interest to citrus researchers and breeders from their potential as new rootstocks (Bitters et al., 1964) and as sources of valuable genetic characteristics (e.g., Barrett, 1990). Although first collected in 1971 by J. McKean near Humpty Doo, NT, little is known scientifically about *C. gracilis*. It is a thorny tree up to 4–6 m high and grows in eucalypt woodlands on sandy or gravely soils (Mabberley, 1998). Its fruits are of interest because of their large size (up to 8 cm in diameter) in comparison to other Australian *Citrus* species.

Distributed in Queensland, New South Wales, and South Australia (Sykes, 1997), *Citrus glauca* is the most pronounced xerophyte in the Aurantiodeae. Following germination and emergence, desert lime seedlings develop extensive root systems before much shoot growth occurs allowing them to withstand severe droughts and hot dry winds. When dormant, it can survive temperatures as low as -14 °C (Young et al., 1983) and this cold hardiness is transmitted to its sexual progeny (Yelon-

sky, 1978). It is considered less susceptible to salt and boron than related genera (Swingle and Reece, 1967; Bitters et al., 1964). Goell (1969) reported that lemon scions grafted to the desert lime tolerated salinity, although they had high leaf chloride concentrations.

The desert lime can be grafted to citrus and vice versa (Bitters et al., 1964). Hearn et al. (1974) reported it highly resistant to root rot caused by *Phytophthora parasitica*. Its fruits mature quickly and drop from the tree 10–12 weeks after flowering, and Barrett (1981) reported that this characteristic was transmitted to its hybrids. Desert limes are acid yet pleasantly flavoured and, as Riley (1982) pointed out, less bitter than many acid fruits of other citrus relatives.

The seven species of *Citrus* classified by Swingle and Reece (1967) as *Microcitrus* are confined generally to rainforests in Australia and southeastern New Guinea (Armstrong, 1975). The five Australian species are distributed from Cape York in far north Queensland to coastal regions of southeastern Queensland and northern NSW. Two of the Australian species, C. *maideniana* and *C. garrawayae*, have a very narrow habitat range whereas *C. australis* and *C. australasica* are more widely distributed (Armstrong, 1975). Pigmented forms of the finger lime are found in SE Queensland. *Citrus warburgiana* (syn. *Microcitrus warburgiana*) is found in SE New Guinea (Swingle and Reece, 1967) and *C. papuana*, which is possibly a variant of *C. warburgiana*, was described by Winters (1976). *Citrus papuana* is of interest to citrus breeders due to its short juvenile period, which may be transmitted to hybrids (Barrett, 1983).

Finger and round limes graft readily with other *Citrus* types (Bitters et al., 1964) and they may be genetic sources of drought tolerance, nematode resistance, tolerance of low soil fertility, and resistance to root rot caused by *P. citrophthora* (Barrett, 1983, Broadbent, 1969, Bitters et al., 1964). The dwarf, shrubby habit of finger and round lime trees suggests they have potential as a source of dwarfing in breeding programs, while forms with red and pink fruits have attracted breeders' attention for developing new pigmented cultivars.

NEW CITRUS CULTIVARS BASED ON AUSTRALIAN *CITRUS* SPECIES

New cultivars involving Australian *Citrus* species have arisen essentially in one of two ways, namely selection amongst specimens collected as propagules from their habitat, and selection of seedlings either from open-pollinated populations or hybrid families from controlled crosses.

Cultivars Selected from Propagules Collected from the Wild. Historically Australian native limes have been harvested from the wild as a food source. From this, they have been seen as candidates for domestication in their own right and cultivars have been nominated and released after selection from material collected from their habitat. For example, new cultivars of finger lime have been selected, propagated, and commercialised. *Citrus australasica* var. *sanguinea* 'Rainforest Pearl'[PBR] (Birmingham, 2002) is one finger lime cultivar and another group includes highly pigmented forms with names such as 'Purple Viola', 'Pink Ice', and 'Jali Red' developed by the Australian Finger Lime Company (Anon, 2005).

Citrus glauca 'Australian Outback'[PBR] (Sykes, 2002) was identified from an arboretum-based collection of desert lime variants (Sykes, 1997). Initially chosen for fruit processing qualities, 'Australian Outback' was also selected for its ease of

propagation, its high yields of larger than average fruits and because its thornless, upright habit makes it suitable as a plantation or orchard tree. It was released to the developing native foods industry to give consistent production of quality desert limes and reduce dependence on wild harvested product.

Cultivars Selected from Hybrid Populations. The use of native *Citrus* in breeding rootstocks and scion cultivars by hybridization has been investigated by CSIRO. Species used have been *C. glauca*, *C. australis, C. australasica*, and the so-called Sydney hybrid (*C. australis* × *C. australasica),* which has been given species status (*C.* ×*virgata*) by some authors (e.g., Hume, 1957). It was anticipated that Australian native limes would benefit rootstock breeding by conferring tolerance to cold, salt, drought, and nematodes, resistance to *Phytophthora* species, as well as dwarf-inducement, to new hybrids. In breeding scions, it was anticipated that native limes would introduce short juvenile time, fruit pigmentation and reduced maturation time, as well as cold tolerance and improved water-use efficiency based on their reported drought tolerance.

Over a period of time, crosses have been made between indigenous *Citrus* species and other *Citrus* species as well as with *Poncirus trifoliata*. In addition, open-pollinated seedlings from non-indigenous *Citrus* seed parents but with obvious *C. australis* and *C. australasica* characteristics have been retained for evaluation. CSIRO now has a collection of hybrids from first and second generation crosses with *C. glauca, C.australis*, and *C. australasica*. In conducting crosses, success has been greater with *C. australis* and *C. australasica*, than with *C. glauca.* Although hybrids have been obtained using the desert lime as both a male and a female parent, there have been problems growing *C. glauca* hybrids on their own roots and grafting them to rootstocks has often been necessary to maintain these hybrids beyond the young seedling stage.

In addition to generating new hybrids, CSIRO also introduced open-pollinated seeds collected from hybrids produced in the U.S.A. Open-pollinated seeds of *C.* 'Faustrimedin' [*Citrus australasica* ×(*Fortunella* sp. × *Citrus reticulata* 'Calamondin')] as well as *C.* 'Eremolemon' (*Citrus glauca* × *Citrus limon* 'Meyer lemon') (see Swingle and Reece, 1967), were obtained from the University of California. Seeds of *C. glauca* hybrids were also received from the United States Department of Agriculture, Florida.

This collection of hybrid material is a genetic resource held specifically for breeding. In making crosses, a primary aim has been to use the progeny as genetic bridges between *C. glauca, C. australis*, and *C. australasica* on the one hand and introduced *Citrus* on the other. To facilitate this, monoembryonic parents were used to increase the chances of obtaining monoembryonic hybrids, which would in turn make them easier to use as parents for introgressing native *Citrus* characteristics into breeding populations. Until the late 1980s, this was the purpose of these crosses and introductions.

In the late 1980s and early 1990s the native food industry started to gain momentum in Australia and *Citrus* was one of the fruits in which the industry took particular interest. An approach by the industry stimulated CSIRO to look at its collection of native limes and hybrids as a resource for this industry. At the same time that the *Citrus glauca* 'Australian Outback'^{PBR} was selected and released, *Citrus* hybrid 'Australian Blood'^{PBR} and *Citrus* hybrid 'Australian Sunrise'^{PBR} (Sykes, 2002) were identified from CSIRO's collection of hybrid material.

The 'Australian Blood' was selected from a progeny of open-pollinated seedlings from a zygotic seedling of *C.* ×*limonia*, Rangpur lime. Seedlings in this progeny displayed finger lime characteristics and, since their maternal Rangpur lime seedling parent was located next to a row of finger lime trees, it was assumed that *C. australasica* was the pollen parent of the 'Australian Blood' (Sykes, 2002). Similarly, 'Australian Sunrise' was selected from seedlings grown from open-pollinated seeds of a faustrimedin hybrid introduced from the University of California (Sykes, 2002).

END NOTE

The use of Australia's indigenous *Citrus* species described here provides two valuable lessons. The first is that wild species of fruit crops can still be considered as candidates for domestication in their own right. The selection of new cultivars of desert and finger limes from propagules collected from the wild clearly supports this idea discussed over 20 years ago by Zagaja (1983). The second lesson highlights the need to conserve and maintain wild relatives of cultivated fruit species in arboreta. While their pedigrees show that the 'Australian Blood' and 'Australian Sunrise' cultivars are not strictly native plants, they have been used by the Australian native food industry to produce fruits for processing and fresh produce. As such, the potential of using Australia's indigenous *Citrus* in breeding novel fruit types has been demonstrated. Hybrids from second generation crosses involving indigenous *Citrus*, which produce fruits larger than the 'Australian Blood' or 'Australian Sunrise' cultivars yet incorporate similar characteristics, suggest that cultivars with greater novelty and thus ability to capture market attention are possible.

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Auscitrus — The Australian Citrus Budwood Scheme©

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PRESENT STRUCTURE OF AUSCITRUS

Auscitrus is the trading name of the Australian Citrus Propagation Association Incorporated (ACPA). The ACPA is comprised of ten citrus and nursery industry organisations. Representatives from each of these organisations are nominated as representatives on the Auscitrus board. Auscitrus is an industry owned and operated, not-for-profit organisation. The seed and budwood scheme is entirely self-funding through seed and budwood sales. Cultivar importation, cultivar evaluation, and the maintenance of foundation trees, are funded by industry grants through Horticulture Australia Limited.

Currently Auscitrus employ a full time manager, part time administration officer, full time scientific officer (indexing), full time casual indexing assistant, full time bud cutter, full time casual bud cutter/nursery hand, plus one or two seasonal casual staff for bud cutting and fruit harvest. New South Wales Department of Primary Industries (NSW DPI) research scientists on behalf of Auscitrus carry out horticultural evaluation.

HISTORY OF AUSCITRUS

1927. Fruit Industry conference recommendation to establish a controlling body for the buying and selling of selected citrus budwood.

1928. Cooperative Bud Selection Society formed — startup funding from government grant of £1500. First selected trees established at Narara Research Station, Gosford.

1938. "Certificate from Nurseries" introduced to identify trees propagated from Bud Selection Society's budwood.

1941. *Phytophthora citrophthora* discovered to be cause of extensive tree losses in Australian orchards. Demand for trees on highly resistant *Poncirus trifoliata* stock increased.

1947. Scaly butt (exocortis viroid) recognised as bud transmitted disease affecting *P. trifoliata.*

1952. Australian Citrus Improvement Association (ACIA) formed with objectives including virus screening/indexing, breeding, selection, improvement, and evaluation of rootstocks and scions.