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NOTES ON NEGLECTED & UNDERUTILIZED CROPS

The forgotten giant of the Pacific: a review on giant taro (*Alocasia macrorrhizos* (L.) G.Don)

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Abstract This article provides an overview over taxonomy, distribution, cultivation and use of giant taro, *Alocasia macrorrhizos* (L.) G.Don. The species belongs to the Araceae (aroid) family, which consists of 3700 species grouped into 107 genera. Among those species are several important crop species from tropical Asia and America. Giant taro, with a thick stem, large leaves and inflorescences, is cultivated as a food crop in several Pacific countries and in tropical Asia. In other parts of the world, it is mainly cultivated as an ornamental species. With a high starch content and its pest resistance, it often forms part of local traditional polycropping and agroforestry systems, e.g. in Tonga, and it contributes to local food security in particular during periods of food scarcity. Few production statistics are available as giant taro is mainly cultivated on a small scale and as part of subsistence agriculture. We consider giant taro a neglected crop. To our knowledge, no breeding or research programmes for crop improvement are currently happening. A database query and literature review revealed only 59 gene bank accessions, held in 7 different gene banks worldwide. We suggest further research into the conservation of landraces and into an increase of the productivity of this crop.

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Introduction: genus and family

The Araceae (aroid) family consists of 107 genera with over 3700 species distributed worldwide (Erlinawati 2010; Arbain et al. 2022). The family is extremely heterogeneous; the majority of aroids are climbers and epiphytes of tropical rainforests. Many species are associated with aquatic or semi-aquatic environments. Species adapted for areas with cooler or dry climates are characterized by dormancy in the form of corms, tubers, underground rhizomes or seeds, thereby surviving unfavourable periods. The main centres of origin are tropical America and tropical Asia. Some members of the family can only be found in the Mediterranean Basin and in Africa. There is an extensive fossil record going back to the Upper Early Cretaceous, Palaeocene, and Eocene (Friis et al. 2004, 2010; Wilde et al. 2005; Herrera et al. 2008).

In the Araceae family, species grouped into five different genera are cultivated in tropical areas as crops for their starch-filled storage organs or herbaceous leaves. Besides giant taro *Alocasia macrorrhizos*, crop plants of varying importance in the family are elephant foot yam (*Amorphophallus campanulatus*), taro (*Colocasia esculenta*), giant swamp taro (*Cyrtosperma chamissonis*) of Asian or Asia–Pacific origin; and tannia (*Xanthosoma sagittifolium*) (=syn. *Xanthosoma atrovirens*) and pises (*Xanthosoma robustum*) of American origin (Ivancic and Lebot 2000; Pacheco-Trejo et al. 2022). These edible aroids are often confused with one another, and often commonly called 'taro'. They are widely cultivated in several world regions and often contribute substantially to local food and nutritional security (Matthews and Ghanem 2020). Most crop species in the Araceae family thrive in moist to flooded conditions and are among the most shade tolerant of terrestrial food crops. Often, they are cultivated in moist tropical environments where other starchy food crops fail to grow successfully. Some crop species are grown as famine crops, while others are valued as staple food. All plant parts contain varying concentrations of an acrid factor, which appears to be carried on the surface of the needle-like calcium oxalate raphide crystals. It is believed to be either a cysteine proteinase or a glucoside that causes considerable irritation or swelling of affected tissues. Concentrations vary considerably among species and varieties. Cooking or other processing procedures destroy the acrid factors in the more popular clones whereas naturalized or 'wild' clones need extensive processing to render them palatable. Reliable production figures are often not available for most of the aroid crops, since they are mostly grown as subsistence crops in small, often mixed plantings (Ivancic and Lebot 2000).

The genus *Alocasia* (Schott) G.Don comprises more than 110 species, which grow primarily in the understorey of perhumid, subtropical and tropical lowland forests (Arbain et al. 2022). Hay (1998) recognised 31 species from Malesia and Sulawesi alone. Many species are yet to be formally described (Boyce 2008). Only a few species grow at altitudes above 1000 m asl., in canopy gaps, clearings, or secondary vegetation (Hay and Wise 1991; Hay 1999; Boyce 2008). Some species of the genus grow as epiphytes on trees, while others can propagate underwater (Ma et al. 2020). Growth forms range from small herbaceous to thick-stemmed massive plants with huge leaves (Nauheimer et al. 2012). The stem, typical for most Araceae, is physiognomically an unbranched sympodium. The foliage leaf may be followed immediately by a pair of inflorescences and another relay axis with a single foliage leaf etc., so that the flowering episode consists of a compressed sympodium of flowering units displaced into lateral positions and interspersed with foliage leaves.

The genus is distributed across tropical Asia, Southeast Asia, the Malesian region, with its principal centre of diversity being in Borneo. The natural range extends with one single species to Australia. Several species, including *A. macrorrhizos* and the closely related Chinese taro, *Alocasia cucullata*, are important food plants or ornamentals. Outside their native range, species of the genus receive considerable horticultural interest as exotic ornamental plants (Hay 1999).

Nauheimer et al. (2012) investigated the biogeography of the genus *Alocasia* using plastid and nuclear DNA sequences from 71 species of the genus. The authors could show that *Alocasia* is monophyletic and sister to *Colocasia gigantea* from the SE Asian mainland. According to their findings, the ancestor of *Alocasia* diverged from its mainland sister group c. 24 million years ago. Borneo then played a central role in the expansion of *Alocasia*. The diversification of the genus started in the Miocene between 19.3 and 13.5 million years ago, at a time when the climate changed to warm and humid conditions, which led to the expansion of rainforest in the Malesian region. Exposed land bridges and smaller inter-island distances due to lower sea levels during that period permitted repeated clade expansion from and to Borneo and the Philippines, as well as occasional crossing of the Wallace line to Sulawesi, New Guinea, and Australia approximately 5–7 million years ago.

Giant taro: general introduction

Giant taro (*Alocasia macrorrhizos* (L.) G.Don), sometimes also called mankachu, giant alocasia, metallic taro, or giant elephant ear taro, with a multitude of different common names used locally across its area of cultivation (Srivastava et al. 2012; Karim et al. 2014), belongs to the Araceae family and as its English name giant taro suggests is a large, succulent perennial herb with a large, elongated stem (Plucknett 1984). It was first described in 1839 (Sweet 1839). In cultivation, the stem, which is above ground, can be up to 1 m long and 20 cm in diameter (Purseglove 1979); Quero Garcia et al. (2008) report on individuals with stem lengths of 3 or more meters. Individuals grow continuously, and when an individual plant becomes too heavy to support its own weight, the stem falls on the ground and thence is decumbent but the plant continues to grow from the tip or lateral buds. The stem can develop adventitious roots. The broadly sagittate leaves, which sometimes can reach a size of 1–2 m, are bluntly triangular in outline, indistinctly leathery and showcase a prominent secondary venation. The leaf midrib is broad and conspicuous with 4–7 primary veins per side. Like many other members of the Araceae family, *A. macrorrhizos* is an allogamous species and pollinated by insects (Shaw and Cantrell 1983; Ivancic et al. 2005). The inflorescences are relatively large. Fully developed plants develop up to 8 to 16 inflorescence clusters (Quero Garcia et al. 2008). The upper part of the spathe is pale yellow, membranous, oblong, and hood-forming, and it falls soon after anthesis (Hay 1999). As for other representatives of the family, the spadix with unisexual flowers is divided into several distinct parts. The female part is at the base of the spadix while the male part is higher up. These two zones are separated by a zone in the centre of the spadix with a band of sterile flowers. The spadix ends in a sterile appendix at its top. The main purpose of this appendix is the release of odorous substances (Bown 1988). Ivancic et al. (2005) investigated the thermogenesis of the inflorescence, which is widely documented in the Araceae family. Heating occurs on the male part of the inflorescence and the sterile appendix, with maximum temperatures of > 25 °C above the ambient temperature and with a recorded maximum at 47.4 °C, lasting for 36–42 h. Ivancic et al. (2005) found that thermogenic activity occurs in cycles and is synchronized with the receptivity of the stigmas, release of odour and pollen, and visits by pollinating insects. Synandria are convex topped, ca. 2 mm in diameter. The stigmas possess 3–5 lobes which are conic and spreading. The fruits (berries) are ovoid, scarlet and 8–10 mm long (Manner 2011). Although flowering individuals can be found throughout the year (Ivancic et al. 2005), observations in Vanuatu over several years showed that flowering is most frequent between the beginning of November and the end of February during the wettest part of the year (Quero Garcia et al. 2008). Plants require deep, well-drained and fertile soils, with moderate exposure to sun (Ivancic and Lebot 2000). Full sun exposure leads to the formation of large leaves and a high loss of water through transpiration (Quero Garcia et al. 2008). Occasionally, red–orange fruits are formed, but seeds develop only very rarely (Quero Garcia et al. 2008), although abundant seed set was described from wild populations in the Philippines (Hay 1999).

Distribution and use

A. macrorrhizos was prehistorically distributed widely in tropical Asia and the South Pacific region and was used as a subsistence crop in times of famine (Boyce 2008). It grows in humid tropical and subtropical climates. It does not support long periods of drought but still copes better during dry spells and is more drought-tolerant than other aroid crops. The species is now a virtually pantropical species (Boyce 2008). In many tropical parts of Australia, Asia, Africa, the Caribbean and South America, it is cultivated in gardens as an ornamental species in several selected forms (O'Hair and Maynard 2003; Ivancic et al. 2005) or as a minor starch crop. In the Philippines, South Asia and many Pacific island countries and territories (e.g. Samoa, Fiji, Tokelau, Tonga, Tuvalu, Wallis and Futuna, Papua New Guinea, the Solomon Islands, and parts of Vanuatu), it is cultivated as a starch food crop, often as part of traditional agroforestry systems, together with banana, cassava, coconut, kava, sweet potato, tannia, taro and yams (Fig. 1a). This crop is cultivated mainly for its starchy upright stem (Bourke 1982; Thompson 1982; Wilson and Cable 1984; Wilson and de Groot 1988; Ivancic et al. 2005; Quero Garcia et al. 2008; Manner 2011) (Fig. 1b). In Bangladesh, giant taro (locally known as *man kachu*) is mostly cultivated as part of homestead farming but shows some commercial importance, too, being sold in local farmer markets (Rahim et al. 2021). In the Philippines, giant taro is grown as a subsistence crop (Pardales 1997). In the Kingdom of Tonga, where it is known as *kape*, giant taro is still an important element in the traditional polycropping farming systems (Fig. 1c, 1d). When an area of land is cleared for a new cultivation cycle, giant taro is the first crop to be planted in the first rotation cycle, intercropped with yams as the main crop. Moreover, it is traditionally second only to yams as a gift presented

Fig. 1 **a** giant taro growing on the edge of a cassava field in Suva, Viti Levu (Fiji), **b** stem of giant taro for sale in a road side market in Tongatapu (Tonga), **c** large field of giant taro in Tongatapu (Tonga), **d** giant taro used to delimit a recently planted yams field in a traditional polycropping system of Tongatapu (Tonga), **e** variety 'Kape Hina', originally collected in Tonga, being conserved in vitro at CePaCT gene bank in Suva, Viti Levu (Fiji). All photos: Filippo Guzzon

to the nobility (Pole 2004). Similar polycropping systems with giant taro are reported also for Niue and for Wallis & Futuna (Foliaki et al. 1990). In the South Pacific countries, the crop is harvested after usually 12 to 24 months, sometimes longer (Manner 2011) and can be harvested all year round (Foliaki et al. 1990). As it can withstand drought periods better than other aroids and can grow in different soil types, it is often considered an important resource during periods of food scarcity on different Pacific islands (MORDI Tonga Trust in prep., Waqainabete pers. comm.). The stem is roasted, baked or boiled and eaten as a source of carbohydrates (starch). In India and Bangladesh, the stem tuber is peeled, cut into pieces and eaten as a vegetable after cooking, usually in curries or stews (Manner 2011). Rashid and Daunicht (1979), talking about edible aroids in Bangladesh, described that sometimes young leaves of giant taro are eaten, too. In Fiji, the leaves are used to cover the *lovo*, the traditional earth oven (Waqainabete pers. comm.). Giant taro yield potential is very high, with certain cultivars producing over 78,600 kg/ha/year (Foliaki et al. 1990; Manner 2011), and Quero Garcia et al. (2008) did not detect any significant pest and disease problems under cultivation. *A. macrorrhizos* is also known as an animal fodder (Weightman 1989; Mayo et al. 1997; Manner 2011). Díaz Díaz and Quinto Solis (2019) mentioned its suitability for the production of bioethanol. This crop is usually propagated by cormlets, suckers or small sections of the stem with the petiole and young leaves (Wilson and Groot 1998; Manner 2011; MORDI Tonga Trust in prep.).

There is no certainty about the centre of origin of *A. macrorrhizos*. Starch grains of *A. macrorrhizos* have been found on Solomon Island stone tools dated to 27,000 years before present (Loy et al. 1992). Several authors assume the centre of origin to be Sri Lanka or the Indian subcontinent (Purseglove 1979; Plucknett 1984; Ivancic et al. 2005). From Asia, the species spread to most tropical and subtropical regions. The exact routes of its spread are unclear but probably show some similarities to those of taro (Ahmed et al. 2020) in that pre-historic colonisers of the Pacific took specimens with them on their migration eastwards. Nauheimer et al. (2012) showed that the domesticated form originated in the Philippines. It has been cultivated for at least 3000 years.

In the scientific literature, the genotypes of *A. macrorrhizos* are divided into two groups, wild (=non-edible) and cultivated. Stems of wild plants are not used as food because of an extremely high concentration of calcium oxalate crystals. Cultivated plants are distinguished mainly by leaf and stem traits. The most important ones are length, diameter, and smoothness of the stem exterior, and traits associated with the stem flesh such as colour, chemical composition, dry matter content, content of fibres, texture, and taste (Ivancic et al. 2005). In the literature, there is a degree of uncertainty whether (and if, where) truly wild populations exist. Several authors describe its close association with human settlements and speculate that *A. macrorrhizos* is a cultigen only (Hay 1999; Boyce 2008). If not in cultivation, the species often found in roadside ditches and margins of wet fields. Also, as among wild plants, feral genotypes that escaped from cultivation can be found, which in their appearance resemble wild plants. Unlike truly wild genotypes, these feral types are in many cases edible (Quero Garcia et al. 2008). Furtado (1941) described several ornamental varieties, and pointed out that *A. macrorrhizos* is often confused with very similar species, e.g. with the Indian *A. odora*. *A. macrorrhizos* can be distinguished from *A. odora* as the latter has peltate leaves and a shorter spadix appendix. Also, *A. macrorrhizos* never produces stolons from the base of the stems (Lim 2015).

There is a relatively large body of pharmaceutical literature on medicinal use and medical effects of secondary metabolites of *A. macrorrhizos*. The crop is widely used traditionally in folk medicine for a range of different conditions and diseases. It is traditionally used for the treatment of diabetes, pus in the ears, jaundice, snake bites, and constipation (Rahman et al. 2012; Arbain et al. 2022). In Malaysia, it is used to treat cough and toothache (Ongpoy 2015, 2017). In India, Bangladesh and parts of Indonesia, it is used as an analgesic medication to alleviate pain in the stomach, head, and rheumatoid arthritis (Al Hassan et al. 2014; Yuliana and Fatmawati 2018). In Vietnam, *A. macrorrhizos* is used to treat inflammation, eczema, and abscess (Yuliana and Fatmawati 2018). In the Philippines, it is traditionally used to cure rheumatism, snake bites and toothache; as well as to treat animal wounds (Pardales 1997). Previous phytochemical investigations have revealed that *A. macrorrhizos* contains a large variety of different biochemical compounds (incl. different kinds of flavonoids, indole alkaloids, aloceramides, oiperidine alkaloids, cyanogenic glycosides and other alkaloids; for details, see Huang et al. 2017a, b; Arbain et al. 2022).

Commercial production worldwide

Commercial production of giant taro is confined to S and SE Asia and the Pacific region, Samoa and Tonga being the two countries with the highest production. Multiple varieties have been described. In Tonga, for example, four varieties are known (‘Kape hina’, ‘Kape ‘uli’, ‘Fohenga’ and ‘Kape fulai’; Pole 2004), and in Samoa, 12 varieties are known, which are variable in yield and growth characteristics (Manner 2011). Paul et al. (2015) mentioned two main varieties grown in Bangladesh, ‘Giraman’ and ‘Dheki Man’. Postharvest handling and processing are similar to those used for taro (Manner 2011). The harvest must be used within a month of harvesting to avoid rotting. Keeping the stems in a cool, dry and dark environment extends the storage life to 3–5 months. There is little reference in the literature to the yield, because most giant taro is cultivated by small-scale farmers and for their own consumption. While theoretical yields have been calculated to reach 80,000 kg/ha, in practise and due to the cultivation in traditional polycropping systems, yields between 15,000 and 30,000 kg/ha seem more realistic (Manner 2011). A small export market mainly from Samoa and Tonga to New Zealand, Australia and the US exists (Foliaki et al. 1990; Manner 2011).

Availability in gene bank collections and current breeding work

Ex-situ gene bank accessions of *A. macrorrhizos* are only very rarely available. An online search on the three global databases for plant genetic resources (Genesys PGR [Genesys PGR 2023], FAO WIEWS [FAO 2023], and GRIN Global of the U.S. National Plant Germplasm System [NPGS 2023]) showed a total of 29 accessible gene bank holdings, of which 10 accessions originating from Samoa (6 accessions), Tonga (3 accessions) and Fiji (1 accession) are stored in the in vitro collection of the Centre for Pacific Crops and Trees (CePaCT), Fiji, 18 accessions are held at the National Plant Resources Center Vietnam, Hanoi, as field collections, and 1 accession collected in Puerto Rico is held at the National Clonal Germplasm Repository Mayaguez, Puerto Rico (USA) (Fig. 1e). Since 2009, CePaCT has distributed a total of 144 plantlets belonging to 10 different accessions of giant taro to five different countries and territories (Belgium, Cook Islands, Kiribati, Tuvalu, and Samoa). In addition to the information held in the abovementioned global databases, Guarino (2004) reported 13 local varieties of giant taro conserved in a field collection of the National Agriculture Research Institute (NARI) in Papua New Guinea and two local varieties conserved in the in vitro collection of the Ministry of Agriculture, Forests, Fisheries & Meteorology of Samoa. Additionally, Global Crop Diversity Trust (2006) reported a collection of 10 accessions at VARTC (Vanuatu Agricultural Research and Technical Center) in Vanuatu. Five local accessions conserved at BAU-GPC (Bangladesh Agricultural University Germplasm Centre) were reported by Rahim et al. (2021).

With a lack of data on growth, yield, quality of many giant taro varieties (Lebot et al. 2023), Chandra (1984) and Manner (2011) recommended further work on agronomy, production systems, breeding, diseases and pests, storage, utilisation, and marketing for this species. However searching the literature, it seems that the principal situation has not changed since Chandra (1984) and Manner (2011) as we could not find any published work that presented new data or indeed any results in these areas. The only exception is the cultivar 'AU Man Kachu-1', recently released by BAU-GPC (Bangladesh). This cultivar is particularly suitable for commercial production in southern districts of Bangladesh (Rahim et al. 2021). This scarcity of published results stands in sharp contrast to the crop's potential to increase the food resources of subsistence and small-scale farmers in those areas where giant taro is currently grown, mainly in the Pacific region. As it currently stands and to the best of our knowledge, we must assume that there is currently no active breeding programme going on. Hammer et al. (2001) defined "neglected crops" as following, "neglected crops have been ignored by science and development but are still being used in those areas where they are well adapted and competitive." Following this definition, giant taro can be considered a neglected crop for tropical Asia and especially the Pacific. Further research efforts should aim at: (I) expanding our knowledge of the culinary use of the crop, (II) long-term conservation of landraces in germplasm collections, considering that genetic erosion is threatening some giant taro cultivars (as demonstrated by MORDI Tonga Trust (in prep.) for Tongan landraces) and that only few accessions of giant taro are currently conserved ex situ; (III) increase the productivity of this crop through research on better agronomic management, crop breeding and strengthening of local value chains. Finally, further research could also explore the potential of this crop in areas of the world where it is not yet cultivated, but with suitable conditions and compatible food cultures e.g. tropical areas of Africa and the Americas.

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