

# *Citrus wakonai* P.I.Forst. & M.W.Sm. (Rutaceae), a new species from Goodenough Island, Papua New Guinea

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## Summary

Forster, P.I. & Smith, M.W. (2010). *Citrus wakonai* P.I.Forst. & M.W.Sm. (Rutaceae), a new species from Goodenough Island, Papua New Guinea. *Austrobaileya* 8(2): 133–138. A new species of *Citrus* is described and illustrated and its putative relationships discussed. *Citrus wakonai* is known from Goodenough Island, Milne Bay Archipelago in Papua New Guinea where it is a small understorey tree up to 6 m tall. It provides small edible fruit, but currently lacks potential as a source of new rootstocks or germplasm for the citrus industry due to viral susceptibility.

Key Words: Rutaceae, *Citrus*, *Citrus australasica*, *Citrus garrawayi*, *Citrus wakonai*, *Citrus warburgiana*, Papua New Guinea flora, taxonomy, nomenclature, new species

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## Introduction

The genus *Citrus* L. occurs in Asia (China), Malesia (including Papua New Guinea [PNG]) and Australia and is now considered to incorporate the genera *Clymenia* Swingle, *Eremocitrus* Swingle, *Feroniella* Swingle, *Fortunella* Swingle, *Microcitrus* Swingle, *Oxanthera* Montrouz. and *Poncirus* Raf. (Bayer *et al.* 2009). Eight or nine species have been recognised for the combined land masses of New Guinea (four or five species when species formerly classified in *Clymenia* and *Microcitrus* are excluded) and Australia (six species when species formerly classified in *Eremocitrus* and *Microcitrus* are included). Most of these taxa have been considered endemic to one land mass or the other, with only *C. garrawayi* F.M.Bailey considered as shared between the two (Forster 1991; Mabberley 1998).

The 1991 identification of *Citrus garrawayi* from fragmentary PNG material collected by Len Brass in 1953 on the 4<sup>th</sup> Archbold Expedition and held at the Queensland Herbarium, was primarily based upon similarities in leaf morphology between

this material and Australian collections of that species. This same material had previously been erroneously referred by Stone (1985) to *C. australasica* F.Muell., a species restricted to south-eastern Queensland and north-eastern New South Wales. The habitats where Brass collected his material on Goodenough Island in the Milne Bay Archipelago are dissimilar to those in Queensland where *C. garrawayi* occurs due to greater elevation and different geology and vegetation community composition (see Brass [1956] for a general vegetation description). Hence, collection of complete material from Goodenough Island was considered a priority, not only to resolve its taxonomic identity, but to trial this genetic diversity for a *Citrus* breeding and rootstock development program at Bundaberg.

In September 2000 Malcolm Smith visited Goodenough Island, and using Brass's original field notes (held in the Queensland Herbarium archives) and the assistance of local villagers from Wakonai was able to relocate the *Citrus* populations collected by Brass. Several plants were located with ripe fruit and fresh seed. Some of these seed were imported into Australia and grown to maturity at the Bundaberg Research Station. Examination

of live material in habitat, together with that grown in Australian cultivation has revealed a number of morphological differences between this and material of other *Citrus* species from Australia and PNG. These populations from Goodenough Island are described here as the new species *Citrus wakonai*.

### Materials and methods

The data and description in this paper are based on live and subsequent dried or pickled material of Australian and PNG *Citrus* species held at the Queensland Herbarium (BRI). Information on Brass holdings of PNG *Citrus* in the Harvard University herbaria was provided by that institution in March 2007. Length and width dimensions are indicated as length × width followed by the measurement unit.

### Taxonomy

***Citrus wakonai*** P.I.Forst. & M.W.Sm., *species nova* differt a *C. warburgiana* stipulis lanceolatis eumorphis (non obsoletis); folii lamina lanceolato-trullata apice acuminato (in illa lanceolato apice acuto usque obtuso); fructibus plus quam duplo longioribus, obovoideis, externe flaveolis, succis vesiculis flaveolis maturitate (in illa globosis, externe viridibus, succis vesiculis pallide viridibus maturitate). **Typus:** Papua New Guinea. MILNE BAY PROVINCE: Utamodi Valley, southwest of Wakonai Village, Goodenough Island (*ex situ* cultivated at Bundaberg), 30 September 2008, *M.W.Smith 09Q005* (holo: BRI [3 sheets + spirit]; iso: CNS, LAE).

*Citrus australasica* auct. non F.Muell.; Stone (1985: 226).

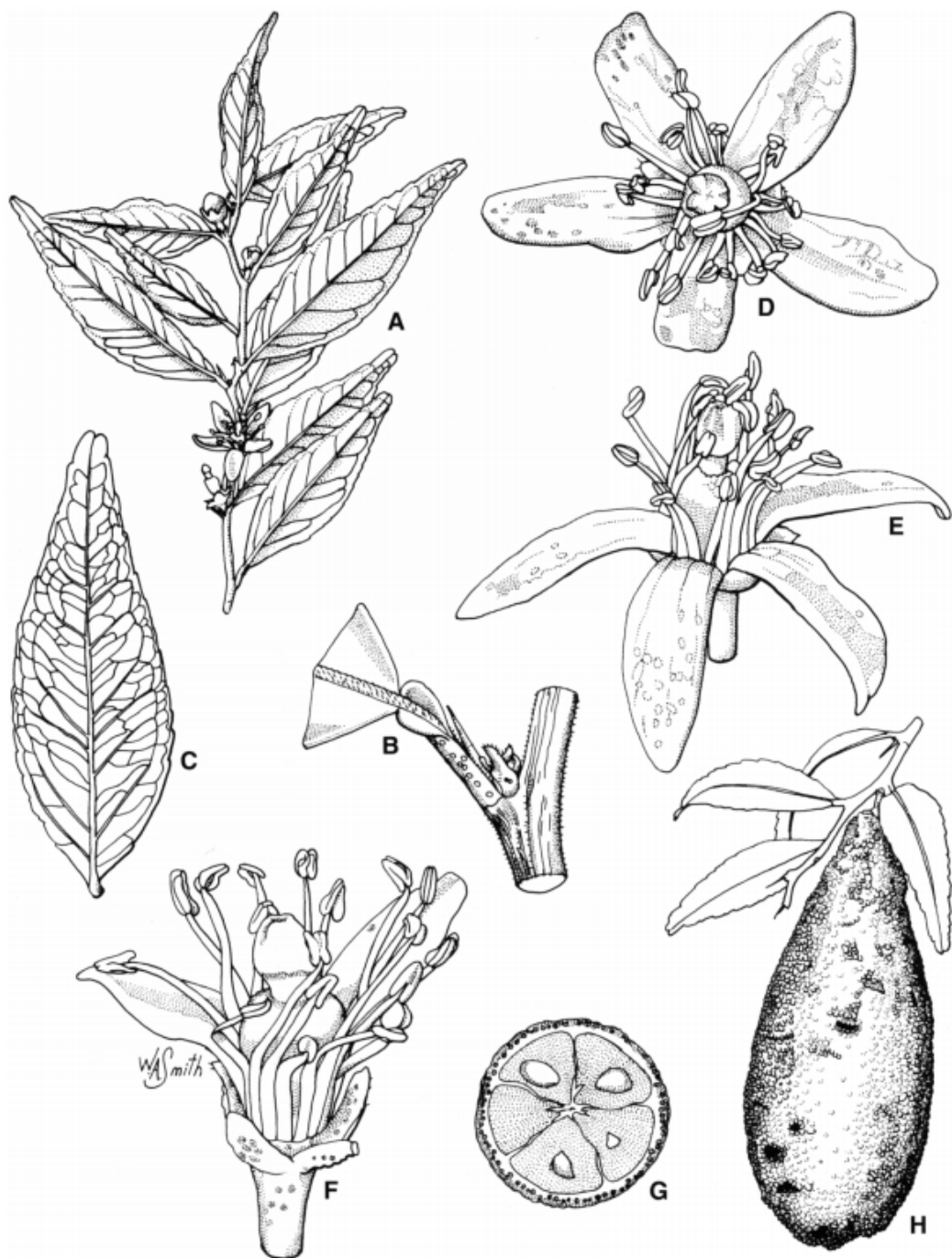
*Citrus garrawayi* (as '*garrawayae*') auct. non F.M.Bailey; Forster (1991: 357), Mabberley (1998: 338).

Tree to 6 m tall, bark somewhat corky, cream; branches somewhat weak and straggling; often coppicing and suckering from base; indumentum of simple, weakly hooked, antrorse trichomes, fawn to uncoloured; most vegetative organs with copious oil glands. Leafy twigs terete, 1–2 mm diameter, axillary spines solitary, 3–5 mm long; stipules lanceolate, 0.8–1 × 0.5–0.7, marginally ciliate.

Leaves 18–65 mm long, glossy; petioles 2–5 × 0.8–1 mm, marginate to winged – the latter obdeltoid towards the lamina base, very weakly articulated at base of leaf lamina, indumentum sparse; lamina lanceolate-trullate, 15–60 × 7–26 mm, dark green above, paler green below, margins crenate-dentate with 17–22 teeth per side of midrib (often with secondary teeth); venation barely visible above, prominent below with 1° midrib and 2° laterals raised, 3° and 4° interlaterals weakly developed; tip acuminate, apically notched due to teeth, base acute; indumentum restricted to lower surface on 1° and 2° veins, scattered. Inflorescence of solitary flowers, or 2 or 3 in a small fascicle; peduncle ± obsolete or short and up to 2 mm long, indumentum scattered; bracts variable, lanceolate to linear, 1–2 × 0.2–0.3 mm, few apical or marginal cilia. Flowers 6–7 mm long, 10–12 mm diameter; pedicels short, 1–2 × 0.8–1 mm, glabrous; calyx cupular, sepals 5, orbicular-ovate, 1.8–2 × 2–2.2 mm, slightly overlapping at margins and with marginal cilia; petals 5, reflexed at anthesis, ecucullate, lanceolate, 7–7.5 × 2.8–3 mm, white, apex acute; stamens 18–20, filaments 3–5 × *c.* 0.3 mm, anthers 1–1.2 × 0.7–0.8 mm; disk very reduced, *c.* 2.5 mm diameter; pistil 5 or 6 ribbed, *c.* 2.3 mm long; ovary 5(–7)-locular, *c.* 3 × 2 mm, green. Fruit an hesperidium (modified berry), obovoid, 44–65 mm long, 22–25 mm diameter at widest point, 6–8 mm wide just above base, surface rough, irregular, yellow-green when mature; flesh dull, pale yellow, edible although rather tart, juice vesicles elongate-fusiform; 12–87 (average 46.3, sample size 60) seeds per hesperidium. Seeds somewhat turbinate, monoembryonic, entirely zygotic, 8–10 × 4–5 mm, with a distinct chalazal spot, fawn. **Fig. 1.**

**Additional specimen examined:** Papua New Guinea. MILNE BAY PROVINCE: Goodenough Island, Oct 1953, *Brass 24925* (BRI).

**Distribution and habitat:** *Citrus wakonai* occurs as an understory treelet in rainforest (complex mesophyll vineforest) at altitudes between 900 and 1500 m. The geology of Goodenough Island is complex due to ongoing and relatively recent, uplift and shearing; however, it is probable that the locality visited has substrates overlying leucogneiss (altered metamorphic rocks) (Davies & Warren 1992;



**Fig. 1.** *Citrus wakonai*. A. habit of flowering branchlet  $\times 1$ . B. node showing stipule and base of leaf lamina with obdeltoid margin on the petiole  $\times 5$ . C. undersurface of leaf lamina showing 1–3° venation  $\times 1.5$ . D. face view of flower  $\times 5$ . E. side view of flower  $\times 5$ . F. side view of flower with petals removed to show disposition of stamens and sepals  $\times 6$ . G. cross-section of fruit showing five compartments and embedded seeds  $\times 1$ . H. branchlet with fruit in natural disposition  $\times 1$ . All from Smith 09Q005 (BRI). Del. W.Smith.

Hill 1994). The vegetation community where this species occurs was described by Brass (1956) as a “transition mid-mountain forest and rain forest. A scattering of two species of oak and one of *Castanopsis* occurred with species of *Terminalia*, *Sloanea*, *Gordonia*, *Podocarpus* near *neriifolius*, and other trees...in a mixed forest in which the larger trees were fully 35 metres tall and of good, big diameter”. Annual rainfall at nearby Bolu Bolu is approximately 1800 mm with almost 40% occurring during the summer months; however, Bolu Bolu is at sea level and it is likely that rainfall in the adjacent mountainous areas is considerably higher.

**Notes:** *Citrus wakonai* appears to be most closely related to those species that were once placed in *Microcitrus*. The new species has some superficial similarities both to *C. australasica* and *C. garrawayi*, the two species with which it has been previously confused, although it is markedly disjunct from both. *Citrus wakonai* and *C. australasica* are immediately distinguished by the former with leaf lamina lanceolate-trullate with many teeth (>15 per side) and obovoid fruit and the latter with leaf lamina obovate, ovate or obdeltoid with few marginal teeth (<10 per side) and the fruit oblong-cylindrical to somewhat fusiform.

The juvenile foliage of *Citrus garrawayi* is markedly dimorphic and much smaller in size than when the plants mature. In comparison, the juvenile foliage of *C. wakonai* is not markedly dimorphic, mainly differing only in size (being smaller). Mature foliage of *C. garrawayi* is elliptic to ovate or more rarely obovate, with few marginal teeth (<10 per side) (versus lanceolate-trullate and with 17–22 teeth per side) and the flower petals are cucullate (versus not). Mature fruit of *C. garrawayi* are always ovoid to oblong-cylindrical and at maturity green in colour with pink flesh, whereas those of *C. wakonai* are obovoid and at maturity are dull yellow-green with yellow flesh.

*Citrus wakonai* is distinct from both *C. australasica* and *C. garrawayi* in the fruit juice-vesicles being elongate-fusiform rather than subglobose.

*Citrus wakonai* differs from the other two species formerly referred to the genus *Microcitrus* that are endemic to PNG in its habit (small tree to 6 m versus shrub to 2.5 m in *C. wintersii* Mabb. and larger tree to 12 m in *C. warburgiana* F.M.Bailey), the well developed stipules that are marginally ciliate (much reduced in *C. wintersii* and  $\pm$  obsolete in *C. warburgiana*), the lanceolate-trullate leaf lamina with an acuminate tip (linear to narrow-elliptic with an obtuse tip in *C. wintersii* and lanceolate with an acute to obtuse tip in *C. warburgiana*) and the obovoid fruit shape (fusiform-cylindrical in *C. wintersii* [Winters 1976] and globose in *C. warburgiana*).

In general foliar appearance, *Citrus wakonai* is superficially similar to *C. warburgiana*, particularly with regards to the extremes of leaf lamina shape. Further differences between the two species are the former with less pronounced leaf margin crenulations (versus more pronounced), the petiole margin sometimes (both usually have petioles that are marginate with the margins forming a channel) well developed and obdeltoid towards the lamina base (versus linear) and the pale yellow juice-vesicles at fruit maturity (versus lime green).

Populations of the two species are only approximately 70 km distant from one another, albeit with sea inbetween. The D’Entrecasteaux Islands (part of the Milne Bay Archipelago), of which Goodenough and Fergusson are the largest, are thought to be of recent origin, only emerging from the sea in the last 2 million years (Hill 1994). Hence, it is most likely that *C. wakonai* and *C. warburgiana* have diverged from *Citrus* progenitors present on mainland PNG in the recent past when sea levels were lower (Hall 2002). The flora of the Milne Bay Archipelago is little explored and described, but like much of PNG is rich in endemics with at least 239 known (Johns *et al.* 2009) of which *Acronychia normanbiensis* T.G.Hartley (known only from Normanby Island) (Hartley 1974) and *Melicope sudestica* T.G.Hartley (known only from Sudest Island) (Hartley 2001) are from the Rutaceae.

*Citrus wakonai* can be hybridised with *C. australis* (A.Cunn. ex Mudie) Planch., *C. australasica*, *C. garrawayi*, *C. glauca* (Lindl.) Burk., *C. inodora* F.M.Bailey, *C. reticulata* Blanco, *C. sinensis* Osbeck, *C. warburgiana* and *C. wintersii*, and the resulting plants are fertile. It hybridises less readily with *Poncirus trifoliata* (L.) Raf. (often now included in *Citrus* on molecular evidence [Mabberley 2004; Bayer *et al.* 2009]) with the resultant progeny weak and dying shortly after germination. *Citrus warburgiana* grouped with the Australian *C. inodora* in the molecular tree of Bayer *et al.* (2009); hence, it is likely that *C. wakonai* may also belong to this part of the *Citrus* clade.

*Citrus wakonai* has the shortest juvenile period known of any *Citrus* species and can flower in as little as 144 days after germination. This is even shorter than that reported for *C. wintersii* which has been reported to flower and fruit within one year of sowing (Winters 1976). In populations of both species cultivated at Bundaberg, it was found that *C. wakonai* consistently commenced flowering at five months of age, whereas *C. wintersii* generally took 14 months. The short juvenile period of *C. wakonai* is transferred to its hybrid progeny, since some hybrids with mandarin (*C. reticulata*) have flowered within 12 months of sowing.

The species is highly sensitive to citrus tristeza virus (family Closteroviridae, genus *Closterovirus*) and field-grown trees exposed to aphid transmission develop stem pitting symptoms and die within a few years of planting. Similarly when used as a rootstock for cultivated citrus, trees quickly become unhealthy and many die (Smith *et al.* 2008). Consequently *Citrus wakonai* appears to have limited potential as a rootstock for commercial citrus crops.

**Etymology:** The species epithet recognises the local people from the village Wakonai on Goodenough Island, upon whose traditional land this plant grows. The name should be considered as a non-declinable noun in apposition and is pronounced 'wōkanī'.

This plant is known as "Kamakuku" by the local people; the same word is used by

people on nearby mainland PNG to describe *Citrus warburgiana*.

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### References

- BAYER, R.J., MABBERLEY, D.J., MORTON, C., MILLER, C.H., SHARMA, I.K., PFEIL, B.E., RICH, S., HITCHCOCK, R. & SYKES, S. (2009). A molecular phylogeny of the orange subfamily (Rutaceae: *Aurantioideae*) using nine cpDNA sequences. *American Journal of Botany* 96: 668–685.
- BRASS, L.J. (1956). Summary of the Fourth Archbold Expedition to New Guinea. Results of the Archbold Expeditions. No. 75. *Bulletin of the American Museum of Natural History* 111: 1–152.
- DAVIES, H.L. & WARREN, R.G. (1992). Eclogites of the D'Entrecasteaux Islands. *Contributions to Mineralogy & Petrology* 112: 463–474.
- FORSTER, P.I. (1991). *Microcitrus garrawayae* (Rutaceae) and its distribution in New Guinea and Australia. *Telopea* 4: 357–358.
- HALL, R. (2002). Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions, model and animations. *Journal of Asian Earth Sciences* 20: 353–431.
- HARTLEY, T.G. (1974). A revision of the genus *Acronychia* (Rutaceae). *Journal of the Arnold Arboretum* 55: 469–567.
- (2001). On the taxonomy and biogeography of *Euodia* and *Melicope* (Rutaceae). *Allertonia* 8: 1–328.
- HILL, E.J. (1994). Geometry and kinematics of shear zones formed during continental extension in eastern Papua New Guinea. *Journal of Structural Geology* 16: 1093–1105.

- JOHNS, R., GIDEON, O., SIMAGA, J., KURIA, T. & BAGOERA, G. (2009). An introduction to the flora of the Milne Bay Archipelago. *Blumea* 54: 251–254.
- MABBERLEY, D.J. (1998). Australian *Citreae* with notes on other *Aurantioideae* (Rutaceae). *Telopea* 7: 333–344.
- (2004). *Citrus* (Rutaceae): a review of recent advances in etymology, systematics and medical applications. *Blumea* 49: 481–498.
- SMITH, M.W., GULTZOW, D.L., NEWMAN, T.K., BROADBENT, P., FORSTER, P.I. & MILES, A.K. (2008). Native Australian *Citrus* species as rootstocks for tangerine and lemon. In C.Zhou (ed.), 8<sup>th</sup> *International Congress of Citrus Nurserymen*, Paper No. 10 (B6). Chongqing, China.
- STONE, B.C. (1985). New and noteworthy paleotropical species of Rutaceae. *Proceedings of the Academy of Natural Sciences of Philadelphia* 137: 213–228.
- WINTERS, H.F. (1976). *Microcitrus papuana*, a new species from Papua New Guinea (Rutaceae). *Baileya* 20: 19–24.