***COLOCASIA ESCULENTA*: AN ACCOUNT OF ITS ETHNOBOTANY AND POTENTIALS**

by

Sayantani Ghosh Dastidar, B.S.

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Dedication

I dedicate my Master’s report to my parents Ranjan Ghosh Dastidar and Alo Ghosh Dastidar.

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I would like to acknowledge my husband Manasij Santra for his relentless support. I would also like to thank my supervisor Dr. Robert Jansen and Dr. Brian Stross for taking out time to help me and guide me. And finally I would like to extend my heartfelt thanks to Peter Kachtik and Eeshita Ghosh Dastidar for proofreading my document.

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Abstract

COLOCASIA ESCULENTA: AN ACCOUNT OF ITS ETHNOBOTANY AND POTENTIALS

Sayantani Ghosh Dastidar, M.A.

The University of Texas at Austin, 2009

Supervisor: Dr. Robert K. Jansen

Taro, *Colocasia esculenta*, is a unique root crop that serves as an important dietary component in the Pacific islands and in parts of Asia and Africa. Cultivation of taro as a food crop might have ancient origin as is evident from variety of ritualistic use of taro in different parts of the world. Even though it has been postulated that taro was domesticated in the old world, the widespread cultivation of taro calls for a discussion regarding its origin. Wild varieties of *C. esculenta* are known from regions of Eastern India, Sri Lanka, Sumatra, and the Malay Peninsula. Other wild varieties have been reported from the Indo-Pacific region and China. The two prominent chromosome numbers are 2n=28 and 2n=42. But, chromosome number series 2n= 28, 42, 36, and 48 have been reported from India indicating the centre of highest diversity. A certain amount of controversy exists over classification and nomenclature of this polymorphic species. Primary products of the plants are the corms and cormels. Taro is also used in traditional medicine. It has been known to be nutritionally superior to other starchy crops like potato. This document looks at previous works done on classification and nomenclature of taro, morphology, origin of taro, production and agronomy, and finally ethnobotanical aspect of taro across the major taro producing countries.

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Introduction

Root crops are an important food source for one fifth of the total world population. With the escalating population, we may have to rely on root and tuber crops more. They are naturally energy rich and have been known to save lives during drought and famine. Taro, for example, has served as a staple in many countries in Asia, Africa, and the Pacific. Based on recorded global gross production data, taro is the fourteenth most consumed vegetable in the world (Lebot and Aradhya 1991). It has been used for centuries as food, for its edible corm, young leaves, and stems, as well as for various ceremonial purposes.

Species of *Colocasia esculenta* are known by many common names, including, tannia, dasheen (from the French word 'dachine' from 'chou de Chine' or China cabbage), eddo (originating from the West African 'edwo' meaning yam), cocoyam, malanga, taro, and others. Many of these same names are also used for *Xanthosoma*, a native to the New World, which is also cultivated for the starchy corms, and is often confused with *Colocasia*. The name *Colocasia* comes from the Egyptian word *colcus* or *kulkas* (Plucknett 1970).

European botanists came across taro first in Egypt where it had not been cultivated for long. The ancient Egyptian monuments carry no signs of cultivation of taro indicating a recent dispersal to the area. Pliny (AD 23-79) in *Naturalis Historia* called taro *Arum Egyptium*. Prosper Alpin (16^{th} century AD) mentions it as *colcus*. Carolus Clusius (16^{th} century AD) mentioned it as *quolkas,* or *koulkas*. The name comes from a plant belonging to Nymphaeaceae which had been introduced to Egypt from India (de Candolle, 1884). The entire name *Colocasia esculenta* stands for 'the edible lotus'. The specific epithet stands for edible.

Colocasia (Araceae) is a tropical genus consisting of twelve or thirteen species (Engler and Krause 1920, Li 1979, Sivdasan 1982, Plucknett 1983, Shaw 1984, Sreekumari and Mathew 1991a, 1991b, Li and Wei 1993, Hay 1996, Mayo et al. 1997, Li and Long 1999, Long and Li 2000, Long and Liu 2001, Cao and Long 2003, Yin et al. 2004, Cai et al. 2006). Present distribution of the members of *Colocasia* is mostly tropical, spreading from Asia to the Polynesian islands and parts of Africa. The plant is known to have originated in the eastern parts of India, spreading further east to Myanmar and China, south to Indonesia (Chang 1958, de la Pena 1970, Plucknett et al. 1970), and afterward to Melanesia, and Polynesia (Trujillo 1965, Yen and Wheeler 1968). It also spread westward to Mediterranean countries (Ochiai et al. 2001). With its significant dispersal the plant integrated itself as an important socio-cultural component in several cultures across the world. The significance of taro socio-culturally manifests itself in many forms. It is known to be the crop of royal choice; it has a major role in traditional feasting, folklores, oral traditions, in both Oceania and Southeast Asia. Various parts of the plant are used in folk medicines in many countries from the Malay Peninsula to Oceania. Countries like Samoa and Tonga have imprints of taro on their coins signifying its economic and socio-cultural importance.

This document reviews previous work done on the classification and nomenclature of taro, morphology, origin of taro, production and agronomy, and ethnobotany of taro across some of the major taro producing countries.

Classification and Nomenclature of *Colocasia*

Araceae is a large monocotyledonous family in the order Arales consisting of about one hundred and four genera and more than thirty seven hundred species (International Aroid Society … [updated July 2009]). Aroids are mostly distributed in the moist climates of the tropics. They prefer wet or shady habitats. Aroids are primarily herbaceous and terrestrial plants, but there are also vines, creepers or climbers, and some epiphytes. Typically they have an acrid milky sap in some parts of the plant. The underground part is a rhizomatoid structure known as the corm from which the aerial parts arise. The leaves are solitary, radical, and if cauline, then alternating. The flowers are usually arranged in a fleshy cylindric or ovoid, unbranched inflorescence called the spadix subtended by a floral bract called the spathe. The small flowers are usually perfect or unisexual with plants with or without a perianth. In cases of unisexual flowers the male flowers grow on the upper part of the spadix while the female flowers are seen in the lower portion. There can be two, four, or eight stamens, which can be free or united. The ovary is either superior or inferior with one or many locules. The fruit is a berry with one to many seeds (Hutchinson, 1959).

The two tribes of aroids, namely, Lasioideae (e.g., *Cyrtosperma* and *Amorphophallus*) and Colocasioideae (e.g., *Alocasia*, *Colocasia*, and *Xanthosoma*) include most of the edible species of the family. Among them *Colocasia* and *Xanthosoma* are known to be the most important root crops in the family. Edible taxa in the two genera can be readily distinguished by the peltate leaves in *Colocasia* and absence of a sterile tip on the spadix in *Xanthosoma*. While *Colocasia* is thought to have originated in the eastern parts of India and Bangladesh, *Xanthosoma* is a native of South and Central America. Chemically both the genera are known to have crystals of calcium oxalate scattered throughout their tissues (Hegnauer 1963, Hare et al. 1908). These crystals are responsible for the acridity in the plants. A burning sensation is caused by the crystals of calcium oxalate when the plant parts are chewed as the needles of the chemicals pierces the mucous membrane of the mouth. However, these raphides can be easily destroyed by drying and heating the plants parts effectively (Font, 1962). The various cultures utilizing taro in their food resources figured this out over the centuries. Also, with the domestication of taro the calcium oxalate crystals are artificially selected against and certain tissues lack them in the domesticated plants.

Linnaeus first described taro in the year 1753 as two species, *Arum colocasia* and *Arum esculentum* (Hill, 1939). Schott in 1832 renamed the genus *Colocasia* with the two species described by Linnaeus as *C. esculenta* and *C. antiquorum*. Later in 1856 Schott combined the two species under one polymorphic form of *C. antiquorum*. Following that Schott merged all species along with *C. esculenta* as varieties of *C. antiquorum*. In 1879 Engler agreed with Schott's taxonomic treatment and added two more varieties to *C. antiquorum*, followed by two more varieties in 1920 while describing *C. aquatilis* and *C. globulifera* with Krause.

In 1939 the treatment of *C. antiquorum* was contested and it was pointed out by Hill that according to the International Rules of Botanical Nomenclature *C. esculenta* took precedence over *C. antiquorum* and the latter should be included as a variety. Some authors however, recognize two different varieties, *C. esculenta* var. *esculenta* and *C.*

esculenta var. *antiquorum*. Finally Purseglove in 1972 differentiated *C. esculenta* and *C. antiquorum* as two different species based on floral characteristics. *Colocasia. esculenta* has shorter sterile portion of the spadix while *C. antiquorum* has the sterile portion tucked inside the spathe and is longer than the male portion. However, this is not always helpful as many *Colocasia* individuals seldom flower. Some researchers believe that the variation in both the genus and species in size, shape, corms, leaf coloration, and rarity of flowers is due to the vegetative reproduction (Greenwell 1947).

In summary, the thousands of cultivars of taro fall into two main categories, the ones that have a small corm surrounded by large cormels (chromosome number 2n=42) and those that have a large corm surrounded by small cormels (chromosome number 2n=28). Nevertheless, it is generally accepted that taro is a polymorphic species, and in this classification system eddoes (2n=42) is *C. esculenta var. antiquorum* while dasheen is *C. esculenta var. esculenta* (Coursey 1968).

Morphology of *Colocasia esculenta*

The stemless herbaceous plant is approximately 1.5-2 m high (Merlin 1978). The part of taro that is aboveground is comprised of large heart shaped leaves that are 30 to 60 cm wide and 25 to 85 cm long. The large leaf laminae are supported by long erect petioles (figure 1). The petioles are green but can often be purple apically. They range from 1-2 m, are spongy, and filled with air spaces. They arise in a whorl from the apex of the corm. Leaf attachment is peltate, unlike *Xanthosoma* where the point of attachment is hastate. The leaf blades range from green to dark green, glaucous, blue-green on adaxial surface, with a red or purple spot at point of petiole attachment. The primary lateral veins are parallel while the secondary lateral veins are netted. The apex is mucronate (Norman 1972, Ahmed and Rashid 1975, Purseglove 1972). Laminae are 275 to 300 nm in thickness. Stomata occur in both adaxial and abaxial surfaces with more stomata on the abaxial surface. Stomatal count on the leaf surfaces is comparatively lower than other plant species (Yarbrough 1934).

Overall, leaves and petioles of taro vary in color, size, and chemical content. Young leaves have lower amounts of calcium oxalate (Strauss et al. 1980). Plants like *Colocasia gigantea* have been artificially selected to have reduced amounts of calcium oxalate in the petioles and are used for traditional Vietnamese dishes such as *canh chua* (sour soup) (Nguyen 2005).

Colocasia has been reported to flower occasionally under domesticated conditions. Flowering has been reported in wild individuals. Flowering occurs from late spring to late fall. Inflorescences of *Colocasia* are fleshy spadices ranging from 9-15 cm, at least three times longer than the peduncle and subtended by a spathe 20-35 cm in length, peduncle green, the blade orange, opening basally, reflexing apically at anthesis to expose the spadix that contains the unisexual flowers (Onwueme 1978, Shaw 1975). Usually two to five inflorescences arise successively in the leaf axil.

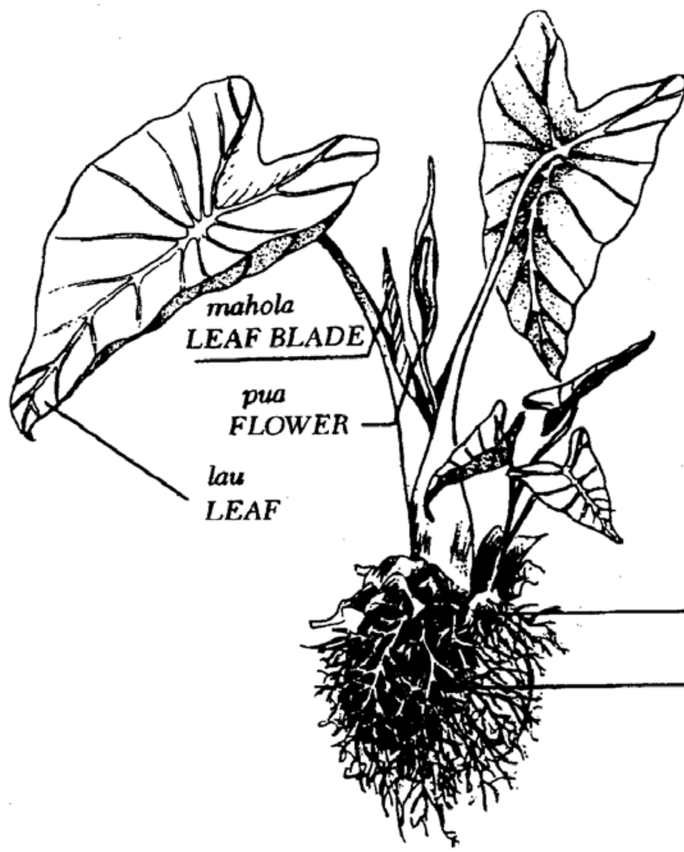
The spadix is unequally divided into two portions. The lower portion is green containing the pistillate flowers. The pistillate flowers are pea green, interspersed with white pistilloides. The ovaries are unilocular with 36-67 ovules arranged on two to four parietal placentas. Sterile flowers are scattered among the pistillate flowers at the bottom of the spadix. These flowers are pale yellow to white in color. The sterile flowers disappear as the fruits mature following pollination (Shaw 1975).

Right above the pistillate flowers is a row of sterile flowers that ranges from 2-5 cm in length, followed by the staminate flowers. The staminate flowers and the sterile tip are pale orange, three to six connate stamens forming a synandrium (Whitney et al. 1939, Shaw 1975). The pale orange sterile appendage has been used as an identification character (Purseglove 1972).

Cultivated forms of taro rarely flower or fruit. The plants are seen to reproduce asexually through stolons that elongate and produce nodes near a surface from which a new plant arises. However, fruits that have been examined were orange in color, with an average of two to five seeds in each ripe berry (Shaw 1975). In an earlier study each ovary was seen to contain 1-12 seeds (Kikuta et al. 1938). The seeds were 1.2 to 1.5 mm in length and 0.7-1.0 mm in diameter. The shape of the seed resembled that of a Japanese lantern (Kikuta et al. 1938). Greater numbers of seeds are found at the upper and lower portions of the spadix with the number diminishing in the middle (Shaw 1975).

Taro possesses starchy storage stems that are underground and known as corms (figure 1). The petioles of taro rise from the apex of the corm and surround it. The corm has an outer brown layer usually protected by papery tunic leaves and dead petiole sheaths. There is also an outer layer of leaf scars and scales. The size of the corm varies based on the availability of water and variations in temperature. In many instances the corm bears smaller secondary cormels that arise from the lateral buds on the corms. In many cultures the cormels are harvested; leaving the corm alone. The average diameter of a corm has been recorded to be 15-18 cm (Brouk 1975, Onwueme 1978). Stolons rise from the lateral buds of the corms and have been known to be used for propagation. The root system in taro is adventitious due to the presence of the corm. It arises from the lower portion of the corm and is restricted to the top part of the soil.

With *Colocasia esculenta,* it has to be kept in mind that the size, shape, color, and characteristic features are highly variable due to thousands of years of cultivation. Hence extensive polymorphism results in taxonomic treatments that are dubious at the species level. Careful studies of the plant morphology and seed production and germination are necessary in the future.



Parts of a typical taro plant.

Credit: Virginia Stewartson

Figure 1 adapted from Merlin, M. 1978 shows the different parts of taro.

Chromosome numbers and Origin of the *Colocasia esculenta*

Cultivation of taro as a food crop might have an ancient origin as evidenced by a variety of ritualistic uses in different parts of Asia and several Pacific Islands, especially in Asia where taro is not a staple food crop at present. Even though it has been postulated that taro was domesticated in the Old World, its widespread cultivation calls for a discussion regarding its origin. Some believe the crop originated in "Indo Malaysia" (de Candolle 1884), while others suggest Indonesia (Engler and Krause 1920), India (Burkill 1935, Chang 1958), Southeast Asia (Sauer 1952), or Malaysia (Good 1964) as the original place of domestication. Taro is generally an outbreeder and hence genetic diversity is prominent in heterogeneous populations (Simmonds 1979).

Some authors believed that during the nineteenth century wild taro was only found growing in Eastern India, Ceylon, Sumatra, and the Malay Archipelago (de Candolle 1884). Assam and Burma, near the eastern border of India, have been suggested as the center of origin, though other archaeological evidence indicates that southern parts of India might have been more suitable as a centre of domestication (Merlin 1978). India has a population consisting of chromosome number series 2n=14, 28, and 42 and 2n=36 and 48, showing India to be the place with highest chromosomal variation. In a study by Lakhanpaul et al. (2002) we see that the weedy, wild, and cultivated taro in India, in spite of high phenotypic and genotypic variations, share a very close gene pool, resulting in high genetic diversity, which in turn indicates a plausible center of origin.

Yunnan province of China is considered the secondary diversification center of taro (Ochiai 2001). Taro may have been introduced to Japan by two plausible routes (Sasaki 1986). In a RAPD study of the Asian taro, it was shown that most likely taro was brought to Japan via Taiwan (Ochiai, 2001), and in this study it was shown that the triploid variety of taro found in Japan might have dispersed along the Yangtze River.

Origin and dispersal of taro has always been a controversial topic. In a chromosomal study of clonal varieties from Southeast Asia and Pacific Islands Yen and Wheeler (1968) concluded that plants with 2n=42 found in New Zealand and not in Polynesia represent a more modern lineage that was brought to that region by humans in historical time after the dispersal of 2n=28 to Polynesia. Somatic chromosome numbers of 2n=28 were found in Polynesia while 2n=42 was found in New Caledonia and New Zealand. From the nature of dispersal of taro from South and Southeast Asia through Oceania to Polynesia, it has been suggested that 2n=28 was the original population that dispersed to Oceania and subsequently to Polynesia. This is based on the fact that the variety of taro found in Polynesia is 2n=28. A much later dispersal of the population 2n=42, which co-exists along with a population of 2n=28 in Oceania, has also been suggested. A further collection and study of genotypes from New Zealand and New Caledonia by Coates et al. (1988) suggested that there is the possibility of two incidents of domestication and that the 2n=42 lineage was separately domesticated in New Zealand and New Caledonia.

In figure 2, adapted from Coates et al. (1988), the authors show that the triploid forms are missing from Polynesia while they are present in New Zealand and New

Caledonia. It has been suggested previously that there was a recent introduction in historic times from Asia (Yen and Wheeler 1968). The authors argue that there might be two separate lineages in Australasia and Pacific. They suggest (as is evident in figure 2) that there might be a separate domestication of taro in this region (Coates et al. 1988).

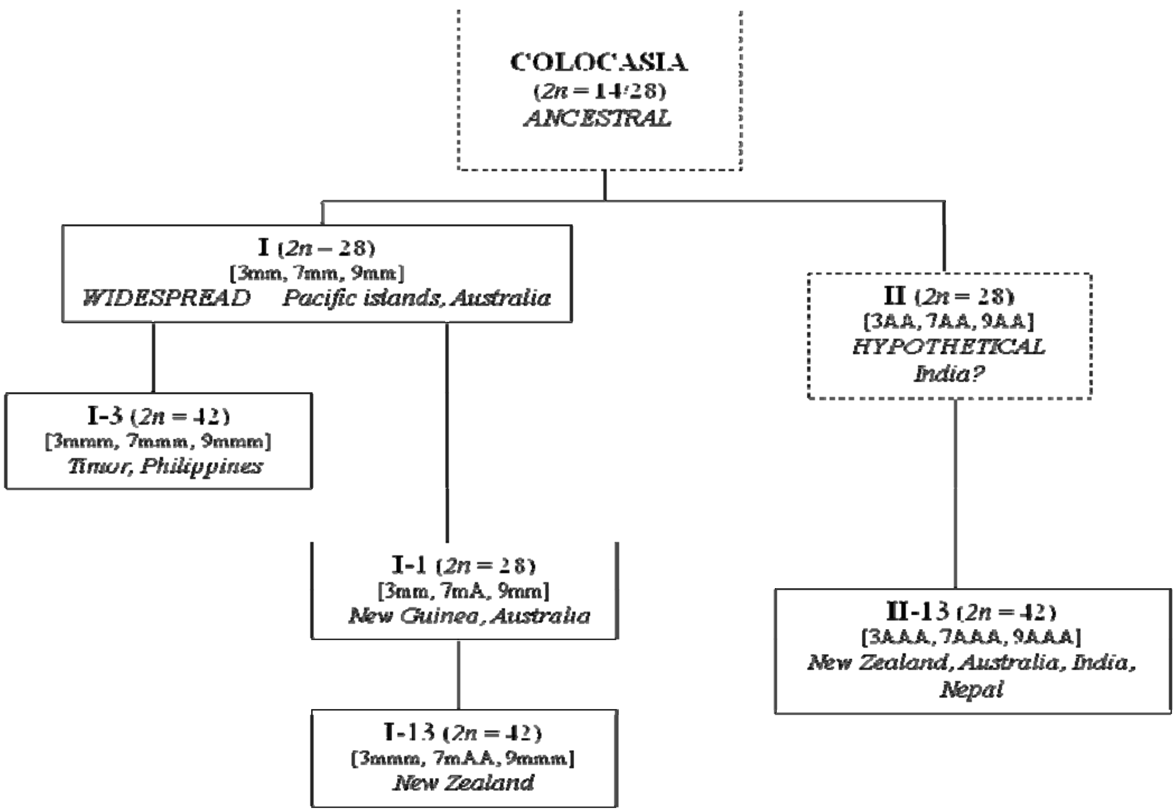


Figure 2. Adapted from Coates et al. 1987. Shows the proposed phylogenetic relationship between the cytotypes collected from various regions. The roman numerals indicate the different cytotypes, 3, 7, and 9 are metacentric (m) or acrocentric (A) marker chromosomes.

In 1990 Peter Matthews, in his dissertation on origin of pacific taro, suggested from a ribosomal DNA study that there might be several locations of domestication including New Guinea. However, he suggested that the Australian taro had no role in the ancestry of the Polynesian taro. Finally an isozyme survey by Lebot and Aradhya (1991) suggests significantly high genetic variation in Southeast Asia. They also suggested that Pacific island taros originated from a narrow genetic base introduced from Indonesia. Further detailed study of the cultivated and wild taro would be necessary to unravel the complex issue of the origin and distribution of taro.

Agronomy and Production of *Colocasia esculenta*

Since taro is mainly a root crop it is seldom grown from seeds. A taro plant is rarely seen in flower and occasionally when it is, the seeds might not be viable, indicating the species might be genetically unstable. Given that taro flowers and fruits rarely, there are very few if any fossils of taro pollen and seeds. Hence the speculations regarding the origin of taro are based on the ecology of taro and its interaction with man (Merlin 1978).

Taro is known to be propagated for centuries via asexual methods, and seed production is rare in the cultivated varieties. In Hawaii as early as 1913 an unknown taro farmer was known to have produced several seedlings while in 1919 Gerrit P. Wilder was known to have successfully in raised taro seedlings (Kikuta et al. 1938). For the most part it was believed that fertile seeds are rare (Caughey and Emerson 1913) and some even believe that taro plants do not set seed (Villimot 1936). However, Kikuta et al. in 1938 succeeded in producing seeds and growing seedlings in the nursery. The optimum temperature at which the seeds germinated was 77^{o}F. The seeds germinated in 14-24 days depending on the depth of planting. Due to the small size of the seeds, they were not viable for long, and do not contain much stored food (Kikuta et al. 1938).

Taro can be grown in various types of soil. It is known to have survived equally well in well-drained, non-flooded land, and humid, waterlogged areas. Upland taros are seen along hillsides where the soil is well-drained and friable, whereas lowland taro grows in waterlogged fields of alluvium soil (de la Pena 1967). Best results are obtained in deep, well-drained, friable loams, particularly alluvial loams, with a high water-table; a pH of 5.5-6.5 with high potassium and calcium content (Sivan 1981). Taro is a flexible crop and can thrive from sea level up to an elevation of 2400 m (Handy 1940) with the right choice of cultivars (de la Pena 1967). An average of 21-27 ^{o}C is optimal for taro cultivation. When grown in higher altitude at least a 6-7 months frost-free period is necessary.

Taros are water-loving plants, but can thrive in various conditions from paddy culture to dry upland conditions with proper irrigation. Wetland taro is extremely water dependent and fields need to be waterlogged to a minimum of 5 cm even before the seedlings are planted. In a taro field, the water level is increased to a maximum of 10 cm during the growth of the plant in order to suppress weeds. In Hawaii the flooded fields and the banked plots suitable for taro cultivation are called lo'i (Cho 1998). Flooding of the fields also allows sufficient weed control. The fields are drained 15 days prior to harvesting. On the other hand upland taro growing in Hawaii, Pacific Islands, or Asia depends on rainfall and is generally not irrigated. There is evidence of taro cultivation alongside sweet potato on the leeward sides of hills (Kirch 1985). Due to flexibility of taro in various water levels, excessive rains do not hurt even the upland taro. An annual rainfall of 250 cm is considered optimal for the crop. However, the time to attain maturity depends on the availability of water. Usually upland taro takes 8-9 months to develop, but the harvesting period can extend up to 12 months due to heavy rainfall (de la Pena, 1967). Dasheen corms when grown under dry conditions show dumbbell-like shapes, while eddoes under dry conditions produce few cormels (Gooding et al. 1961).

Traditionally, in both SE Asia and the Pacific Islands, fertilizer is not used and people rely heavily of leaf mulches to enrich the soil. Rotation of crops is required in order to get a better yield in taro plants. They do not grow well if cultivated consecutively in the same field (Takahashi 1984). A previous crop of *Phaseolus atropurpureus* is grown during the fallow period and is later incorporated into mulch (Sivan 1981). It has been shown that higher yields can be obtained by rotating crops and using organic soil disinfectant (Murota et al. 1984). The Jinuo, a tribe in the Xishuangbanna region of China, grow taro at an altitude ranging between 800-1600 m, rotating the crop with tea (You-Kai et al. 2004). In a study by Asao et al. (2003) the research shows that root exudates from taro can inhibit vegetative growth resulting in low yields. Their research shows that the allelopathic property of taro root exudates, especially benzoic acid, hinders the growth of taro plantlets over the course of time.

Taro is harvested when the parts above ground become dry and yellow. Primary products of the taro plant are the corms and cormels. In the dasheen taro the corms are larger than the cormels, whereas eddoe has a smaller central corm. The maturation period and flesh color varies depending on the cultivar. The former ranges from 6 to 18 months. The shortest crop duration reported is 3 months in Sri Lanka, while the others are India 7-9 months, the Philippines 7-11 months, Hawaii (lowland crop) 12-15 months, Fiji 10-12 months, Nigeria 6-8 months, Trinidad 8-10 months (dasheens), 5-6 months (eddoes). The flesh color of taro varies from white to yellow and orange to reddish purple (Onwueme 1999).

World Production of taro from 1961 to 2007 was published by the Food and Agriculture Organization of the United Nations and has been plotted to show the trend in total annual production of taro (figure 2). We can see that there has been an increase in production of taro over the last decade. One of the major reasons for the increase in taro production might be an increase in demand as a result of recent globalization. Taro has been an unknown food product outside the indigenous cultures that grew up on it. With recent globalization we see a more diverse diaspora around the world and with that the integration of indigenous ingredients into various markets (Yokoyama 1989).

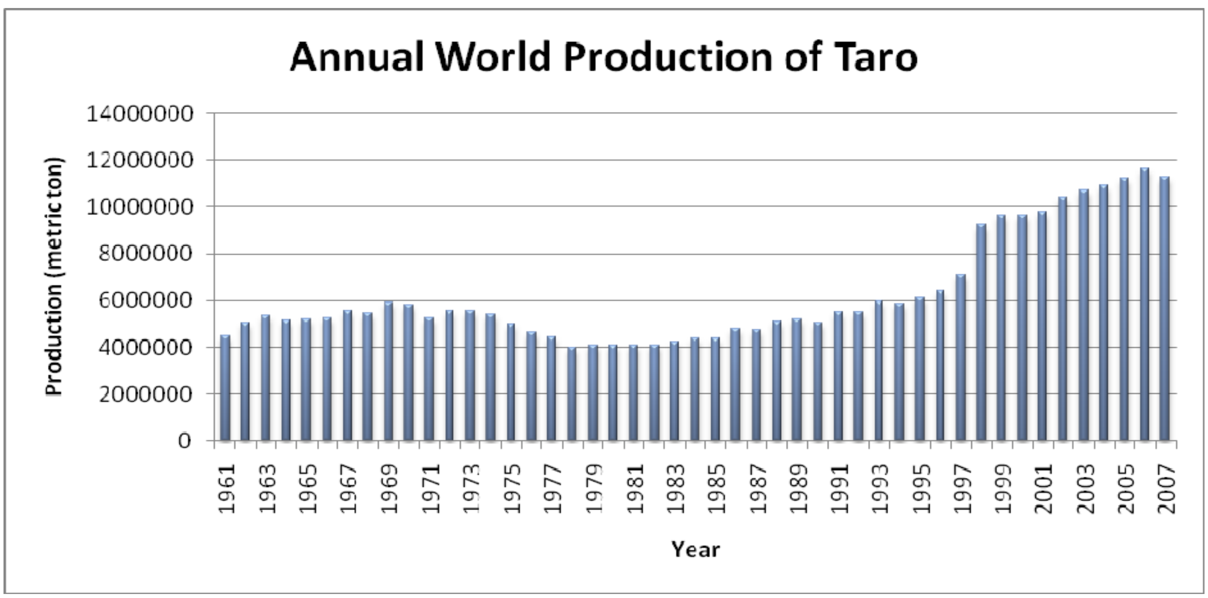


Figure 3 shows the production of taro in metric ton from the year 1961 to 2007. Data accumulated from FAO.

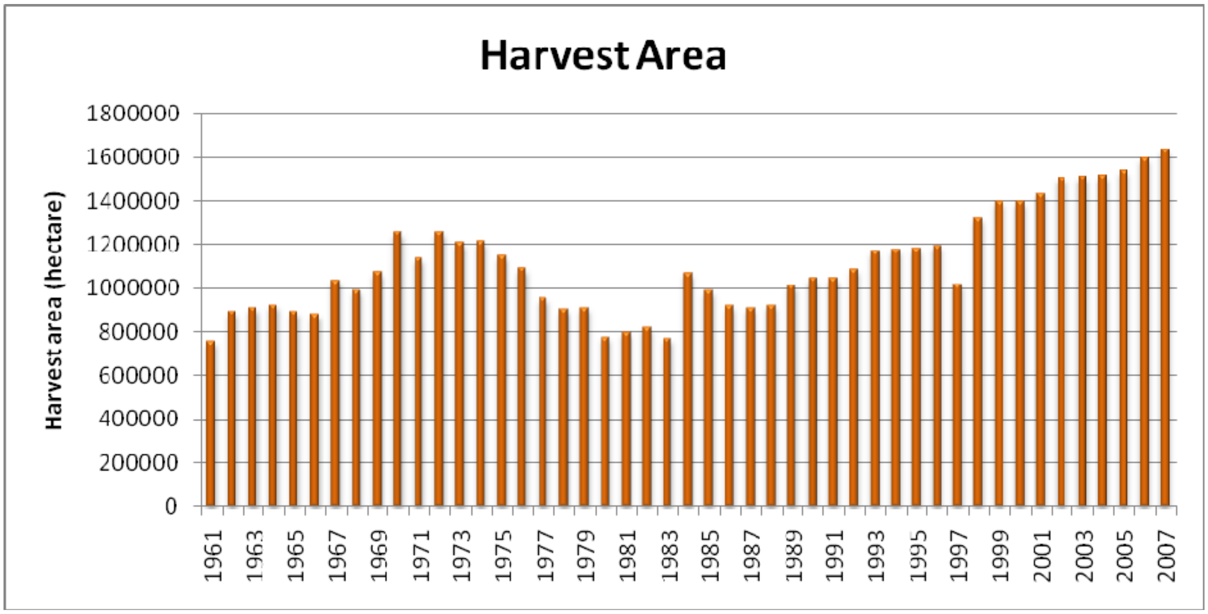


Figure 4 shows the harvested area of taro in hectare from the year 1961 to 2007. Data accumulated from FAO.

In 1975 taro was being cultivated in fifteen countries in Asia, Africa, and Oceania on 762,000 hectares of land with a gross production of 4.353 million metric tons (FAO 1975). According to FAO Production Yearbook in 1987, 5.72 million metric tons of taro were produced worldwide. In total 987,579 hectares of land were tied up in the production of taro (FAO 1987). The leading producers of taro are Africa (8 billion pounds), Asia (3.9 billion pounds) and Oceania (667 million pounds) (Hollyer 1987). In the year 2005 the production of taro across the world was 9.2 million metric tons (FAO 2005). The harvested area of taro (as is evident from figure 4) has increased considerably over the time period due to the increase in production and export of taro. Recorded average yield (ton/hectare) varies according to the cultivar, habitat conditions, and crop duration. Highest yield has been recorded in Hawaii 37.5 – 75, followed by India 34, the

Philippines 25, and Malaysia 9-10. In Hawaii the crops are heavily irrigated and receive additional fertilizers (Kay et al. 1987). Other countries like East Africa 5-12.5, West Africa 5-10, Cook Islands 14, Egypt 26, and Fiji 7.5-15 also produce a considerable amount of taro (Kay et al. 1987).

The scope of cultivation of taro on a large scale is hindered by several factors. One of the major constraints of taro production is diseases like taro leaf blight and the taro beetle (Jackson 1980). Some countries like Tonga have escaped the diseases, while countries like Samoa have been affected by both diseases. As a result the country has been quarantined from exporting its yield of taro (FAO 1997), impacting the lucrative taro export of the country. The other constraint is the labor-intensive production system even in countries like Hawaii that use Hi-tech agronomy practices. Scarcity of planting materials also affects taro production. In countries like Tonga, where drought is prevalent, not only are crops destroyed on a regular basis, but planting material becomes scarce (Onwueme 1999). The planting material in taro, just like in other root crops is bulky and perishable. Hence transporting planting materials also becomes difficult across the world. For a similar reason post harvest handling of taro is complicated. The yield has a short shelf life, which makes exporting the product tricky. Frozen and dried products of taro can be a solution to this problem, but because of the traditional sentiment attached to the crop consumers do not prefer the preserved version. Extensive research on agronomy and production of taro would facilitate overcoming the present constraints in taro production. It is likely that importance of taro as a food crop will remain significant in immediate future due to the sentiment attached to the crop in some cultures and its role as subsistence food crop in some cultures.

Ethnobotany of Taro

Among the various root crops much adulation and prestige is attached to taro in the Pacific Islands. It is also widely used in countries and regions such as the Caribbean, Hawaii, the Solomons, the Philippines, Fiji, Sri Lanka, Nigeria, Indonesia, Papua New Guinea, Egypt and India (Plucknett 1970, de la Pena, 1970). In addition to the tuber of taro (the most widely used edible part) the young leaves are important component of traditional diet.

Even though taro is grown all over the world it has not been given much reverence outside Oceania. The first written record about taro comes from China in a *Materia Medica* (Greenwell 1947), which describes the medicinal value of the leaves and seeds in controlling flatulence in pregnant women. The plant was considered a delicacy in China even though it is considered a staple in Japan. Taro could have reached Japan either from China or India as two varieties are present in Japan. The plant is called ‘imo’ in Japan and ‘wu’ in China.

The earliest Western records of taro are in the writings of Pliny (23-79 AD) who saw it in Egypt. The plant reached Egypt through Arabia in recent times, as there is no hieroglyphic evidence of taro. In Arabia the plant was called ‘culcas’, a broken from of Sanskrit ‘kuchoo’ and in Egypt it was called ‘qolqas’. It was often confused with lotus and the genus name is derived from the Greek word for lotus. The western route of dispersal of taro is not well documented. However, it can be found naturalized in many Mediterranean islands (Greenwell 1947).

In French colonies, slave traders fed the African slaves their native comfort food eddo while transporting them to the American colonies. Eddo was cheap, durable, and traveled well. In Barbados taro is still called eddo as a reminiscent of how the crop got introduced in the country. Later on another variety of taro was imported from China known as ‘eddo de la Chine’. This later came to be known as Dasheen. In Trinidad still taro is called by this name (de Candolle 1884).

The eastward journey of taro is better documented. Anthropological theories believe that Polynesian people moved through the Malay Peninsula carrying plants that supplied food. These people traveled through Sunda Islands to New Guinea. In Java the plant received the name of ‘tales’, which became ‘taro’ in Tahite, ‘ndalo’ in Fiji, ‘talo’ in Samoa, and ‘kalo’ in Hawaii. According to Dr. Peter Buck (Buck 1929), the first Polynesians had to travel through the volcanic, Caroline Islands as the shorter route through Melanesia was not conducive for the plants they were carrying. Evidence for this route lies in the cultivation of taro in these low volcanic islands. The first Polynesian islands to be settled were the Samoan Islands, approximately 2000 years ago. From there people ventured out to the fertile, volcanic Society Islands in which taro flourished. Since then taro has been grown in the Society Islands for corms (pohiri), young leaves (pota) and inner leaf stem (fafa). Over thirty named varieties of taro have been recorded on the islands (Lepofsky 2003). Future journeys to the Pacific were made with these islands as the center.

The places that grew the best taro at that time were Rapa Islands southwest of Tahiti and Hawaii in the North. Many varieties of taro were developed on these islands.

Both of these islands are known to make a paste out of steamed corms called ‘poi’. In the Rapa Islands, poi is made by women and the method differs considerably from poi used in Hawaii. Steamed corms are crushed by stones along the streams, and then water is added, as the dough in kneaded. Finally it is aerobically fermented for a couple of days, at the end of which it is eaten by making small balls and dipping it in water or lemon juice.

In Hawaii taro became the basis of the civilization. Taro arrived in Hawaii around 4^{th} or 5^{th} century A.D (Merlin 1978) in a large double-hulled voyaging canoe originating from the Marquesas Islands carrying taro, breadfruit, and other crops. Only a few varieties of taro were brought to the island. However, Captain Cook in 1778 documented 300 varieties of taro in the island (Handy 1940, Cho 1998). The existing varieties in the Hawaiian Islands outnumber all of the varieties found in Polynesia. Specific varieties were selected by royalty for particular uses. For example, Lehua and Pi’i were selected for low calcium oxalate content, while Lauloa and Haokea varieties were selected for medicinal and ceremonial purposes (Cho 1998). With the increase in the Hawaiian population, taro became the primary crop as most of Hawaii cannot produce coconut, breadfruit, or sweet potatoes in vast quantities. Festivities commenced in the wet taro patches called ‘lo’i’. The men measured out fields and dug down to the hard soil and built walls around the fields to retain water. Later water was allowed in the fields to create waterlogged environment suitable for wet taro agriculture. Men were called to trample the muddy water and at the end of the day there was a feast. Around these fields of taro other garden vegetables were planted. Taro was harvested nine to twelve months from the time of planting. Only the amount needed to make daily poi was dug up and the hole was filled with another plantlet. Upland taro, on the other hand, was cultivated along the leeward side of the hills that received plenty of rainfall and did not require any supplemental irrigation (Handy 1972).

In Hawaii all taro related work is done by men (Handy 1940, Greenwell 1947) as it is considered one of the auspicious crops of the culture. After harvesting taro, it is roasted, boiled, or made into poi. Poi is a starchy paste made by cooking taro corms, peeling them, and then pounding them with a stone pestle in a shallow stone while adding water to get the desired consistency. The amount of water added controls the thickness of poi, which is finally strained through a cloth. Poi is eaten with a quick motion of the index and middle finger. One-finger poi is thick, sticky poi that can be picked up by just dipping one finger into the bowl. Most people prefer two-finger poi over three-finger poi as the latter is too thin in consistency. Many different varieties of taro might be mixed according to taste while making poi. Usually the chieftains preferred pink taro for poi. After it is ground into a fine paste with a light hand, it is left to ferment aerobically for up to three days depending on the amount of sourness preferred. Yeast and lactic acid bacteria found naturally on the plant ferment the mixture (Allen and Allen 1933). The acid production by the bacteria drastically changes the pH of poi from 6.3 to 4.5 in 24 hours. The pH continues to decline over the next three or four days at the end of which poi is discarded. Researchers identified three *Lactobacillus* species and two *Lactococcus* species in poi (Huang et al. 1994). Poi has been suggested as a medicinal treatment for certain conditions. This starchy fermented paste can be regarded as a possible probiotic to treat diseases like diarrhea, gastroenteritis, Crohn's disease etc. that improve with the use of fermented dairy products, because of presence of *Lactobacillus lactis* in significant amount. It is also recommended as a treatment for infants with food allergies because of its low allergenic protein content (Brown and Valerie 2004). In addition it can be used as a starchy nutritional supplement to induce weight gain in failure-to-thrive patients of cancer, AIDS etc.

Apart from the corms, leaves and petioles of taro are used as side dishes. Taro leaves are a valued delicacy while taro tops are used as animal feeds. The traditional 'luau' or Hawaiian feast gets its name from the leaves of taro. The leaves and petioles are often cooked with coconut milk, spadices are baked with fish or pork, and sweetmeats are made out of grated taro and coconut milk (Greenwell 1947). Taro is also used for its medicinal properties in traditional medicine practices. Corms with mild acridity are grated raw and mixed with sugarcane juice for pulmonary congestion. Taro has been known to be nutritionally superior to other starchy crops like potato. The smaller starch grains in taro make it more easily digestible (Potgieter 1940) and thin consistency poi was fed to infants and invalids for easy digestibility. When Captain Cook arrived on the Hawaiian Islands he found approximately three hundred thousand people thriving on poi, sweet potato, seaweeds, fish, and other green vegetables (Potgieter 1940). Animal proteins were rare to these people, but still they were healthy and had good dentition. A study in Melanesia, in the Manus Islands also showed that people whose staple diets consisting of taro had better dentition compared to the people who ate sago (*Metroxylon* sp.) (Kirkpatrick 1935).

At present, taro is an important agricultural commodity in Hawaii and continues to be consumed and used in cultural functions and gift giving. Most of the corms produced today are utilized to make poi. The corms are washed, peeled, pressure-cooked, and mashed before undergoing the fermentation process with *Lactobacillus* spp. for a day. The fermented sour tasting paste with a pH of 3.9 is then strained and packaged for the Hawaiian market. The other product made from taro corms is chips. A cottage industry thrives in Hawaii making taro chips to give taro a longer shelf life (Onwueme 1999) for export purposes.

Year	Area (ha)	Production (tonnes)
1972	185	4000
1983	150	2472
1984	150	2868
1985	162	3118
1986	158	2878
1987	162	2818

Table 1 shows production and area harvested in Hawaii (adapted from Onwueme 1999)

From table 1 it is evident that owing to urbanization, the area harvested has declined over time in Hawaii. In 1972 (de la Pena 1970) 185 hectares of land was cultivated and 4000 tons of taro were produced. Since then the amount of land harvested and production has declined steadily until recently when it attained a more stable peak. Production of taro now serves the North American tourists for a cultural experience while providing a staple to Hawaiians to retain their traditional dietary habits. In Hawaii taro agriculture has been modernized with fertilizers and machines, and as a result Hawaii boasts of one of the highest crop yields in wetland taro production in the Hanalei valley (figure 5).

Figure 5. Wetland taro cultivation in Hanalei valley (adapted from Onwueme 1999).

In other parts of the world corms and tubers of taro are produced and used in ways different than in Hawaii. In the Philippines, taro is a subsistence crop for many individuals. They use the corm in stews and as a sweet. The sweets are made of boiled and sliced corms sprinkled with coconut and sugar. In Brazil, on the other hand, the boiled corms are mixed with cornmeal to make bread while in Southern Colombia taro, otherwise called ‘sicse’, is sliced into half inch pieces and fried in pork fat. A fermented drink called chicha is also prepared from the corm. In Brazil, juice of corms is also used as an abortifacient, as poultice for ulcer treatments, and as anthelmintics (Plowman 1969). In India *Colocasia* is used in veterinary medicine, as well as being mixed with bulbs of *Zingiber cassumunar* Roxb., bark of *Oroxylum indicum* Vent., old tamarinds (*Tamarindus indicus* L.), and distilled seeds of *Semecarpus anacardium* L. f and given to drink as a treatment of dysentery (Jain, 1974). In Bangladesh, among the Marma tribes, the leaf and petioles of the plant are cooked as vegetables and have been reported to be effective treatment for cataracts (Alam 1992).

Taro is also considered poisonous and has been reported to cause severe irritation, in cattle grazing on them. The primary reason for irritation is the presence of calcium oxalate crystals, but Webb (1948) mentions the presence of prussic acid being partially responsible for the toxicity of the plant. Taro has also been associated with leprosy in India (Watt 1962). It had been proposed that there was a positive correlation between new cases of leprosy if taro was harvested during the dry season. The plant has also been documented to cause glomerule-tubular nephritis and a marked degeneration of the adrenals, a condition attributed to a highly toxic acid sapotoxin (Watt 1962).

Finally, let us take a look at the current cultivation rates of taro across some countries. The Philippines has the largest area devoted to taro cultivation next to China. Yet taro is a minor crop in both the Philippines and China. In 1996, in the Philippines, about 34,000 hectares of land were devoted to taro, producing about 117,000 tons (FAO, 1997). Rice is the dominant staple in both cultures, thus the role of taro remains that of a vegetable. On the other hand, taro was introduced to Japan many years ago and achieved the status of a staple food. Somehow, over time, there has been a steady decline in its popularity only to be replaced by sweet potato and Irish potato resulting in a decline of production and consumption of taro. Similarly in Malaysia, which is considered to be one of the centers of domestication of taro, it is not considered a staple food. However, incorporation of taro into medicinal uses and folklore indicates that the crop dates back about 2000 years in this region. Wild taro occurs along the Malay Peninsula and is locally called keladi. Other aroids and yams are similarly called in this region. A similar situation exists in India, another center of domestication of the plant. Locally all yams and aroids are lumped together and called kuchoo. In some cultures of Western India taro is known as arbi. Both the corms and the leaves are part of traditional Indian cuisine, but are treated as vegetables. To a great extent it is thought to be a food for the poor, helping them sustain during famines. It is interesting nonetheless to notice that in India taro is also a part of folklore, rituals, and traditional medicine showing the ancient tie with the crop.

Even though we see that taro is a secondary crop in the rice cultures of Southeast Asia, it is well appreciated as a vegetable and a subsistence crop. The field production system of wetland taro in waterlogged fields is similar to that of rice production and hence taro fits in as an alternative crop. In Oceania taro is regarded as the staple and much reverence is attached to the crop socio-culturally. So in these cultures taro will continue to be the most important crop. Overall, taro has a unique ecological niche. It can survive in waterlogged soil and swamps, in shady areas and can tolerate up to 25-50% salinity (Onwueme 1999). Most of the above conditions are difficult for other crops. Hence taro will be less likely to have any competition in exploiting the above niche. In future, taro shows the promise of continuing as a subsistence crop, while boosting the economy of producing countries, and enriching the lives of people socio-culturally.

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Vita

Sayantani Ghosh Dastidar was born in Kolkata, India on December 28, 1981, the daughter of Ranjan Ghosh Dastidar and Alo Ghosh Dastidar. After completing her high school at Patha Bhavan High School, Kolkata, in 2000, she started school at Texas State University at San Angelo, Texas. During the summer of 2002, she worked for Texas Department of Transportation as an intern. She received her Bachelor of Science in May 2004. During the following year she was employed as a Research Assistant at Texas State University at San Angelo, before she entered graduate school at University of Texas at Austin, in 2005.

Permanent address: 2501 Lake Austin Blvd, Apt B201. Austin, Texas 78703

This report was typed by the author.