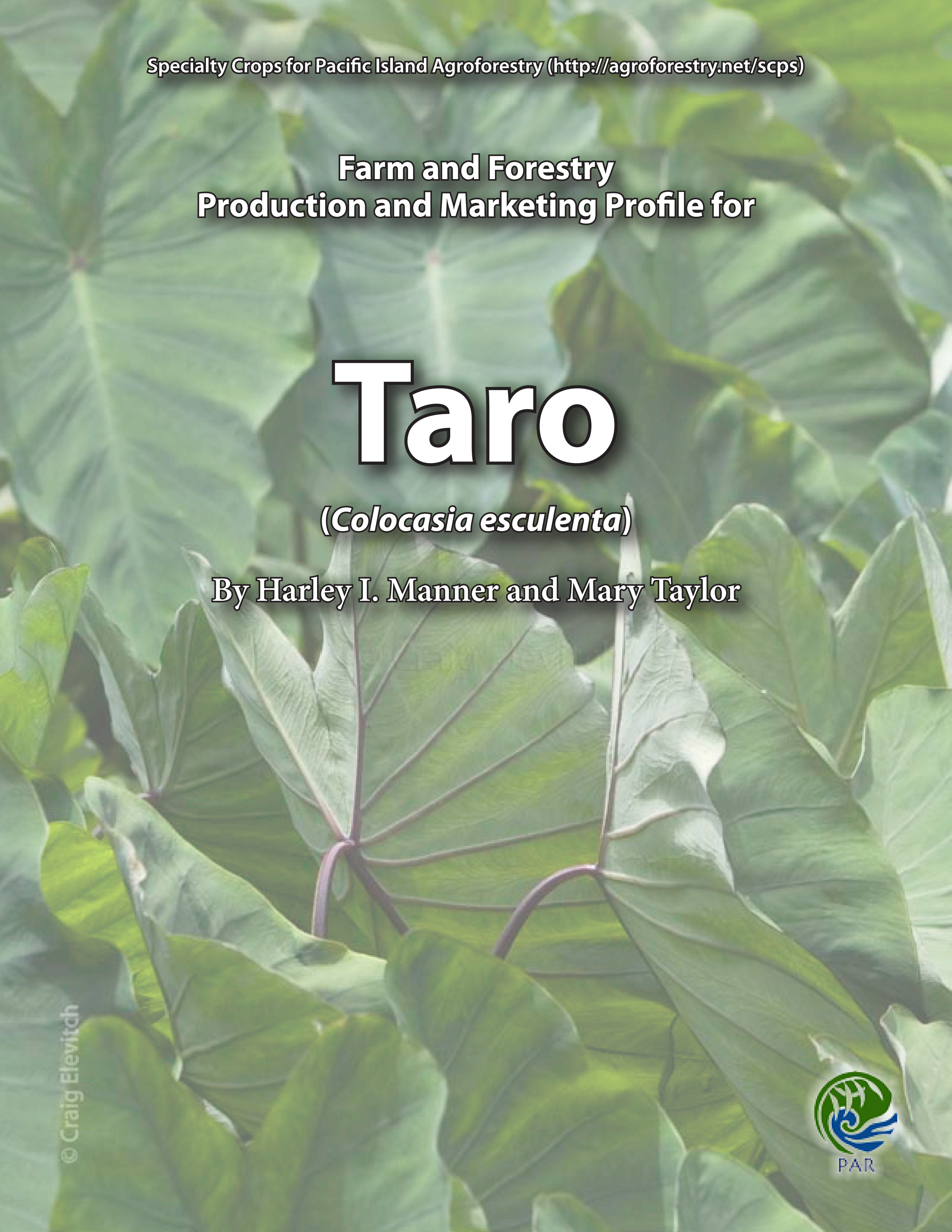
Specialty Crops for Pacific Island Agroforestry (http://agroforestry.net/scps)

Farm and Forestry Production and Marketing Profile for

Taro

(*Colocasia esculenta*)

By Harley I. Manner and Mary Taylor



PAR

USES AND PRODUCTS

The primary food products from *Colocasia* taro throughout much of the Pacific islands for both subsistence and commercial purposes include: corm, leaves, and petiole, which can be prepared in a number of ways. The corm is boiled in water, baked, fried, or steamed in underground earth ovens (known in various languages as *imu*, *umu*, *um*, and *lovo*). The leaves and petioles are often boiled and served as a kind of spinach. In Fiji, the petioles are boiled and served with coconut cream in a dish known as *basese*. Often as in Samoa and Fiji, the leaves are steamed with coconut cream, onions, and sometimes with corned beef in a dish called *palusami*. Taro features in traditional desserts such as the Samoan *fa'ausi* or the Hawaiian *kūlolo,* which consist of grated, cooked taro mixed with coconut milk and brown sugar. In Vanuatu, it has been reported that taro flowers are used to make a soup.

In Hawai'i, *laulau*, consisting of meat, fish, and/or vegetables wrapped in taro leaves is bundled in the leaves of ti (*Cordyline fruticosa*) and steamed. Ninety-five percent of the taro produced in Hawai'i in 2006 was used in making poi, a sticky paste made from the boiled taro corms. Poi is also canned/bottled as a hypoallergenic baby food and a freeze-dried poi powder has also been produced. The Hawaiian cultivar *Maui Lehua* is mainly used for making poi, while the most common upland cultivar, *Bun Long* (also called Chinese taro) is not.

Other products made from the corms include chips, flour, ice cream, breakfast cereals, flakes, noodles, canned taro, and meal. In Palau, *shochu* (a Japanese-type of vodka), is reported to be distilled from taro. A fairly complete listing and description of these products can be found in Moy and Nip (1983).

BOTANICAL DESCRIPTION

Preferred scientific name

Colocasia esculenta (L.) Schott

Smith (1979) and Fosberg (1987) consider *C. esculenta* (L.) Schott var. *esculenta* and *C. esculenta* (L.) Schott var. *antiquorum* ((Schott) Hubbard & Rehder) as non-preferred synonyms of *C. esculenta*. If we follow Fosberg, then the considerable discussion of these two varieties of *Colocasia* becomes moot. As reported by Vinning (2003), a study by the Taro Network for Southeast Asia and Oceania (TANSAO) aimed at enhancing the competitive position of taro in Southeast Asia and Oceania found that Pursglove's (1975) taxonomic differentiation of *C. esculenta* var. *esculenta* and *C. esculenta* var. *antiquorum* did not enable clear distinction between the two varieties. Instead, it was preferable to consider *C. esculenta* as a single polymorphic species with numerous named cultivars and cultivar groups. The study involved eight research organizations that "worked on five components: (a) germplasm characterisation, (b) disease resistance and improvements, (c) agronomic evaluation of cultivars and hybrids, (d) genetic diversity of *Phytophthora colocasiae*, and (e) physico-chemical characteristics of the corms from selected cultivars. Morphological characterisation of more than 2000 accessions was conducted." (Vinning 2003: 36). However, most horticulturalists follow Pursglove (1968) and consider *Colocasia esculenta* as a polymorphic species with two botanical varieties, *Colocasia esculenta* var. *esculenta* and *Colocasia esculenta* var. *antiquorum*. The differences between the two varieties are presented in Table 1.

Colocasia esculenta var. *antiquorum* is not widely grown in the Pacific islands. Cultivation in Tonga indicated that it is not very tolerant of dry conditions and preliminary trials in Samoa of a few varieties of *C. esculenta* var. *antiquorum* showed susceptibility to taro leaf blight. Therefore, this text will address only *Colocasia esculenta* var. *esculenta*.

Left: Taro corms ready for sale at market in Apia, Samoa. Right: Healthy patch of taro in Hōlualoa, Hawai'i.

Table 1. Characteristics differences between *Colocasia esculenta* var. *esculenta* and var. *antiquorum*.

	Colocasia esculenta* var. *esculenta	***Colocasia esculenta* var. *antiquorum***
Synonyms		C. e. var. *globulifera* (Eddoe of West Indies)
Common English names	Taro (in the Pacific) Cocoyam* (Also refers to *Xanthosoma*)** Dasheen* Dasheen of West Indies*	Cocoyam* (Also refers to *Xanthosoma*)** Dasheen (In the Pacific and Asia)* Eddoe of West Indies* Chinese eddoe+
Number of chromosomes	Mainly diploid cultivars (2n = 28)++	Commonly triploid cultiars (2n = 42)++
Characteristics of spadix	All parts (basal female flowers, sterile zone, male flowers, and sterile appendage) are generally one-half the size of the spadix of *Colocasia esculenta* var *antiquorum*. The sterile appendage is exserted beyond the spathe and is shorter than the male portiona (Pursglove 1972).	Larger spadix, all parts are about 2x the size of spadix of Colocasia esculenta var esculenta. The sterile appendage is retained within the inrolled tip of spathe and is longer than the male portion (Pursglove 1972).
Geographic origin	SE Asia (including India)	Developed and selected in China and Japan after introduction from SE Asia+
Geographic distribution	Polynesia*, Southern China*, Eastern Mediterranean+, Egypt+, Africa+, West Indies+, Trinidad+	East Asia*, Japan*, Northern China*West Indies+, Puerto Rico+, Trinidad+, Hawaiʻi+, Southern USA+
	Mainly large corm and petioles used for food.	Mainly small cormels are used for food. In some varieties the main corm is acrid and inedible. Some cormels are practically free of acridity.+
Corm size and number of cormels	Large main corm, cylindrical, edible, and 4–8 sucker cormels.	Small to medium sized main corm and a large number of edible cormels (15–20 or more)
Uses	Main corm, leaves and petioles used for food	Small cormels used for food
Others+++	In Malaita, Solomon Islands, 2n = 28 are called *alokine* (female) in Kwaraʻae language. These plants develop the disease symptoms called *bobone*.	In Malaita, Solomon Islands, 2n = 42 are called *alowane* (male) in Kwaraʻae language. These plants develop the disease symptoms called *alomae*.

*Wang 1983; **Wilson 1984; + Pursglove 1975; ++ Cable 1984; +++ Jackson et al. 1977

Family

Araceae (aroid family), subfamily Aroideae

Non-preferred scientific names

Caladium colocasia W.F. Wight ex Safford
Caladium esculentum (L.) Vent
Arum colocasia L.
Arum esculentum L.
Colocasia antiquorum Schott
C. esculenta (L.) Schott var. *esculenta*
C. esculenta (L.) Schott var. *antiquorum* (Schott) Hubbard & Rehder
C. esculenta var. *typica*
C. esculenta var. *globulifera*

To further add to the confusion in the literature, what was formerly known as *Colocasia gigantea* Hook. f. is now preferred to be known as *Alocasia macrorrhiza* (L.) G. Don and the former *Colocasia macrorrhiza* (L.) Schott is now called *Alocasia macrorrhiza* (L.) G. Don (Fosberg et al. 1987).

Common names

There are numerous common names for *Colocasia* taro throughout the Pacific islands. Unfortunately, eddoe and dasheen have been used interchangeably for *Colocasia esculenta* var. *esculenta* and var. *antiquorum*, and the term cocoyam is also used for *Xanthosoma* species. Pursglove (1968) suggests that the English names taro, dasheen, and cocoyam be used for *C. esculenta* var. *esculenta* while eddoe be used for *C. esculenta* var. *antiquorum*. Many references now tend to refer to *Xanthosoma sagittifolium* as cocoyam (Lebot 2009; http://www.cocoyam.org/).

Botanical description

Taro is a large perennial herbaceous plant up to 2 m in height. Leaves are large (20–85 cm long and 20–60 cm wide), peltate (petiole attached to the leaf near the center rather than margin), entire, ovate to saggitate with leaf tips pointed and rounded basal lobes. Petioles are up to 2 m in length, rise up in whorls from the apex of the corm, variable in color from light greenish yellow to dark red depending on cultivar, and not necessarily uniform, variegated petioles occur.

Inflorescence is a spadix (a simple fleshy spike) surrounded by a bract-like spathe. The spathe consists of two unequal parts: the lower green, up to 5 cm; the upper part deciduous, yellow, up to 35 cm and distally rolled. The overall length of the spathe reaches 40 cm and usually twice as long as a spadix (Strauss 1983; Pursglove 1975; Smith 1979).

Flowers are unisexual and located on the spadix. Green pistallate flowers are found at the base of the spadix with sterile or aborted flowers located above, followed staminate

The *Colocasia* taro petiole is attached to the leaf near the center rather than at the margin.

flowers toward the end of the spadix (Strauss 1983). Fruits are small ellipsoid berries. Not all taros flower naturally. Breeding work on taro in the Pacific indicates that flowering occurs more readily with taro from Melanesia, whereas with taro from Polynesia, gibberellic acid (500 ppm) is used to encourage the taro to flower and set seeds.

Roots are mainly on the surface, fibrous, and adventitious. The corm is large underground starchy stem, oblong or globular in shape with diameters up to 20 cm and weighing up to 1 kg or more. Colors cover a range from grey to purple to red and yellow. Corm color is also not necessarily uniform throughout.

All parts of the plant contain calcium oxalate raphides, which can be destroyed by cooking. Almost all varieties require cooking to render them edible. The leaves of one cultivar that has been introduced to Guam can be eaten raw. For the traditional *palusami* where taro leaves are used with coconut cream, the youngest leaves are selected for producing this dish, as they have lower levels of calcium oxalate and require less cooking than older leaves.

DISTRIBUTION

Native range

Taro originates from humid tropical rainforest regions of Southeast Asia including India. There are four species related to taro (*C. fallax, C. affinis, C. indica,* and *C gigantea*). These four species are all confined to northeast India and Southeast Asia. Therefore it has been suggested that *C. es-*

Table 2. Pacific island common names for *Colocasia esculenta* taro (Jardin (1974), Smith (1979), PIER (2008)).

Chuuk: *eot, oat, ot, omi, óni, oot, ori, otau, sawa, wodj, woot, woot, yoot, sarawai*
Commonwealth of the Northern Mariana Islands (CNMI): red taro
English: taro, elephant's ear, cocoyam, dasheen, eddoe
Fais: *ioth, eoth, yooth*
Fiji: *dalo, ba, boka, botiki, doko, qau, soli, suli, sulo, votuki, ronidoko* (leaves), *rourou* (leaves)
French: a*rouille carri, colocasie, songe*
Guam, Mariana Islands: *aba, suni, sune, suno*
Hawai'i: *kalo*
I-Kiribati: *te taororo*
Irian Jaya (Star Mts.): *om*
Kosrae: *kutak, katak, kohtahr*
Loyalty (Mare): *ama-ane, waude*
Maori (Cook Islands): *mamio, taro, wawa, rukau* (leaves), *rukou* (leaves), (*Pukapuka*) *wawa*
Marquesas: *kalo, kalo eu* (leaves)
Marshall Islands: *jibabwãi, katak, kõtak, kotak*
Mokil: *chawa*
Nauru: *de taro*
New Caledonia: *dap, di, diale, ekengai, inaga, io, kening, moa, moe, né, nere, waela, wa enilokapu, walo, wamo, wamu, wane, weeo*
New Hanover: *kierak*
New Ireland: *kala* (Tisar)
Niue: *talo*
Palau: *bisupsal, dait, kukau*
Papua New Guinea: *anega, ba* (Iega), *biaoe, biloun* (Huon Gulf), *boege, bolo* (Dobu, Ferguson), *daang* (Maring), *dadi diale, diamboilate, doboua, fiank* (Trans Fly), *garo* (Iega), *gu* (Huon Gulf), *harenik, kakun, kalen, kemb, kom, kudo, mavo* (Sepik), *guarava, niang* (Wampit R.), niku (Purari Delta), *nomo, omera* (Purari Delta), *hekere, hemar, ifan, jam* (Trans Fly), *jawa* (Misima), *joekwau, ka* (Rossel Is.), *jefam, kukun* (Ninigo), *lip taro* (Pidgin for taro leaves), *mabo* (Central Papua), *menkoko, mom, munda, mwedu* (Trobiands for leaves and stems), *naita* (Trobriands = leaves), *oema, keu* (Iega), *puku puku* (Nukumanu), *pupu* (Nukumanu), *sagani, sikwaku* (Trobiands for young leaves and stems), *tani* (Uga), *udo, ument, ument yafur* (Markham R.), *uri* (Trobriands), *warimoe*
Pingelap: *sawa*
Pohnpei: *sawa, oht* (Ant Atoll), *taaua*
Pukapuka: *wawa*
Puluwat: *oat, wot*
Samoa: *talo, fuauli*
Satawal: *wot omalu*
Society and Tahiti: *taro, pota* (young leaves), *ta'o*
Solomon Islands: *aro, nadal* (Banks Islands, Merelava), *neqet* (Banks Islands, Motalava), *tango* (Rennell Is.), *alo* (Kwara'ae), *tiko* (Kwara'ae), *karo Ontong Java* (Luangiua)
Spanish: *alcocaz, malanga, tayoba*
Tonga: *matiete, talo, taro, tara, lu* (leaves)
Tongareva: *talo* (spoken), *taro* (written)
Tuamotu: *fakea, kaho, wawa*
Ulithi: *ioth*
Vanuatu: *mbuack, mbwack, naqete* (Torres), *obwer, peita* (S. Santo), *ta, tari, ubwer, vembier* (Ambrym)
Woleai: *uot, woot*
Yap: *mal, uot, wot*

culenta originated in this area also, although there is little evidence to prove it. Within the last 10 years new *Colocasia* species (*C. lihengiae, C. gaoligongensis, C. heterochoma, C. yunnanesis, C. bicolor*) have been identified in China, and given the presence of *C. esculenta, C. fallax, C. gigantea,* and *C. affinis* there, China now has the distinction of having the most number of *Colocasia* species (Cho 2010). The problems associated with the origin, domestication and spread of taro have been studied by different teams, who have concluded that it is not possible to determine a single centre of origin (Yen and Wheeler 1968; Plucknett 1984; Matthews 1990; Lebot and Aradhya 1991; Lebot 1999). There are two different gene pools in Southeast Asia and Melanesia. The Asian origin of taro has been well documented (Matthews 2002). Evidence from the highlands of Papua New Guinea, indicates that taro processing was active by at least 10,000 BP (Lebot 2009), while *Alocasia* and *Colocasia* starch residues have been found on stone implements from Buka, Solomon Islands that date back some 28,000 years (Loy et al. 1992).

Current distribution worldwide

The species is now found throughout the Pacific islands and worldwide. For example, it is grown in New Zealand, Australia, and in the southern parts of Europe. In New Zealand, high quality pink taro is the focus, providing a supply for the large Samoan population. Most of the taro production in Australia occurs between Tully and Babinda in northern Queensland. According to FAO data (2007), West Africa (Nigeria, Ghana, Cameroon, and Ivory Coast) is the largest producing region. In the Pacific, although the combined production of *Colocasia* taro is small by world standards, it is the dominant root crop there.

Table 3. Distribution in the Pacific (PIER 2007)

American Samoa	Marshall Islands
Australia	Nauru
Christmas Island Group	New Caledonia
Chuuk	New Zealand (Aotearoa)
Commonwealth of the Northern Mariana Islands	Niue
Cook Islands	Norfolk Island
Fiji	Palau
French Polynesia	Papua New Guinea
Galápagos Islands	Pitcairn Islands
Guam	Pohnpei
Hawaiian Islands	Samoa
Kiribati	Solomon Islands
Kosrae	Tonga
Lord Howe Island	Tuamotu Archipelago
Makatea	Tuvalu
Mariana Islands	Vanuatu
	Yap

ENVIRONMENTAL PREFERENCES AND TOLERANCES

Climate

Taro grows in humid rainforest climates (Af), monsoon (Am) and tropical winter dry climates (Aw), and subtropi-

Left: Taro islet (*ma'a*) composed of organic material, Puluwat Atoll, Chuuk, Federated States of Micronesia. Both *Colocasia* taro (shown here) and *Cyrtosperma chamissonis* (giant swamp taro, often considered synonymous with *C. merkusii*)) are cultivated on the *ma'a*. July 1988. Right: Close-up of a 6-month-old swidden at 1,800 m above sea level, Kompiai, Western Highlands District, Papua New Guinea. Taro is harvested as needed 7–12 months after initial planting. Gardens are replanted with sweetpotato (*Ipomoea batatas*), pitpit (*Saccharum edule*), sugarcane (*Saccharum officinarum*) and other long-lived plants and remain in production for up to 2.5 years before abandonment to fallow. The heavy leaf cover may be effective in curbing soil erosion of steep slopes. 1967.

Table 1. Elevation, rainfall, and temperature for Hawai'i

Elevation range	**lower:** sea level **upper:** upper: 1,800 m (According to Martin 1984); up to 600 m in Fiji (Smith 1979)
Mean annual rainfall	**lower:** Optimum growth when rainfall exceeds 2,500 mm **upper:** None as cultivation technology (for example, ditching) can be used to remove excess water.
Rainfall pattern	Taro grows well in climates with summer, winter, bimodal, and uniform rainfall. Irrigation is used when and where needed. The plant would probably not survive if there were more than 4 months with rainfall of less than 40 mm/month.
Temperature	The preferred temperature range for maximum photosynthesis is 25–35°C. A lower temperature increases the days to maturity and reduces the size of the corm and the yield (Prasad and Singh 1991). Generally, an optimum mean annual temperature of 23–30°C is found in the literature. The minimum temperature of the coldest month is 10°C.

cal humid continental climates (Cfa) that have high rainfall throughout the year, although the species can do well without irrigation in climates where there is 1–2 months of low rainfall.

Soils

This species will grow in a wide range of moist to semi-moist soils with a pH range of 5.5–7.8. Some cultivars do best in deep, friable loams that have a high water table. Others prefer hydromorphic soils or flooded conditions, while some cultivars do well on sandy, mesic soils. On atoll islands such as Puluwat, this species is often cultivated on raised beds composed of decomposed organic materials (anthropic histosols); on Ulithi Atoll, *Colocasia* taro is cultivated in metal or cement tanks filled with organic matter and water, in raised beds, and as a dryland crop.

Many countries in the Pacific region grow taro using upland cultivation, where planting is aligned with the wet season. In Fiji, for example, taro is grown mainly in the wet areas where rainfall exceeds 2,500 mm. Cultivation occurs on both alluvial flat land as well as on fertile hillside slopes. Taro will also thrive in soil with a tendency to waterlogging or which is saturated for long periods.

GROWTH AND DEVELOPMENT

Growth, maturation and harvest period of *Colocasia* taro depends upon cultivar. After initial planting, growth rates are initially slow but increase rapidly 1–2 months after

Top: An 8–9-month-old *Colocasia* taro garden at Malhaha, Rotuma Island. Taro and other crops are often grown in small plots cleared from secondary forest. July 1987. Middle: A 2–3-month-old taro plot at Welmaas on Fais Island, Yap State, Federated States of Micronesia, elevation 18 m. Unlike the atolls, Fais is an upraised limestone island. All dryland taro cultivation relies on rainfall, as the freshwater lens is far beneath the soil surface. June 2008. Bottom: Taro, banana (*Musa* spp.), coconut (*Cocos nucifera*), and sago palm (*Metroxylon warburgii*) agroforest on Tutuila Island, American Samoa. April 2003.

planting; the most rapid leaf growth occurs 3–5 months after planting (Wilson 1984). Maximum leaf size and leaf area are attained at 5 months after planting, while maximum number of leaves is more variable. Peak leaf number varies between 3 and 7 months after planting and dependent on cultivar and cultural conditions. After peaking, leaf size, area, and number decrease as leaf senescence exceeds leaf production. Corm growth is initially slow. Maximum corm growth occurs 5–11 months after planting and continues to increase in size and weight as leaf area, leaf size and numbers decrease. Corms mature 6–9 months after planting and can last in the field up to 12 months after planting.

Corm yield and productivity is positively correlated to leaf area and the leaf area index (LAI, the ratio of leaf area to soil area). In general a LAI of 3 is considered to be full cover and the most effective in terms of light interception and thus, photosynthesis. However, the optimal LAI for *Colocasia* taro varies depending on cultivar, plant density, and water management. With furrow irrigation, the optimal LAI ranges from 4.6 to 6, although in many cases, the maximum LAI for *Colocasia* taro is usually 3 or less (Wilson 1984). Fijian studies have shown that “a LAI of 3 was not reached by two of the *Colocasia* cultivars studied until four months” after planting or later “and then maintained for only one and one-half to two and one-half months out of a 12-month growing season” (Wilson 1984).

If used, fertilizers should be applied during the pre-planting stage and in small applications after the onset of two leaves up to 5 months after planting. Artificial fertilizers should not be applied within tree months of harvesting (Berwick et al. 1972).

Flowering and fruiting

Inflorescences are axillary. There may be between two to five inflorescences per plant. In Malaysia, Ghani (1984) reports that the inflorescence appears after the first 10–12 leaves have been produced.

Some varieties have not been observed to flower and fruit. In fact, many varieties in the Pacific do not flower naturally especially in Polynesia, although they can be induced to flower with gibberellic acid, as previously noted.

Scale of commercial production worldwide

Table 5 contains 2007 worldwide production totals of taro, when the world’s annual production stood at over 10 million metric tons (MT). Table 5 data reflect both commercial and subsistence production because most taro is produced for subsistence purposes. Readers should be aware that the production figures for *Colocasia* are questionable as *Colocasia* and *Xanthosoma* taros are both reported as cocoyam, and as such the production of *Colocasia* taro for Africa and South America may be exaggerated. For Africa, it is quite possible that much of the *Colocasia* production figures reported are actually *Xanthosoma* where this species is very widely grown, and the FAO has no production figures for *Xanthosoma* from Africa. In addition, much of the *Colocasia* production for Asia, Southeast Asia, and perhaps other regions of the world, may be from *Colocasia esculenta* var. *antiquorum*.

Data from China, which is a leading producer of taro in Asia, was not available for inclusion in Table 5. Also missing because of incomplete reporting, lack of data, and the small scale of production are numbers from many Pacific islands. On a regional basis, production totals in the Pacific islands are much smaller than that of Africa and Asia. However, when compared to the production totals for all root crops such as sweetpotato, yam (*Dioscorea* spp.), and cassava (*Manihot esculenta*), *Colocasia* taro is the dominant for the Pacific islands.

Also missing from the FAO data is Australia, which now produces *Colocasia* taro in the Northern Territory, Queensland, and NE New South Wales. The Australian production is aimed with an eye toward the increasing population of Asians and Pacific islanders resident there and exporting to Japan.

Recent data (FAO 2008) indicate that the international market for taro is increasing. For 2005, the major exporting countries by quantity in decreasing order included China, Fiji, Thailand, the United States, Dominica, Samoa, Trinidad and Tobago, and Tonga. Major importing countries for 2005 by quantity in decreasing order included Japan, the U.S., American Samoa, Trinidad and Tobago, China, Macao, Thailand, Antigua and Barbuda, and Fiji.

In the Pacific, Papua New Guinea is the largest producer with more than 260,000 MT of *Colocasia* taro in 2007. Fiji has a thriving export market, which it inherited when taro leaf blight hit Samoa and wiped out their export market to Samoan communities living overseas.

Carton from taro exported from China to Hawai‘i through Los Angeles, California. February 2008.

Top left: *Colocasia* taro and *Cyrtosperma* taro in a concrete tank filled with water and organic matter on Falalop Islet, Ulithi Atoll, Yap. These tanks afford protection from salt water damage, a prevalent constraint for agriculture on atolls. This tank continues to produce taro to this day. January 1990. Top right: Dryland taro growing in a raised bed made with lava rocks. Hōʻōpuloa, South Kona, Hawaiʻi. June 2008. Middle left: Growing taro in a World War II-era aluminum landing barge on Falalop Islet. January 1990. Bottom left: Flooded taro fields in Waiheʻe Valley, Maui. October 2008. Bottom right: Raised beds over lava rock. The sides of the beds are made of black ground cover cloth attached to steel fencing. Pāhoa, Puna, Hawaiʻi. October 2007.

Table 5. 2007 production area harvested and yield of *Colocasia esculenta* taro (cocoyam) by region (FAO 2008b).

Region and Country	Production Quantity (MT)		Area Harvest-ed (ha)		Yield (0.1 kg/ha)	
American Samoa	9000	F	2500	F	36000	F
Fiji	38000	F	3200	F	118750	F
Kiribati	2200	F	450	F	48888	F
New Caledonia	400	F	125	F	32000	F
Niue	3300	F	440	F	75000	F
Papua New Guinea	260000	*	40000	*	65000	F
Samoa	17600	F	3600	F	48888	F
Solomon Islands	40000	F	2000	F	200000	F
Tonga	3800	F	450	F	84444	F
Wallis and Futuna Islands	1700	F	130	F	130769	F
—Melanesia +	338400	A	45325	A	74660	F
—Micronesia +	2200	A	450	A	48888	F
—Polynesia +	35400	A	7120	A	49719	F
Benin	2200	F	750	F	29333	F
Burundi	62000	F	15000	F	41333	F
Cameroon	1133000	F	205000	F	55268	F
Central African Republic	96000	F	36000	F	26666	F
Chad	39000	F	13000	F	30000	F
Comoros	9000	F	1300	F	69230	F
Congo, Democratic Republic of	65000	F	16200	F	40123	F
Côte d'Ivoire	355000	F	262000	F	13549	F
Egypt	112000	F	3600	F	311111	F
Gabon	56000	F	9500	F	58947	F
Ghana	1662000	F	261000	F	63678	F
Guinea	31000	F	4950	F	62626	F
Liberia	25000	F	3000	F	83333	F
Madagascar	200000	F	30000	F	66666	F
Mauritius	370		32		115625	F
Nigeria	5485000	F	725000	F	75655	F
Rwanda	130000	F	26000	F	50000	F
Sao Tome and Principe	27000	F	3000	F	90000	F
Sierra Leone	2600	F	1000	F	26000	F
Togo	14000	F	12000	F	11666	F
—Eastern Africa +	401370	A	72332	A	55490	F
—Middle Africa +	1416000	A	282700	A	50088	F
—Northern Africa +	112000	A	3600	A	311111	F
—Western Africa +	7576800	A	1269700	A	59673	F
Antigua and Barbuda	45	F	12	F	37500	F
Barbados	300	F	75	F	40000	F
Dominica	11200	F	1150	F	97391	F
French Guiana	4100	F	760	F	53947	F
Guyana	5250	F	650	F	80769	F
Saint Lucia	350	F	70	F	50000	F
Trinidad and Tobago	4900	F	480	F	102083	F
United States of America	1810		162		111728	F
—Northern America +	1810	A	162	A	111728	F
—Caribbean +	16795	A	1787	A	93984	F
—South America +	9350	A	1410	A	66312	F
Cyprus	2500	F	110	F	227273	F
Japan	195000	F	15500	F	125806	F
Lebanon	800	F	35	F	228571	F
Maldives	760	F	125	F	60800	F
Occupied Palestinian Territory	50	F	2	F	250000	F
Philippines	116500	F	19000	F	61315	F
Thailand	78500	F	7000	F	112143	F
Turkey	65	F	13	F	50000	F
—Eastern Asia +	195000	A	15500	A	125806	F
—Southern Asia +	760	A	125	A	60800	F
—South-Eastern Asia +	195000	A	26000	A	75000	F
—Western Asia +	3415	A	160	A	213437	F
World +	10304300	A	1726371	A	59687	F
Net Food Importing Developing Countries	1303480	A	445282	A	29273	F
Low Income Food Deficit Countries	11472300	A	1767700	A	64899	F
European Union	2500	A	110	A	227272	F
Least Developed Countries	763360	A	168375	A	45336	F
Land Locked developing countries	327000	A	90000	A	36333	F
Small Island Developing States	433475	A	59659	A	72658	F
Africa	9506170	A	1628332	A	58379	F
Americas	27955	A	3359	A	83224	F
Asia	394175	A	41785	A	94334	F
Oceania	376000	A	52895	A	71084	F

* = Unofficial figure; A = May include official, semi-official or estimated data; F = FAO estimate

For the Pacific, trade in taro is increasing and will continue to do so because of the number of projects that focus on market access and value chains. These value chain analyses will take into account all aspects of the value chain from cultivar identification for high value processing to postharvest handling. Opportunities for adding value will be investigated, such as partial processing nearer the point of production as well as flour production and other more durable, starch-rich products.

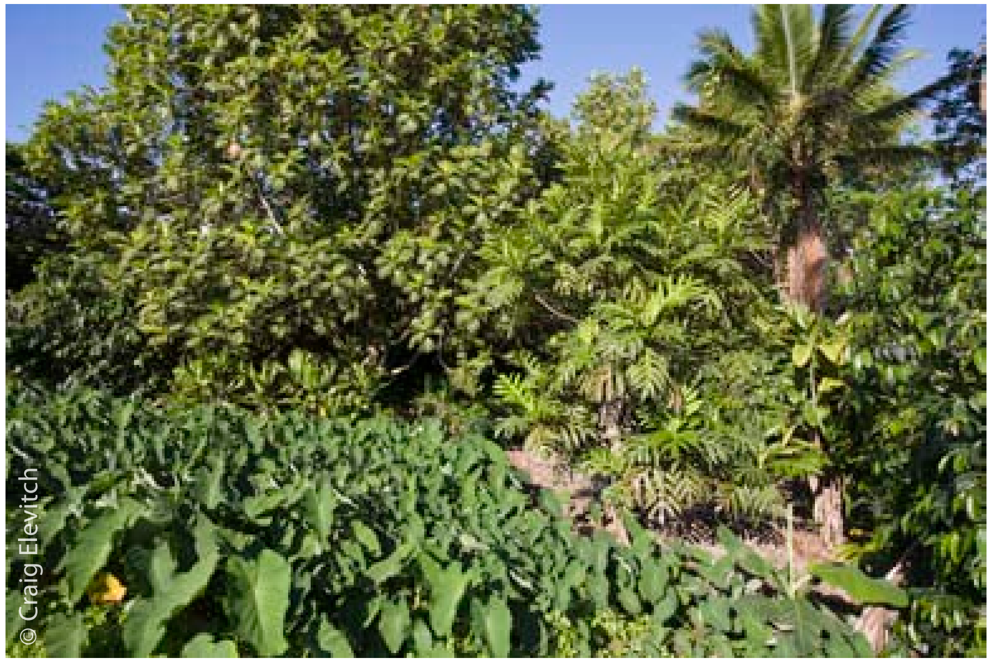
A RIRDC (Vinning 2003) study on the market potentials of Australian taro and other root crops for export to Japan and the U.S., notes that an estimated 3,000 MT are imported annually into Australia. Taro has been imported into Australia from Fiji and Tonga, and from Samoa prior to the taro leaf blight outbreak in 1993. New Zealand has imported taro from the Cook Islands, Fiji, Niue, Tonga, Samoa, Australia, Korea, Philippines, Thailand, and Vietnam. In 1997 the value of taro imports was NZ$8,772,583.

AGROFORESTRY AND ENVIRONMENTAL SERVICES

While this species can be found growing in pure upland (dry) and wetland monocultures (e.g., *lo'i* in Hawai'i), it is often found as an understory species in recently established swiddens (slash and burn gardens), along with yam and other crops that require fertile soils. In the Maring culture area of the Western Highlands of Papua New Guinea, these *daang-wan duk* (taro-yam gardens) are succeeded by longer lived species more tolerant of less fertile soils such sweetpotato, banana, sugarcane, etc. Monoculture production of taro tends only to occur for export production, such as in Fiji. In many countries in the Pacific, taro is a very common home/backyard garden crop and is grown with other crops/species, more in an agroforestry system.

Environmental services provided

The broad leaves are effective in reducing the erosive impact of raindrops on bare soil surfaces and they keep the soil cool and moist.



Left: Mokilese backyard garden at Nanier, Sokhes Powe, Pohnpei, Federated States of Micronesia. *Colocasia* taro in the foreground and *Cyrtosperma chamissonis* and bananas in the background. August 1989. Right: Small dryland taro patch growing with breadfruit, coconut, and coffee in Hōlualoa, North Kona, Hawai'i. April 2007.

PROPAGATION AND PLANTING

The planting materials are either setts or cormels. In most of the Pacific island countries, setts are prepared from mature corms and consist of the top 1 cm of the corm and about 20–50 cm of the petiole. Setts are also made from suckers in a similar fashion. Larger setts are preferred as they produce larger yields. Setts should be planted within a week of harvesting. All dead leaves and outer petiole bases should be removed, trimming to a new leaf inside.

A cormel is a small, immature corm produced by a more mature main or mother corm. Cormels or sucker corms are also used as planting material. For example, among the Maring cormels are the main propagative material used for planting dryland taro.

Planting material should be clean of pests and diseases. Virus-free material is important, as the presence of viruses can depress the yield of the crop. Ideally planting material should be sourced from virus-tested stock, or plants should be identified through positive selection.

Recommended outplanting techniques

Planting techniques vary with the system of taro cultivation, soils and climatic factors. In the Pacific, taro is grown either as a dryland, wetland or paddy, or patch taro. As a rainfed, dryland crop in slash and burn systems, planting techniques are relatively simple and require little disturbance to the soil. After clearing the forest cover, taro setts or cormels are planted in holes punched or enlarged in the ground with a dibble stick, then gently tamped down with the hands or feet. The ash from burning the vegetation and litter serves as a source of nutrients. Paddy or pond taro as exemplified by the Hawaiian *lo'i* is continuously flooded with slowly moving water. The *huli* are pushed into the mud to a depth of 20 cm or more by hand. Patch taro cultivation requires the construction of drainage ditches, turning and mounding the soil to a height of about 50 cm above the water table, and the incorporation of green manures into the organic soil (anthropic histosol), as in Palau

In Fiji, taro is grown mainly in areas where rainfall exceeds 2,500 mm. Both alluvial flat land and fertile hillside slopes are used for cultivation. A small degree of mechanization (using animal or tractor power) is used when taro is cultivated on flat lands, but cultivation on slopes relies mainly on

Setts prepared for planting.

Top left: Newly planted and mulched taro patch in a clearing in a banana-coconut agroforest in Tutuila, American Samoa. April 2003. Top right: In this waterlogged Palauan soil, pits were dug to form "mini wetlands" into which three setts were planted. June 2006. Middle left: Young plants growing in pits excavated in the lava rock substrate. Tutuila. April 2003. Middle right: Taro islets (*ma'a*) such as this one in Puluwat Atoll are composed entirely of organic materials constructed in depressions that expose the fresh water lens. July 1988. Bottom left: Newly planted setts in a paddy or *lo'i* in Hanalei, Kaua'i, Hawai'i. In *lo'i* systems, stagnant water and high water temperatures are avoided by maintaining a continuous flow of water. March 2008. Bottom right: Small-scale taro planting in home garden in Palau. The setts are planted between mounds of soil and mulched with banana, breadfruit, and coconut leaves. June 2006.

manual operations. Fijian taro tends to be grown in pure stands especially on slopes. Wetland or flooded cultivation occurs in some locations, but the majority of the crop is upland (not flooded) taro. Ideally planting is done in October–November when the rainy season is just starting, although some off-season planting occurs in March–June.

Two of 23 varieties of *Colocasia* taro being field tested in Rota Island, CNMI at Tongo Jungle by the Cooperative Research, Extension and Education Service, Northern Marianas College, Saipan. The varieties were propagated through tissue culture and were procured through the Regional Germplasm Center (now the CePaCT) of the Secretariat of the Pacific Community, Fiji. The varieties selected for the trials have superior agronomic characteristics (i.e., high yield, disease and pest resistance, vigorous growth, and good taste). January 2009.

CULTIVATION

Variability and known varieties

This is a highly variable polymorphic species which been vegetatively propagated for thousands of years. Handy (1940) listed a total of 346 varieties of taro in Hawaiʻi, which he compiled from his field notes and other lists. Handy also briefly described the colors of the junction of the petiole and leaf blade, petiole margins and the petiole base for 75 cultivars, most of which he had observed, collected and identified in native gardens. In another table he described the planting habitat (wet or dry), colors of the corm (*kalo*), petiole (*ha*), leaf margin (*lihi*), leaf (*lau*), months to maturity and remarks for 82 varieties. Only a few dozen Hawaiian varieties still exist today.

Bryan (1935) listed 18 varieties for Samoa. Papua New Guinea holds by far the largest field collection of taro, currently at 484 accessions (PAPGREN meeting, September 2009, Fiji). Manner (1981) found an average of 10 varieties of taro per 25 m^2 in 3-month-old swiddens at Kompiai, Papua New Guinea.

The 1998–2003 Taro Genetic Resources: Conservation and Utilization (TaroGen) project collected some 2,500 varieties from several countries in the region. A core collection was identified and this is now conserved in the Secretariat of the Pacific Community Centre for Pacific Crops and Trees (CePaCT). The CePaCT now holds over 850 accessions, the largest *in vitro* collection of taro globally. The TaroGen project showed that diversity decreased from west to east with the greatest diversity in Papua New Guinea. Significant diversity also exists in Solomon Islands and Vanuatu. Tolerance of taro leaf blight has been found in Palau. The main export cultivar in Fiji is Tausala ni Samoa, which is very similar to the cultivar that had been exported from Samoa called Niue.

The Taro Improvement Programme (TIP) located at the University of the South Pacific, Alafua Campus, Samoa is an excellent example of participatory varietal selection and plant breeding that has helped small farmers produce taro after taro leaf blight wiped out production there. The initial aim was to select varieties that had tolerance/resistance to taro leaf blight. This was achieved through a varietal selection process initially followed by conventional breeding. The focus is now extending to more climate change traits, such as drought and flooding tolerance. The program has recently made some crosses between Asian and Pacific taro, which have received excellent feedback from the farmers (Island Business 2008). Breeding programmes also exist in Vanuatu and in Papua New Guinea.

Some interesting Pacific island cultivars are briefly described below.

Alafua Sunrise

A yellow-fleshed cultivar developed at IRETA (Institute for Research, Extension and Training in Agriculture) at the University of the South Pacific in Alafua, Samoa. Yields are higher than cultivar Niue by 13–50% in most trials with the greatest advantage under conditions of drought and low soil fertility. This cultivar shows less symptoms of dasheen mosaic virus (DsMV) than other local cultivars (Wilson et al. 1994).

Bun Long

Also known as Chinese taro in Hawaiʻi, *Bun Long* is a wetland cultivar introduced from China and cultivated for table taro, chips, and leaf. It is now cultivated in Queensland and the Northern Territory of Australia. In 2006, 8 ha of the 154 ha of taro grown in Hawaiʻi was of this cultivar. The other 146 ha was used for growing poi taro.

Maui Lehua

A native Hawaiian cultivar of the dasheen type, with a reddish-purplish corm, used in the production of red poi and the most common commercial cultivar of taro grown in Hawaiʻi. This cultivar is cultivated in both upland and wetland conditions, but produces the best poi when cultivated in the wetlands. It needs 13–14 months to reach maturity. It has high calcium oxalate content (Nip 1997). Research suggests that the high oxalate content is responsible for this cultivar's tolerance for high levels of aluminum (Ma and Miyasaka 1998). *Maui Lehua* is highly susceptible to taro leaf blight. This cultivar was selected as the female parent for crossing with *Ngeruuch* to produce *Pāʻākala, Pāuakea*, and *Pālehua* described above (Trujillo 2002 a, b, c).

Ngeruuch

Palauan cultivar (also referred to as P10) with long stolons but highly resistant to taro leaf blight. The pollen from this cultivar was used to produce *Pāʻākala*, *Pāuakea*, and *Pālehua* described above (Trujillo 2002 a, b, c). This cultivar enabled Samoa to recover from the taro leaf blight which wiped out taro production in the early 1990s. The local cultivar, Niue, was very susceptible to the disease, as too were the other local varieties. *Ngeruuch* was highly recommended as a potential parent for the Samoan taro breeding programs for its higher level of resistance against taro leaf blight with good yield and eating quality (Iosefa 2010).

Niue

A popular cultivar that is widely grown taro in Samoa, presumably from Niue. Samoa calls their variety Niuean Pink to gain market cache. Fiji refers to this variety as Samoan Pink in order to retain its affinity with Niuean Pink.

Pāʻākala, Pāuakea, and *Pālehua*

These three varieties are crosses developed at the University of Hawaiʻi between *Maui Lehua*, a Hawaiian taro and *Ngeruuch* from Palau and for which U.S. patents were granted in 2002. All three varieties are characterized by a combination of resistance to taro leaf blight caused by *Phytophthora colocasiae* and tolerance of root rot caused by *Pythium* spp. They also have vigorous growth, large to extra large mother corm size, very good flour quality, and good poi and/or good eating qualities (Trujillo 2002a, b, c). After vigorous protests over the patents, the University filed three terminal disclaimers for the patents on June 16, 2006 (Ostrander and Gaines 2006). These hybrids are now available to be freely shared among growers.

Basic crop management

These vary with the system of taro cultivation used. In subsistence dryland systems such as slash-and-burn or forest and bush fallow systems, taro is usually one of the first crops planted in a newly cleared garden because it favors fertile soils and fertilizers are not readily available or used. Taro is rarely replanted as a succession crop without using some form of fertilizer/organic input.

In monoculture production more intensive crop management is obviously required. In Fiji, many taro cultivation areas have to practice control of taro beetle.

In some countries, the cropping system used depends on the location. For example, in the northern Cook Islands, which are coral in nature, taro is grown in brackish muddy water. Three kinds of cropping system are used to grow taro in the southern Cook Islands, which are volcanic in origin. These three systems comprise upland, paddy fields and raised beds. Similar systems exist throughout the Pacific.

a) Dryland cultivation is done with no free-flowing water beneath or around the taro. Clay-loam soil is preferred. Fertilizer or organic matter may be added.

b) Wetland fields or paddys are flooded fields to which water is diverted from rivers. The water flows constantly through the fields and is never allowed to be stagnant. Vegetation pulled up during weeding is incorporated into the mud as organic matter. The paddy is replenished by addition of new soil every few years.

b) Patch cultivation takes place on raised beds that are prepared so that water constantly flows around each bed, keeping the bed moist. Vegetation is incorporated into the bed during bed preparation and during weeding. The bed is mulched with coconut leaves, plastic sheets, banana leaves, or paper.

Advantages and disadvantages of growing in polycultures

There are significant advantages if taro is grown with other crops and also if more than one cultivar is grown, including an extended period of harvesting crops because of their different rates of maturation, more efficient use of vertical space, and the reduced risk of total crop loss resulting from pests or weather extremes, among others.

One study from Samoa (Rogers and Iosefa 1993) reported higher corm weight under 50% shadecloth (analogous to tree-cast shade) and greater weed suppression under tree shaded plots. In Samoa, where taro is intercropped with *Erythrina* spp., farmers ring-bark the tree upon planting taro so as to gradually decrease the amount of leaf shade as the tree dies (Iosefa 2010). By the third to fourth month, the growing taro is exposed to full sunlight. Preliminary data from Pohnpei shows that the growth of *Piper nigrum* may be higher when intercropped with *Colocasia* taro (Silbanus and Raynor 1993). They also suggested that weed pressure may be reduced as a result of this intercropping although a longer study period was needed for a definitive statement.

Top left: At the Agana Swamp in central Guam, Palauan migrants have grown *Colocasia* and *Crytosperma* taros since the mid-1970s using the *dechel* method of cultivation. The vegetation is cleared and taro is planted directly in the ground using a digging stick. Foreground mainly *Colocasia* with *Cyrtosperma* in the back. Other species on higher ground include bananas, betel nut (*Areca catechu*) and betel leaf (*Piper betel*). March 2000. Top right: Wetland taro cultivation in Agana Swamp. Here *Colocasia* taro is planted together with *Cyrtosperma* taro. October 2007. Middle right: In the traditional Paluan *mesei,* turning the soil and incorporating organic matter into the soil was assiduously practiced. Recently, these practices are being abandoned, replaced by a *dechel* system, which does not require turning the soil. Cultivation may be continuous in the *mesei* and *dechel* systems. Bottom left: A 3-month-old dryland taro plot at Welmaas on Fais Island, Yap, at 18 m elevation. Unlike the atolls, Fais is an upraised limestone island. All dryland taro cultivation relies on rainfall, as the freshwater lens is far beneath the soil surface. June 2008. Bottom right: Taro patch, Aunu'u Island, American Samoa (14º 17' S, 179º 33' W). Despite their geographic separateness, this Samoan taro patch functions in the same way as the Puluwatese *ma'a*, as pictured earlier. December 1989.

The advantages of polyculture production can be seen when considering the collapse of the taro export market in Samoa in 1993 when the one cultivar grown for the taro export market was 100% susceptible to taro leaf blight. Yields have also been shown to increase if alternated with legumes and other nitrogen-fixing plants.

Disadvantages of taro grown in polycultures are few if any, but may include reduced photosynthesis because of shading effects, a reduced production of taro per area of cultivated land (a function of lowered planting density), and increased skill needed for complex management systems. However, close planting of taro can reduce weeding effort because of shading effects.

PESTS AND DISEASES

Susceptibility to pests/pathogens

This species is very susceptible to a wide range of pests and pathogens, which may help explain the traditional practice of cultivating taro in cleared slash and burn gardens, intercropping, fallowing, as well as the selection in some parts of the Pacific for paddy cultivation.

Of the diseases found in taro, one of the most serious is *Phytophthora* leaf blight that reduces corm development 30–100%. In Samoa, *Phytophthora* leaf blight destroyed the taro export market in 1993. This disease is especially a serious problem in the humid tropics where the rainfall is greater than 2,500 mm per annum and there is little seasonal variation. This disease has also led to the decline of *Colocasia* taro in parts of Papua New Guinea and the Solomon Islands (Jackson 1980). Other serious diseases are *Pythium* rot, dasheen mosaic virus, and nematode diseases. Alomae-bobone complex is very serious and can lead to the death of the plants. It appears to be restricted to Papua New Guinea and Solomon Islands.

A very extensive list and discussion of the invertebrate (insects, snails, mites, etc) and vertebrates (birds, mammals), that damage the different parts of the taro plant is presented by Mitchell and Maddison (1983). Their tables include 140 invertebrate and two vertebrate pests of leaf, 16 invertebrate pests of the petiole, 36 invertebrate and three vertebrate pests of roots and corm, 94 invertebrate predators of taro pests, and a listing of invertebrates and vertebrates associated with aroid cultivation.

The taro planthopper, *Tarophagus proserpina*, caterpillars, and the taro army worm are among the most serious and widely distributed pests (Mitchell and Maddison 1983). Other serious pests of the Pacific region are taro beetle (*Papuana spp*.), whitefly (*Bemisia spp*.), taro hornworm (*Hippotion celerio* L.), cluster caterpillar (*Prodenia* [*Spodoptera*] *litura* F), and spider mite (*Tetranychus* spp.) (Howel 1982). Some of these pests transmit virus diseases, e.g., the taro planthopper that transmit *Colocasia* bobone virus and possibly a related virus, taro vein chlorosis rhabdovirus. Taro beetle is a significant problem in some of the islands of Fiji and Vanuatu. The impact of beetle feeding is considerable, as export markets do not tolerate any damage and more than 15% will make the crop unacceptable for local markets. Further information on taro pests and diseases in the South pacific can be found in TaroPest (Carmichael et al. 2008).

In Hawai‘i, the common fungal diseases of the leaf are *Phytophothora* Leaf Blight (*Phytophthora colocasiae* Rac.), *Phyllosticta* leaf spot (*Phyllostictsa colocasiophila* Weedon), and *Cladosporium* leaf spot (*Cladosporium colocasiae* Sawada). Significant fungal diseases of the corm include *Pythium* rot (*P. myriotylum* Drechsler), *Sclerotium* or Southern blight (*Sclerotium rolfsii* Sacc.), M*arasmiellus* sp. corm dry rot, Black rot (*Ceratocystis fimbriata* Ell. And Halst.), and *Rhizopus* rot. A bacterial soft rot caused by *Erwinia* sp. produces a soft, watery, and foul-smelling corm (Evans 2008). Dasheen mosaic virus, root knot nematode, the physiological condition known as loliloli are also found. A major pest of taro is the taro root aphid. Minor pests include the apple snail (*Pomacea caniculata*), crayfish, aphids, taro plant hoppers (*Tarophagus prosperina* and *T. colocasiae*), mealybugs, and the Chinese rose beetle (Evans 2008).

Preventing pests and diseases

A wide range of sustainable methods for pest and disease management in use in many of the Pacific islands can be found in Vargo (1993). These include intercropping crop rotation, field rotation, adjusted planting times, applications of lime and ash, mulching with organic matter, and fallowing. Maintaining high varietal diversity in the field may be beneficial although this needs to be tested.

Disease management practices also include selecting disease free planting materials, selecting resistant cultivars, and removal of infected materials to name a few. Sustainable methods of insect management also include hand removal of pests, torching of infested plants with flaming coconut fronds, burning infested leaves, and using soap-bleach solutions.

A cautionary note

Many traditional Pacific island agroforestry systems are characterized by high species and cultivar diversity, which some experts believe fosters agricultural sustainability and stability. For example, Altieri (1999: 29) wrote that correct "biodiversification results in pest regulation through restoration of natural control of insect pests, diseases and nematodes and also produces optimal nutrient recycling and soil conservation by activating soil biota, all factors leading to sustainable yields, energy conservation, and less dependence on external inputs." While the relationship between biodiversity and stability is appealing, Lebot's (1992) study is instructive.

According to Lebot (1992: 310), many of the traditional food plants of the Pacific are losing their positions in the traditional cropping systems because of historical and environmental factors and their genetic vulnerability to pests and pathogens which results in the "rapid deterioration in yield potential and agronomic performance." Traditional food plants such as taros (*Colocasia esculenta* var. *esculenta*, *Alocasia macrorrhiza*, and *Cyrtosperma chamissonis*), sugarcane, yam, seedless breadfruit, and bananas are the clones of vegetatively propagated plants that do not produce viable seeds. The many different cultivars of these traditional plants in Polynesia and Micronesia are the clonal descendants of the very few zymotypes (proteinase patterns). As an example, only three zymotypes were identified in a group of 149 Polynesian cultivars of *Colocasia* taro, an indication that their morphological variation is controlled by very few genes" (Lebot 1992: 313).

Polyculture and intercropping of different crop species provides some protection because pest and pathogens are not able to increase in populations to destructive levels on isolated individuals of a species. Abandonment of the subsistence garden to fallow further keeps pest populations low. However, these pests and pathogens, some of which are polyphagous and have different hosts, remain in relict plants in surrounding the area for future population increase and garden damage when the site is replanted (Lebot 1992). Lebot also argues that the selection of cultivars for disease resistance by traditional farmers is ineffective and inefficient because the planting materials and the agroecosystems themselves are infected by pathogens from previous cultivation cycles. This results in poor agronomic performance of the traditional food plants of the Pacific islands and their replacement by higher yielding crops such as sweetpotato, cassava, and *Xanthosoma* taro. Other factors, including continuous cropping, the loss of natural and socio-cultural barriers, improvements in interisland transportation systems, to name a few, also lead to the spread of infected plants, and their pathogens and diseases.

In brief, the majority of Polynesian and Micronesian cultivars of *Colocasia* taro that were derived from a narrow genetic base are very susceptible to today's pests and pathogens.

DISADVANTAGES

Good harvests require fertile and moist soils during the growing period as well as high amounts of potassium, nitrogen, and phosphorus. Generally, taro requires a heavier input of labor for weeding and cultivation than other root crops, particularly cassava. Taro is susceptible to weed competition in the early growth stages (Plucknett 1982).

Potential for invasiveness

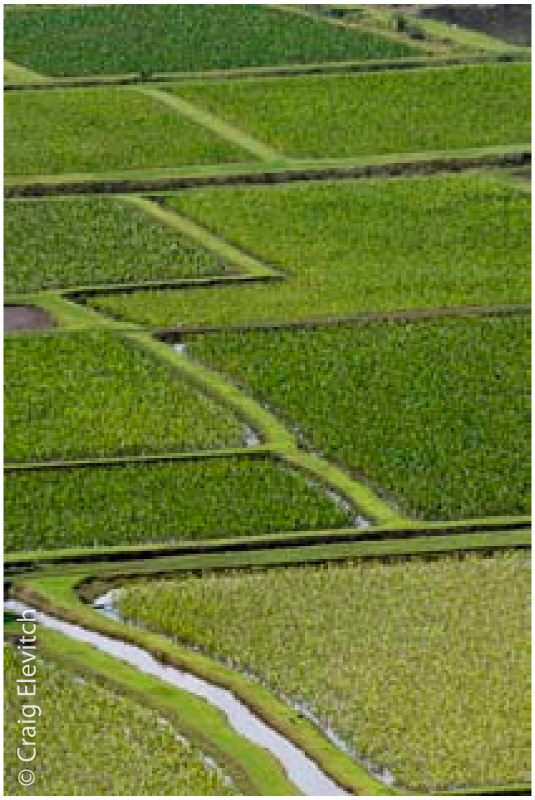
For the Pacific islands, PIER (2008) lists *Colocasia esculenta* as an invasive species in the major islands of Hawai'i except for Kaua'i, Lord Howe Island, Santa Cruz Island and San Cristobal Island in the Galapagos Islands, Raiatea and Tahiti Islands in French Polynesia, Kermadec Islands, Raoul Island, and New Zealand. In the other countries and islands of the Pacific, taro is not considered an invasive species.

In Florida, *Colocasia esculenta* (wild taro) is listed by the Florida Exotic Pest Plant Council (FLEPP 2007) as a Category I invasive exotic which by their definition is "altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives."

Table 5. Number of cultivars for the major vegetatively propagated food plants of the Pacific islands of SE Asian and/or Papua New Guinean origins (Lebot 1992)

	New Guinea	Solomon Islands	Vanuatu	Fiji	New Caledonia	Tonga	Samoas	Tuvalu	Cooks	Tahiti	Hawai'i	Pohnpei
Colocasia esculenta	452	262	154	72	82	14	28	13	91	35	82	15
Cyrtosperma chamissonis	NA	NA	1	1	0	0	12	23	0	0	0	24
Alocasia macrorhiza	2	4	3	2	3	9	19	2	2	1	1	10
Dioscorea alata	159	238	136	89	111	16	12	1	8	4	2	157
Dioscorea esculenta	94	117	17	16	23	1	2	2	1	2	1	13
Dioscorea nummularia	8	31	9	1	12	0	6	0	0	4	1	7
Piper methysticum	4	0	82	12	0	7	6	0	1	4	12	2
Artocarpus altilis	NA	140	132	20	16	10	25	12	8	30	1	50
Musa spp.	420	NA	52	26	NA	25	28	4	28	18	23	55
Saccharum officinarum	244	5	4	13	20	2	2	1	NA	4	31	16

NA = Not available



Left: In this ancient Palauan cultivation system, there is a large variety of species and cultivars. Use of fallow and addition of organic matter help build soil fertility. June 2006. Middle and right: In this modern monoculture where a single species and cultivar is grown and high chemical inputs are used, there are constant problems with pests and diseases. A single pathogen could halt production. Hanalei, Kauaʻi, Hawaiʻi. March 2008.

COMMERCIAL PRODUCTION

Postharvest handling and processing

Corms of some varieties can be stored in the ground for up to 3–4 weeks after reaching maturity. Harvested taro corms can be stored for a considerable length of time if they are thoroughly cleaned, washed, and drained before storage. Refrigeration will prolong the life of the corms. Poi taro cannot be stored for any considerable length of time without seriously impairing its quality, whether for poi or table use (de la Peña, R.S. 1998), although poi that has naturally soured for a few days is preferred by many people. Young taro leaves for *lūʻau* or *laulau* can be harvested at any time during the growth of the crop and stored refrigerated.

Small-scale processing

In the Pacific, the value-added products made from the taro corm are chips, fresh and dried poi, taro flour, canned taro leaves and preparations. Other potential taro products are starch, mucilage, frozen chunks and patties, peelings for mulches and animal feed Nip (1990). Taro flakes and frozen taro cake are available in Taiwan and frozen taro chunks in China (Nip 1990). Vivid purple taro ice cream is common in Japan, Taiwan, Hong Kong, and Singapore (Vinning 2010). There has been considerable research on the use of taro leaves for silage.

Of these value-added products, taro chips are the most widely processed product in the Pacific islands, with about eight small companies in Hawaiʻi, at least three in Samoa, and one large U.S. mainland producer. Poi manufacturers are mainly limited to Hawaiʻi. At least two companies in Hawaiʻi produced dehydrated poi powder, which can be exported as a non-allergenic baby food. Further, because taro starch is small grained, it may be suitable for the plastics and cosmetic industries. Research into its physiochemical properties could result in other opportunities.

Chips

Taro chips made from sliced and dried taro are produced widely thoughout the Pacific islands. Details, preparation and processing directions, and equipment for the commercial production of taro chips for a hand-labor, small-scaled operation mainly for Hawaiʻi can be found in Hollyer et al. (2000) and Evans (2008). Equipment costs depend on production scale and other factors, such as health department regulations for commercial kitchens. Hollyer et al. (2000) recommends equipment totaling about $15,000–$20,000. On the other hand, a Samoan woman has been successful in producing taro chips on an initial South Pacific Business Development loan of $875 for a stove and materials (Kiva, undated).

Poi

Poi, a viscous food, is made from cooked taro corms. While Hawaiians made poi for many traditional cultivars, most poi today is made from three cultivars, *Lehua maoli*, *Maui lehua*, and *Moi*. These cultivars are grown in *lo'i*. In 1947 the data in Evans (2008) showed that the total area under taro cultivation was slightly more than 400 ha (1,000 acres). By 1993, the total area under taro cultivation had decreased to 206 ha (510 acres) of which only 119 ha (295 acres) were planted with poi taro (NASS 1998). Today only 150 ha of poi taro are cultivated (NASS 2009). In addition, during the early 1900s in Hawai'i, poi was mainly produced on-farm by many individual taro farmers. Today, by contrast, only a few taro farmers produce poi, while a handful of companies make poi for the entire state.

While the demand for poi is high, there are a number of obstacles to new startups succeeding due to the shortage of viable wetland taro area, the high cost of land, and the heavy labor requirement for wetland taro cultivation, to name a few. Processors may succeed with high-value specialty poi made from *'Ele'ele Naioea*, *'Ele'ele Makoko*, *Piko 'Ula'ula*, *Pi'iali'i,* or *Kaī 'Ala*. These cultivars have unique characteristics in color, fragrance or taste and fill the demand for high quality, traditional poi.

Flour

Taro is an excellent source of starch and dietary fiber but low in fat, protein, and ash (Tagodoe and Nip 2007). Nip (1990) suggests that taro corms deemed unsuitable for the fresh taro market or taro chips can be converted to flour, starch, or mucilage. The flour can be used in making "taro bread, taro cookies, *kūlolo*, baby food, pasta, instant or flavored poi, or other products" (Nip 1990: 4) Some of these products are suitable for shipping due to their long shelf life at room temperature.

Product quality standards

No U.S. or international standards regarding the grades, sizes and packaging of taro exist. Paull and Chen (2004) note that corms are often graded by size, skin color, shape and flesh texture. They are frequently packed in 22.5 kg (50 lb) cartons, crates, or sacks. Dasheen, with its small corms, may also be sold in 4.5 kg (10 lb) cartons.

Import and quarantine regulations vary from country to country. Imports into New Zealand and Australia must pass stringent requirements. Corms must weigh 0.8–1 kg, scraped clean, washed clear of soil, de-eyed, tailed, trimmed to 5 cm of top, packed in 30 kg bags, and under quarantine inspections (Vinning 2003).

Product storage requirements and shelf life

Roots must be eaten within 2 days of removal to ambient temperature (Snowdon 1992) and storage life is decreased with higher temperatures. Cooling and good ventilation prolongs shelf life. Paull and Chen (2004) write that taro should be room-cooled to 10–14°C (50–57°F) and recommend storage at 7–10°C (45–50°F) with 80–95% RH for up to 18 weeks.

After harvesting, attention to careful handling and storage can extend the shelf life of the product, as mechanical in-

Top: Harvesting taro from a *lo'i* at Waipi'o Valley, Hawai'i Island. Changes in lifestyles, the high cost of land, the heavy work demands for growing taro using this method, and other factors have led to a reduction Hawai'i's wetland taro production. 1970. Bottom: Open canopy planting of *Colocasia* taro at Salailua, Savai'i, Samoa. *Pate* (*Coleus blumei*) is planted around and within the plot to repel or attract the taro planthopper (*Tarophagus proserpina*). The invasive species *Merremia peltata* is visible at the bottom left of the photo. December 2003.

Left: Taro corms and leaf are traditionally sold shortly after harvest. There are methods that can extend their shelf life. Apia, Samoa. September 2005. Middle: Storing leaves under refrigeration can extend their shelf life to at least 2 weeks. Right: Fresh leaves for sale at Apia market. September 2005.

jury during harvesting predisposes the corm to pathogens in storage. Corms can be stored for 4–5 months at 7–10°C if harvested and handled carefully (Masalkar and Keskar 1998). Good air circulation and treating corms with fungicides can reduce storage rot caused by bacteria and fungi such as *Phytophthora colocasiae*, *Pythium* sp., *Botryodiplodia theobromae*, *Ceratocystis fimbriata, Corticium rolfsi*, *Aspergillus niger*, *Fusarium solani*, *Rhizopus stolonifer,* and *Sclerotium rolfsii* (Masalkar and Kaskar 1998; Humanity Development Library 2008). After fungicide dipping, drained and air-dried corms can be packed in polyethylene bags for shipping. Benomyl and sodium hypochlorite are effective against the most common decay organisms. Such bags, packed in banana-type cartons and shipped at ambient temperatures have a storage life of 26–40 days. It should be noted that fumigation shortens the storage life of taro.

Storage of the corms under conditions that allow desiccation is not recommended, as moist conditions that keep corms physiologically active promote curing of wounds and minimise water loss. Taro appears to suffer chilling damage at 3–5°C, where it is expected to keep only 5–6 weeks, but, in Egypt, taros are successfully stored for periods of 12–15 weeks at 7°C.

Jamaican exports of fresh taro to the U.S. are "hardened" by lying on the ground for a period of time after being uprooted. This process toughens the skin and reduces the amount of bruising during transport.

Folded taro leaves packed in low density polyethylene bags and stored at 10°C can last for 2 weeks, while unpackaged leaves will turn brown-yellow after 8 days and lose weight due to the lower humidity. Chilling injury was observed as browning discoloration after 12 days at 3°C (CQ University 2008; Sankat et al. 1995).

Recommended labeling

Labels should be educational and pique the interest of the consumer. Other items to include are recipes, handling instructions, certifications such as organic, variety, and the name and contact information of the producing farm. Labels should be attractive and colorful.

Genetic modification (GM) of taro in Hawai'i is a highly sensitive issue that has spurred legislative attempts to ban experimentation and development of GM crops. This reflects the attitude to GM crops throughout the Pacific island region. The question of informing consumers on GM contents in processed foods is ongoing. Since 2001 Australia and New Zealand have enacted stringent regulations concerning the sale and labeling of genetically modified (GM)

There has been a strong popular movement in Hawai'i and throughout the Pacific to stop use of genetically modified taro.

Top left: Taro cultivation on 16–20 m^2 soil mounds resting on soapstone in the periurban suburb of Tamavua, Suva, Fiji. The taro is planted for the Suva market. 1981. Top right: Petioles and leaves of "red taro" drying on the clothes line in Sinapalu Village, Rota Island, Commonwealth of the Northern Mariana Islands. The partly dried leaves will be shredded and cooked with coconut milk, pork, and spices to make *laing*, a Filipino taro dish. January 2009. Bottom left: Six-month-old field of *Colocasia* taro at Sabana, Rota Island. Taro and sweetpotatoes are the two major agricultural exports of Rota. The two weeds are *Ageratum conyzoides* and a recent invasive, *Mimosa invisa*. January 2009. Bottom right: At roadside stands and at the airport gift shop on Rota Island, 11.3 kg (25 lb) bags of cleaned and washed taro can be bought for $20. Travelers often take bags of taro and sweetpotato to friends and relatives on Guam. January 2009.

foods. Such foods must by evaluated and approved as safe to eat by the Food Standards Australia New Zealand (FSANZ). All GM foods must be identified on food labels. In Hawai'i, given significance of *kalo* in Hawaiian culture and the controversy over GM taro, Hawai'i and Maui Counties have banned the testing, propagation, introduction and cultivation of genetically modified crops. There are also safety concerns over the effects of genetically modified foods. It is only appropriate that food labels indicate whether or not the food item is genetically modified.

Processed taro product labels should contain nutritional information and list of ingredients. Other information could include details on location of origin, processing, storage recommendations, weight, harvest date, shelf life, etc.

SMALL SCALE PRODUCTION

In many parts of the Pacific, taro is grown in small plots or as a part of a polycultural system. In Tamavua suburb in Suva, Fiji, taro was intensively grown for the market on small mounds of soil approximately 16 m^2 in area and 0.5 m high. In his discussion of urban gardening, Thaman (1990:46) notes that *Colocasia* taro is "particularly well suited to urban conditions, because it can be grown on small plots, either as

Table 6. The nutritional content of poi (taro and water)

Serving size: ⅓ cup (90 g). After mixing with water: 5/8 cup (140 g).

	Amount	% Daily Value*
Calories	70	
Total Fat	0 g	0%
Saturated Fat	0 g	0%
Cholesterol	0 mg	0%
Sodium	30 mg	1%
Total Carbohydrate	18 g	6%
Dietary Fiber	2 g	8%
Sugars	0 g	0%
Protein	0 g	0%
Vitamins A & C		Less than 2%
Calcium		2%
Iron		4%

*Percent Daily Values are based on a 2,000 calorie diet
Source: HPC Foods Ltd (n.d.)

a staple for its corms or for its leaves…" Simply put, the crop is well suited to small-scale commercial production.

Household use in the Pacific

The crop is extensively used in almost all households throughout the Pacific islands if available and affordable. It is a preferred starch, although rice, noodles, and cassava have largely replaced taro. It is less commonly eaten in the Solomon Islands.

Nutrition

The corm is high in carbohydrates and potassium, but low in calories. A half a cup of cooked leaves provides 97% and 39% of the U.S. RDA of vitamins A and C, respectively (Yokoyama et al. 1989). Taro with yellow-fleshed corm contains higher levels of beta-carotene than the corms with white flesh. High levels of beta-carotene support vitamin A production, important for a healthy immune system. Foods containing high levels of carotenoids have been shown to protect against chronic disease, including certain cancers, cardiovascular disease, and diabetes (Englberger et al. 2003).

Given its nutritional value and digestability (98.8%) and because it is a hypoallergenic starch, *Colocasia* taro in the form of poi makes an excellent food for babies and the elderly. Taro has a low glycemic index and as such is an excellent food for diabetics, who require glucose to be released into their bloodstream slowly. All parts of most cultivars contain calcium oxalate, which is destroyed by lengthy cooking. Additional nutritional information on various taro parts and preparations are presented in Table 7. Other data can be found in Murai et al. (1958), Parkinson (1984), Standal (1983), English et al. (1996), and Kumar et al. (2001).

Left: Locally processed breadfruit, taro, sweetpotato, and cassava chips. Hakalau, Hawai'i. Middle: Primary traditional starches taro, breadfruit, and sweetpotato for sale at farmers' market in Tongatapu, Tonga. April 2003. Right: Volunteers pound poi the traditional way for a cultural festival at Amy B.H. Greenwell Ethnobotanical Garden in Captain Cook, Hawai'i. February 2009.

Table 7. Nutrient composition of taro (*Colocasia esculenta*).

	Edible Portion g	Water g	Energy kj	Energy kcal	Protein g	Total Fat g	CHO available g	Dietary Fiber g	Cholesterol mg	Sodium (Na) mg	Potassium (K) mg	Calcium (Ca) mg	Magnesium (Mg) mg
Taro leaves raw	52	83.3	155	37	5.8	1.3	0.9	5.7	0	5	748	276	47
Taro leaves boiled	52	91.3	98	23	3.8	0.6	0.7	n/a	0	5	305	214	24
Taro stems raw	97	94.5	48	11	0.7	0.3	1.6	2.1	0	12	393	46	28
Taro corm raw, peeled		65.7	526	126	1.1	0.4	28.0	2.1	NA	25	487	16	35
Taro corm lovo		66.0	524	125	1.1	0.4	27.5	2.9	NA	25	521	19	37
Taro corm boiled		73.4	389	93	0.9	0.3	20.3	2.2	NA	19	329	12	28
Taro chips Lelei Brand		1.3	2131	509	6.7	29.4	51.6	6.6	NA	435	1783	5	76
Taro chips Tausala Br.		1.0	2399	573	2.4	38.3	53.0	5.1	NA	271	564	9	55
Corm		75.4–73.1		94–102	1.80–2.20	0.01–0.40	21.0–23.8	0.80–1.00		10.00	448.00	34–51	
Leaves		92.7		24.0	0.5	0.20	5.8	0.9		4.0	334	49	

	Iron (Fe) mg	Zinc (Zn) mg	Copper (Cu) mg	Manganese mg	Total Vitamin A Equiv. µg	Retinol µg	ß-Carotene Equiv. µg	Thiamin mg	Riboflavin mg	Niacin mg	Vitamin C mg	Phosphorus mg	Ash g
Taro leaves raw	2.8	0.6	0.2	6.9	1015	0	6090	0.08	0.216	1.2	81		2.2
Taro leaves boiled	1.7	0.3	0.1	6.0	828	0	4973	0.06	0.13	1.0	20		1.1
Taro stems raw	1.2	0.3	0.3	3.7	34	0	201	Trace	Trace	Trace	4		0.9
Taro corm raw, peeled	0.5	1.5	0.2		<5	NA	<5	0.11	0.02	1.3	<1		1.1
Taro corm lovo	0.6	1.2	0.3		NA	NA	NA	0.07	<0.02	1.3	NA		1.1
Taro corm boiled	0.3	0.8	0.2		NA	NA	NA	0.07	<0.02	0.9	NA		0.8
Taro chips Lelei Brand	1.3	2.0	0.8		<5	<5	<5	0.26	0.02	3.6	<1		3.8
Taro chips Tausala Br.	0.9	1.1	0.6		<5	<5	<5	0.17	0.04	1.1	5		1.9
Corm	1.20						Trace	0.1–0.12	0.03–0.04	0.8–1.0	8.0	62–88	1–2
Leaves	0.9						180	0.02	0.04	0.4	13	25	0.8

Data for first three rows from: English et al. (1996), with ash data from Kumar et al. (2001). Data for rows 4–8 from: Kumar et al. (2001). Data for rows 9 and 10 from Martin (1984).

Import replacement

As discussed above, taro is a highly nutritious crop. It is believed that one of the contributing factors to the alarmingly high fatality rate from non-communicable diseases in the Pacific is the move away from the traditional foods such as taro to increased consumption of nutritionally poor foods, such as white rice, refined sugars, and fats. Increased production of taro on family farms could help replace retail purchases and/or off-island imports, provided the economics were favorable. The low cost of white rice and its convenience makes it attractive, and these issues have to be addressed as well as increasing productivity.

Table 8. Comparative features of taro cultivated in Fiji (Vinning 2003).

Attribute	*Wararasa*	*Tausala ni Samoa*
Yield	30–32 MT/ha	12–13 MT/ha
Time to maturity	7–9 months	9–12 months
Corm weight	1–2 kg	0.7–2 kg
Corm dry matter	30–35%	31%
Sucker	5–6 per plant	3–4 per plant

YIELDS

Average 2007 yield worldwide was around 6.0 MT/ha, but the U.S. and Japan reached 11.2 and 12.6 MT/ha respectively, and Egypt reported yields of 31.1 MT/ha (see Table 4). Example yields in Pacific island countries are from 11.9 MT/ha for Fiji to about 6 MT/ha for Papua New Guinea.

Yield fluctuates with cultivar, planting density, fertilizer application levels, and natural and cultural factors. Yield data for individual plants are not readily available. In most cases, yields are expressed in MT/ha and unless the planting density is given, it is not possible to determine the average yield per plant, although with proper irrigation or abundant rainfall and good soil fertility, corms weighing between 6 kg and 10 kg could be possible.

In one study from the Philippines, the yields of the two cultivars *Kalpao* and *Lehua* were shown to vary with planting density and fertilizer application levels. In all cases *Kalpao* out-yielded *Lehua* (Pardales and Villanueva 1984). In another example comparing two upland Hawaiian cultivars, *Lehua Maoli* (a poi taro) was shown to out-yield *Bun Long* in all treatments of nitrogen fertilization levels, age at initial cutting, and cutting intervals (de la Peña and Melchor 1984). The effect of cultivar differences on yield and other factors from a Fijian study are shown in Table 8.

Newly planted setts in a *lo'i* in Hanalei Valley, Kaua'i. Cultivar, planting density, and management methods all influence yield.

Recommended planting density

Planting density affects yield per area and individual plant size. Generally, increasing density results in smaller corm size, but can improve overall yield. In addition, the response of genotypes to planning density can vary and the traditional cultivars are better suited to intermediate densities. To a large extent, planting densities depend on market demand and the purpose for production.

Recommended spacing varies, ranging from 30 cm × 30 cm up to 120 cm × 120 cm (CQ University, undated). Planting densities are quite variable both within and between regions. In New Caledonia a density of 15,000–19,000 plants/ha is recommended while in Hawai'i planting densities lie between 7,000 to 35,000 plants/ha (Lambert 1982). Lambert (1982) recommends planting at least 8,000 plants/ha in order to make production worthwhile. Recommended distances are "usually 90 cm × 90 cm (12,000 plants/ha) or 90 cm × 60 cm (26,900 plants/ha)."

For Fiji, 60 cm × 60 cm has been shown to give maximum yields of marketable tubers, although where mechanization is practiced, rows 100 cm apart and plants at 45–60 cm apart in the row (26,900 plants/ha) are recommended (Humanity Development Library 2008). In Papua New Guinea, trials using the cultivar *Numkoi* planted at a spacing of 1 m × 0.25 m produces a 66% yield increase from the standard spacing of 1 m × 1 m (Gendua et al. 2001). Mechanization requires a minimum row spacing of 90–100 cm to allow for inter-row cultivation. This results in a planting density of 17,930 plants/ha (Vinning 2003). Even closer spacings are possible, provided artificial fertilizers are added. Typical spacing in paddy culture is usually 45–60 cm (27,000–49,000 plants/ha) (Humanity Development Library 2008).

MARKETS

Local markets

Because of the cultural relationship of taro with many of the cultures of the Pacific islands, there is widespread interest in this traditional food plant. In Hawai'i, for example, *kalo* symbolizes the Hawaiian cultural renaissance. Taro's cultivation commands the attention of students and visitors interested in ethnobotany, cultural studies, and agriculture. Many commercial taro farms foster agritourism and encourage visitors to learn about taro cultivation and at the same time sample and buy their products. Tourists can also visit the various taro industries where poi, chips, flour, bread, baby food and other industrial products are manufactured.

Roadside markets are on the increase in Pacific island countries. Roadside sales, often on the back of a pickup truck, are inexpensive venues where small farmers can market their produce and make a profit with their surplus. Customers who question the safety of genetically modified plants or prefer organically certified produce can meet the farmer at such markets and ask about the origin of their taro variety and the cultivation methods used.

The recent upswing in food prices as a result of increasing energy costs may spur greater interest in home gardening and small local market development and sales as cost savings measures. This has already been seen in Fiji and other Pacific island countries, especially those who have grown to be more dependent on imported food.

Agricultural field days are very well attended in many islands. On Moloka'i, Hawai'i, the Cooperative Extension Service holds an annual Taro Variety Field Day each Fall. The event promotes some of the rarest native Hawaiian taro varieties, educates visitors about the varieties and the importance of taro in Hawai'i, and encourages the visitors to take the varieties home to cultivate and perpetuate them (Arakaki 2008). Similarly, the East Maui Taro Festival celebrates the cultural significance of taro through demonstrations and other activities (Lilly 2008). Taro festivals are an excellent example of how to promote taro as a nutritious food and also to promote the importance of dietary diversity. Taro festivals do not take place in other Pacific island countries, although taro is included in diversity fairs, which are quite common in the Solomon Islands.

Export market

Worldwide taro imports are presented in Table 9. Caution should be exercised, as the data are incomplete and may include other aroids in addition to *Colocasia* taro. Generally, it is difficult to find complete and up-to-date information on the taro imports and exports for Pacific islands. Fiji, Tonga, Solomon Islands, Kiribati and Samoa produced 125,000 MT in 2007 (FAOSTAT 2009), but of these countries only Fiji is a significant exporter. Australia and New Zealand are the two major destinations for Pacific taro exports. The USA is also a significant market with imports of US$2.6 million from Fiji in 2006. Per Table 9, Japan is the largest importer of taro.

Table 9. Taro (*Colocasia esculenta*) imports quantity (MT) and value ($1,000) (FAO 2008a).

	1990 Quantity	1990 Value	2000 Quantity	2000 Value	2005 Quantity	2005 Value
American Samoa	1600 F	245	3000 F	447 F	3000 F	447 F
Antigua and Barbuda	0	0	0 F	0 F	50	46
Azerbaijan					0 F	0 F
Bangladesh			0 F	29 F	0 F	0 F
Barbados	60	9	122 F	116	0 F	0 F
China	1	1	252	4	921	574
China, Macao SAR			18	0	250 F	40 R
Estonia			0	0	0 F	0 F
Fiji	24	21	0	0	0	2
Japan			55873	53536	46276	43370
Kazakhstan			0	0	0 F	0 F
Maldives	0	0	0	0 F	0 F	0 F
Russian Federation			0	0	0 F	0 F
New Caledonia					0 F	0 F
Saint Lucia			0	0	0 *	0 F
Saudi Arabia	412	156	0	0	0 *	0 *
Thailand	3	2	11	8	61	55
Trinidad and Tobago	1233	437	663 *	570	979	623
United States	21515	12122	38695	33291	39215	36295

* = Unofficial figure; F = FAO estimate; R = Estimated data using trading partners database

Note: For 2005, Belgium and Luxembourg appear in the listing, but with either no values or quantities were indicated.

Note: Value and quantity of imports for American Samoa are indicated as being the same for both 2000 and 2005.

Specialty markets

There are many taro preparations for the specialty market. These include poi, *kūlolo, lūʻau* (taro leaves), and taro leaf preparations (e.g., *laulau* and *palusami*). Frozen taro corm is another specialty product.

Many grocery stores and supermarkets in Hawaiʻi carry *kūlolo*, *lūʻau* (taro leaves), and *laulau*. *Kūlolo* is a somewhat chewy dessert made of steamed grated and mashed taro, grated coconut or coconut milk, sugar, and honey. Favored cultivars for making *kūlolo* are *Mana ʻUlu*, *Mana Lauloa*, *Lehua Maoli,* and *Maui Lehua* (Evans 2008). *Laulau* are steamed packet combinations of *lūʻau* (taro leaves), pork, beef, salted butterfish, and vegetables wrapped in green *ti* leaves (*Cordyline fruticosa*). Throughout the Pacific, fresh taro leaves (*lūʻau* in Hawaiʻi) are cooked as vegetable or steamed in combination with meat and coconut milk. *Palusami* is a Samoan dish made of taro leaves and coconut cream wrapped in breadfruit leaves for steaming. Variations include the addition of onions, fish, and/or canned corn beef and taro leaves. The Tongan equivalent of *palusami* is called *lupulu.* Canned and frozen *palusami* are now produced in Fiji and Samoa, respectively. Frozen taro is also prepared in Fiji for export and given the large numbers of Pacific islanders in metropolitan countries, frozen and canned taro leaves are a potential specialty market item. The future is bright for frozen compared to fresh taro because frozen taro is more convenient to ship, store, and use than fresh taro; and consumers are assured there will be little waste (Vinning 2010).

Branding possibilities

Taro's digestibility, because of small starch grains, and its hypoallergenic qualities are other qualities that make it a unique product. Nutritionally, taro has a broader complement of vitamins and nutrients than the other starches, and this should also be promoted. Taro provides opportunities to develop nutritionally rich products such as crisps and noodles.

As a result of the close relationship between Pacific peoples and taro, particularly the efforts of keeping Hawaiian taro varieties free of genetic modification, taro could be labeled as GM-free, a quality that is attracting an increasing number of consumers.

Potential for Internet sales

Various web sites feature taro products and companies that specialize in taro products for example, taro chips, poi, etc. Thus the potential for Internet sales is there, but only limited by the number of consumers who have access to the Internet and are looking for taro products. Also, the weight and limited shelf life of many taro products limits the feasibility of shipping many taro products.

EXAMPLE SUCCESSES

Joseph Ganbay, Yap

By most socio-economic yardsticks, the Federated States of Micronesia (FSM) is a less developed state. For example in 2000, the per capita GDP of the FSM was $1,997 compared to $29,164 for Hawai'i (Osman 2000). In Yap State, the minimum wage for government employees is $1.60/hour. The private sector is not well developed and subsistence farming and fishing are the main economic activities. Imports ($132.7 million FOB in 2004) greatly outweigh exports ($14 million in 2004).

In an effort to stimulate appropriately-scaled economic development, the Yap State Small Business Development Center in cooperation with the University of Guam's Pacific island's Small Business Development Center initiated in 2000 a Micro Traders project, essentially a micro finance project with the aim of increasing access to capital and market resources through credit, increased incomes, and the development of employment and markets (Ames 2007). Those who became members of the initiative (by paying various fees and submitting to certain regulations) were entitled to sell their produce in the Micro Traders marketplace (People's Market) and apply for small interest-free loans to help increase their market sales and profits (Ames 2007). The initiative currently has seven member groups and has been deemed a success. Joseph Ganbay is a member.

Table 10. Joseph Ganbay's earnings for five market days March 14–June 6, 2008.

Produce	Quantity in kg	Price per kg in US$	Total amount in US$
Colocasia esculenta	93	1.10–1.66	167.95
Xanthosoma saggitifolium	20	1.66	33.00
Yam (*Dioscorea* sp.)	9.5	1.43	13.65
Sweetpotato (*Ipomoea batatas*)	19.5	1.66	32.25
Pineapple (*Ananas comosus*)	4.1	1.66	6.75
Passion fruit (*Passiflora edulis*)	3.2	1.10	3.50
Breadfruit (*Artocarpus altilis*)	126	1.10–1.66	153.20
Betel nut (*Areca catechu*)	5 swb	9.93	22.50
Pumpkin (*Curcubita pepo*)	1.8	1.10	2.00
Total for period of record			434.80

Source: Ames (n.d.), Field notes. The five market days were March 14, April 11, May 8, May 23, and June 6, 2008.

Joseph Ganbay of Thol Village, Tomil, Yap, stands next to a recent planting of heavily mulched *Colocasia* taro in a mixed agroforest. June 2008.

Joseph Ganbay, age 65 in 2009, is a traditional chief and resident of Thol Village, Tomil Municipality. Mr. Ganbay is a retiree from the Yap State Department of Agriculture who now earns his livelihood mainly through subsistence agriculture. He is, like many rural-dwelling Pacific islanders, self-sufficient.

Mr. Ganbay practices traditional agriculture, growing *Colocasia* taro, bananas, breadfruit, betel nut and other food plants in the mixed agroforest around his home. In all, Mr. Ganbay, cultivates about 1 ha of land. About 70% of Mr. Ganbay's agricultural production is used for subsistence while the rest is sold at the Micro Trader's Market in Colonia twice a month on Fridays.

Mr. Ganbay has been a member of the Micro Trader's Market since it first started in 2000 with an initial capitalization of $2,000. His earnings for five market days in 2008 indicate a satisfactory return given the wage structure of the island (see Table 10).

Yukie Erriong, Guam

Mrs. Yukie Erriong is one of about 25 Palauan women who grow *Colocasia* taro (*kukau*) and *Cyrtosperma* taro (*brak*) in the Agana Swamp in central Guam using the traditional Palauan *dechel* method of cultivation. Unlike the labor intensive *mesei* system, the less intensive *dechel* method does not require green manuring and turning of the soil. Rather, the standing vegetation is cut and cleared and the taros planted in their place. The two aroids are interplanted in the same garden plot with little to no fallow period. For a detailed description of the Palauan taro cultivation systems see McCutcheon (1981) and McKnight and Obak (1960).

The Agana Swamp soils are classified as troposaprists (Young 1988). These are deep, highly permeable soils derived from decomposed organic materials, neutral to mildly alkaline in reaction, and relatively poor in nutrients. Yukie, who is in her 60s, has been growing taro in the Agana Swamp for 20 years. She does not use artificial fertilizers or pesticides. Her garden area at the Swamp is approximately 15 m × 25 m and is cultivated continuously. As shown in the accompanying photograph, the harvested corms weigh between 1 and 2 kg each. Yukie grows more than enough taro for her family, friends, and church gatherings. She does not grow taro for sale but will accept cash gifts when they are pressed upon her.

The Erriongs left Palau in 1965 to live and work in Saipan. They migrated to Guam in 1983 where her husband, now retired, worked for the Government of Guam while she worked as a housekeeper and domestic in the hotel industry.

The *mesei* or taro swamp is an integral part of Palauan culture. In Palau, women are the taro cultivators and their status in the community is based on the taro that they produce. However, as a consequence of modernization and other developments in Palau, the role and significance of taro cultivation by women has been supplanted by wage income. Most of the taro now grown in Palau is produced by immigrant men from Taiwan, Bangladesh, and the Philippines. Thus,

Top left: A general view of the Palauan taro patch in the Agana Swamp. The area under cultivation is government-owned land. Top right: Mrs. Yukie Erriong resting after working in her taro patch. Yukie, now in her 60's, visits the taro patch three to four times a week. About 25 middle to older-aged Palauan women cultivate taro here. The taro patch also functions as a place for Palauan women to socialize. Bottom left: Two Palauan named varieties of *Colocasia* taro. On the left is *Ngaswas*; on the right is *Merii*. Both taros are 8 months old. Most of the Palauan women recognize 8 or 9 varieties of *Colocasia* taro. Bottom right: Yukie surveying her patch of *Colocasia* and *Cyrtosperma* taros in the Agana Swamp of Guam. Originally from Palau, Yukie has been growing taro in the Swamp for more than 20 years using traditional Palauan *dechel* method.

the cultivation of taro by Palauan women in Guam's Agana Swamp is significant because it represents the continuance of a tradition and culture, albeit far from its home islands. Mrs. Erriong visits her taro *dechel* three to four times a week. By growing taro in the Swamp, Yukie is able to fulfill her social and cultural responsibilities and save considerably on household expenditures for food. In Guam's markets, local *Colocasia* taro sells for $2.19/lb. The per capita average annual salary for Guam's residents in 1990 was $9,885.

T.H. Plantation, Samoa

T.H. Plantation in Samoa was established with the intention of supplying a healthy, locally grown, and produced snack foods. Taro chips is one of their products. Their aim was to produce a product of high quality and standard that would be competitive locally, and could have potential for export. The T.H. Plantation now has 12 full-time staff. The majority of raw materials are purchased and supplied by 3–4 local growers, and also from the Fugalei market, with the exception of vegetable oil, salt, and packaging. Since their establishment in 2002, they have achieved a reputation for being reliable and consistent in the manufacturing and production of high quality chips. A recent change in the labeling and packaging resulted in a dramatic increase in the amount of sales.

King Laulau Brand Poi, Waipi'o, Hawai'i

The Cain family started producing poi in 1998 using taro grown on their 2.4 ha (6 ac) farm in Waipi'o Valley. They got their start in Honoka'a Ohana Kitchen, a state-funded certified kitchen for start-up businesses. In addition to use of the kitchen, the incubator program also provided training on business planning, operations, and accounting. After 3 years, the Cain family set up their own poi shop in Honoka'a, where they continue to produce their products. In addition to poi, their primary product, they sell raw taro, cooked taro, *kūlolo*, and sometimes *lū'au* leaf and *laulau*.

Their poi processing includes cleaning the taro corms, cooking, grinding, mixing, and packaging. They make poi once a week, with most sales directly to retail customers. Some customers are local "community wholesalers," buying in bulk at $4/lb ($8.83/kg) and selling it for $5/lb ($11.03/kg) to their community. Small distributors sell the poi at farmers' markets. Party orders also constitute a large percentage of their business, allowing them to connect to families through baby luaus, weddings, funerals, graduations, etc. The community connections have made it unnecessary to advertise their products—new customers either find their poi at farmer's markets or hear about it from other customers.

The taro cultivar the Cains grow is *Api'i*, which is also known as "Waipi'o taro." *Api'i* produces well in Waipi'o and is tough. The grey colored poi it yields has a taste that is favored and

King Laulau Brand Poi is sold periodically at local health food stores, but it is primarily sold directly to consumers or through farmer's markets.

it sours very nicely. Their poi is also preferred because they mix in less water than large processors and it can be purchased on the day it was made, as opposed to poi that is shipped from another island.

The biggest challenge for the Cains is to come up with a steady supply of taro year-round in sufficient quantity. They buy taro from other farmers in addition to their own production, which means lining up harvests and purchases 2–3 months ahead of time.

The Cain family believes one of the keys to their success is that they love what they do. The benefits of their business are well beyond economic. They feel it is an honor to provide high quality poi to the community while making a living.

ECONOMIC ANALYSIS

Taro production expenses and income vary both within and between countries. For Australia, Daniells et al. (2004: 96) consider taro a "good complementary crop for an orchard, ensuring a positive cash flow between fruit harvests." They note further that the costs of producing and marketing an average yield of 20 MT/ha are AUS$40,000 with labor accounting for 50% of the costs. Gross incomes amount to approximately AUS$70,000/ha.

Production costs are not easy to obtain but data from Fiji Ministry of Primary Industry gave the following as percentages of the total cost of production per plant:

Planting material: 14%
Land preparation: 9%
Fertilizer: 11%
Weed control: 56%
Harvest: 9%

Fleming and Sato (n.d.) have developed a spreadsheet to determine the economics of wetland taro production for Hawai'i. To use this spreadsheet, the farmer is required to fill in the certain spreadsheet cells with the specific costs and values. The spreadsheet can calculate items such as the amount and percentage of gross profit, the breakeven point, returns to labor, land, and equipment, and it can be modified to fit current and other local conditions or crops.

Using the Fleming and Sato spreadsheets, Tipton et al. (1993) conducted an economic analysis of dryland taro production costs and returns for American Samoa, Commonwealth of the Northern Marianas, Guam, Hawai'i, and Pohnpei. The economics of taro production in these five political entities are presented in Table 11. As to be expected, there are wide differences in fixed and variable costs, in part a reflection of each states' stage of socio-economic development, the role of subsistence and commercial agriculture, and the changing use of mechanization and fertilizers to name a few. The table provides only a snapshot of taro production costs.

The study by Tipton et al. (1993) and others also point out that the economics of taro systems can vary widely depending on the level of labor, machinery, materials, yields, and returns. There is a wide variation in fixed and variable costs both within and among countries and regions.

Table 11. Estimated costs of dryland taro production for five American-affiliated entities in the Pacific.

	American Samoa	CNMI	Guam	Hawai'i	Pohnpei
Yield (lbs/acre)	8000	3662	7779	30000	7744
Price ($/lb)	0.50	1.00	1.36	0.39	0.41
Gross Sales ($/acre)	4000	3662	10604	11750	3175
Fixed Costs ($/acre)					
Land	0	2	525	424	NA
Buildings	321	50	83	72	NA
Machinery	149	401	542	777	NA
Overheads	413	557	1448	300	NA
Subtotal	793	1010	2598	1573	NA
Variable Costs ($/acre)					
Land Preparation	317	161	225	645	180
Planting		122	420	1690	574
Weeding/hilling	48	239	367	916	240
Fertilizing	102	0	216	a	607
Pest Control	282	88	36	a	401
Harvesting	75	134	560	2663	300
Marketing	415	20	175	a	25
Interest	45	51	133	532	334b
Subtotal ($/acre)	1281	816	2133	6447	2661
Total Costs ($/acre)	2074	1826	4731	8020	2661
Returns ($/acre)	1927	1836	5873	3730	514
Fixed Costs/Total Cost	38%	55%	55%	20%	NA
Variable Costs/Total Cost	62%	45%	45%	80%	100%
Breakeven Yield (lbs/acre)	4147	1825	3478	20476	6467
Breakeven Cost ($/lb)	0.26	0.50	0.61	0.27	0.34
Cost of Labor ($/hr)	1.50–2.50	1.25–4.00	7.00	4.50–8.00	1.50
Est. Labor Cost/Total Cost	39%	11%	32%	40%	45%

Source: Tipton et al. (1993).

Notes: a= included above; b=includes $248 for contingencies. See Tipton et al. (1993) for background information and assumptions for each case.

FURTHER RESEARCH

Potential for crop improvement

Many taro researchers express the need for crop improvement, particularly disease resistance. Good examples of this potential are the efforts of many research institutions at developing new varieties with resistances to pests and diseases. For example the Samoan cultivar *Alafua Sunrise* was developed at the University of the South Pacific Alafua campus in response to dasheen mosaic virus. More recently the work of the Taro Improvement Programme, also at USP, Samoa, has focused on breeding lines with tolerance/resistance to taro leaf blight.

Improving potential for family or community farming

As Pacific island populations at home and overseas in Australia, New Zealand, and the U.S. mainland continue to grow, the demand for taro food products will most likely increase. Research and extension on sustainable agricultural methods and the continued development of high yielding varieties of taro resistant to taro pests and diseases can help in easing this pressure and increase farm incomes. Improvement in marketing infrastructure, education on domestic and export standards and quarantine requirements can increase the returns to agriculture. The close linkages between taro and many Pacific island cultures also mark taro as a vital and prestigious crop. In view of the rising rates of obesity and diabetes throughout the Pacific, taro should be promoted as nutritionally superior to rice and cassava. There is increasing interest in promoting local foods for their nutritional superiority over imported foods. A recent Pacific Food Summit (Vanuatu 2010), stressed the importance of increased production and consumption of local foods.

Genetic resources where collections exist

Taro germplasm collections are stored at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria; the Philippine Root Crop Research and Training Center, Beybey, Philippines; the Koronivia Research Station, Fiji; and the Bubia Agricultural Research Centre in Papua New Guinea (Onwueme 1999). The Secretariat of the Pacific Community, Centre for Pacific Crops and Trees (SPC CePaCT) maintains the largest *in vitro* collection of taro (over 850 accessions), consisting of mainly Pacific taro but also Asian accessions. The tissue culture facility at the University of the South Pacific, Alafua Campus, maintains a duplicate of the CePaCT taro collection. Some other countries in the Pacific maintain their own national collections, such as Papua New Guinea and Vanuatu.

Table 12. Taro collections and number of accessions in the Pacific islands (2001) (SPC, n.d.)

Country	Location of Collection	Number of Accessions
Papua New Guinea	BARC, Lae	859
Solomon Islands*	Malaita (313), Choiseul (245), Guadalcanal (220), Temotu (46)	824
Vanuatu	VARTC, Santo	502
New Caledonia	Wagap, Northern Province	82
Fiji	Koronivia Research Station	72
Niue	SPC, Nabua, Fiji	25
Samoa	SPC, Nabua, Fiji	15
Tonga	SPC, Nabua, Fiji	9
Cook Islands	SPC, Nabua, Fiji	18
Total		2406

* These collections no longer exist as a result of the civil strife in Solomon Islands, which significantly impacted the agriculture stations where these collections were held.

In Hawaiʻi, there are collections of taro varieties on all of the major islands. The University of Hawaiʻi, Kauaʻi Agricultural Research Center located in Kapaʻa, has the original collection from Whitney et al. in the 1930s. To this day, UH Kauaʻi maintains a major taro collection including all the remaining Hawaiian varieties, several varieties that were collected by Lebot in 1991, all of the Palauan varieties that were collected by Trujillo, and several Philippine varieties collected by de la Peña. The Hawaiian varieties from this collection are replicated at the UH Agriculture Station in Hoʻolehua, Molokaʻi. For many years, the Lyon Arboretum at the University of Hawaiʻi had a collection started from the UH-Kauaʻi materials. Tissue cultures of some Hawaiian taro varieties are stored at the Lyon's Arboretum in Mānoa, Oʻahu (Lindsey 2009).

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OTHER RESOURCES

Public assistance

There are many sources of information available either free or for a modest price. These include: CTAHR: College of Tropical Agriculture and Human Resources at the University of Hawaiʻi; IRETA at the University of the South Pacific, Alafua, Samoa, and at Secretariat of the Pacific Community (SPC).

Internet

This University of Hawaiʻi web site contains links to a wide range of literature of downloadable literature on *Colocasia esculenta* and other traditional Pacific island crops: http://libweb.hawaii.edu/libdept/scitech/agnic/index.html

The Office of Communications Services at the College of Tropical Agriculture and Human Resources at the University of Hawaiʻi. A wide range of agricultural literature on agriculture, soils, agricultural pests and diseases can be downloaded free: http://www.ctahr.hawaii.edu/ctahr2001/PIO/FreePubs.asp

Bishop Museum in Honolulu has many references and links to sources of information on taro in Hawaiʻi. Many Hawaiian cultivars and their uses are described. http://hbs.bishopmuseum.org/botany/taro/key/HawaiianKalo/Media/Html/info.html

The Secretariat for the Pacific Community has an extensive listing of downloadable documents related to germplasm conservation, crop improvement and conference presentations/abstracts: http://www.spc.int/tarogen/Miscellaneous_Publications.htm

The New Zealand Digital Library by the Department of Computer Science at the University of Waikato has many online development related materials: http://www.nzdl.org

Specialty Crops for Pacific Island Agroforestry (http://agroforestry.net/scps)

Farm and Forestry Production and Marketing Profile for Taro (*Colocasia esculenta*)

Author: Dr. Harley I. Manner, Emeritus Professor of Geography and Micronesian Studies, University of Guam, College of Liberal Arts and Social Sciences, UOG Station, Mangilao, GU 96923 USA; Tel: 671-735-2870; Fax: 671-734-5255; Email: hmanner@uguam.uog.edu; hi80865inlado@yahoo.com

Dr. Mary Taylor, Genetic Resources Coordinator/Centre for Pacific Crops and Trees Manager, Secretariat of the Pacific Community, Private Mail Bag, Suva, Fiji; Tel: +679-3370733, ext. 271; Fax: +679-3370021; Web: http://www.spc.int/

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