Genetic Diversity in Taro, and the Preservation of Culinary Knowledge

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Abstract

The origins, domestication and dispersal of taro are outlined, as far as they are known, and recent surveys of genetic variation are reviewed. These surveys have established that taro, an ancient root crop in Asia, Africa and the Pacific, is genetically very diverse. Across the full geographical range of taro, very little is known about what forms of taro are grown for what economic and culinary purposes. Ethnographic research on taro as a food, and the preservation of culinary knowledge associated with taro, are needed for the preservation of genetic diversity in this crop. Much will depend on how the crop is developed and promoted commercially, and on active interest and support for the crop among local growers, cooks, distributors and consumers.

本論文は、現在明らかになっている限りのサトイモの起源、栽培、拡散について概説し、遺伝的多様性に関する最新の調査結果を検討している。これら最新の調査により、アジア、アフリカ、太平洋諸島で古くから栽培されてきた根菜作物であるサトイモが遺伝子的に非常に多様であることが立証されてきた。サトイモが分布する全地理的範囲においても、どんな品種のサトイモがいかなる経済的目的、料理目的で栽培されているのかほとんど知られていない。遺伝的多様性を持続させるためには、食物としてのサトイモについての民族学的調査、サトイモ関連料理の知識の保存は不可欠であるが、サトイモをいかに開発し商品として促進するか、また地元栽培者、料理関係者、卸業者、消費者が積極的に関心を持ち支援することに依拠するところが非常に大きいであろう。

Introduction

In this paper I explore the connections between genetic diversity in taro, *Colocasia esculenta* (L.) Schott, and diversity in the culinary knowledge associated with this plant. To what extent is one dependent on the other? Because different cultivars are used in different ways, it seems likely that preserving culinary knowledge is important for preserving genetic diversity in taro, and vice versa. Without the one, the other may lose relevance for people.

This suggestion may seem obvious, but in fact the relationship between genetic diversity and culinary diversity is not simple. On a local scale, within one community or country, the two kinds of diversity are not necessarily correlated. A single cultivar can be used in many different ways, and more than one cultivar can be used in the same way. The relationship also depends a great deal on social context and the nature of the wider cuisine within which taro is used. On a global scale there is almost certainly a correlation, but we do not yet have a global view of diversity in the culinary knowledge associated with taro. We do have the beginnings of a global view for genetic, morphological and biochemical diversity in this crop.

The suggestion that genetic diversity in taro may depend on the preservation of culinary knowledge is a special case of the more general claim that protecting plant genetic diversity requires respect and support for human cultural diversity (Fowler & Mooney 1990; Balick & Cox

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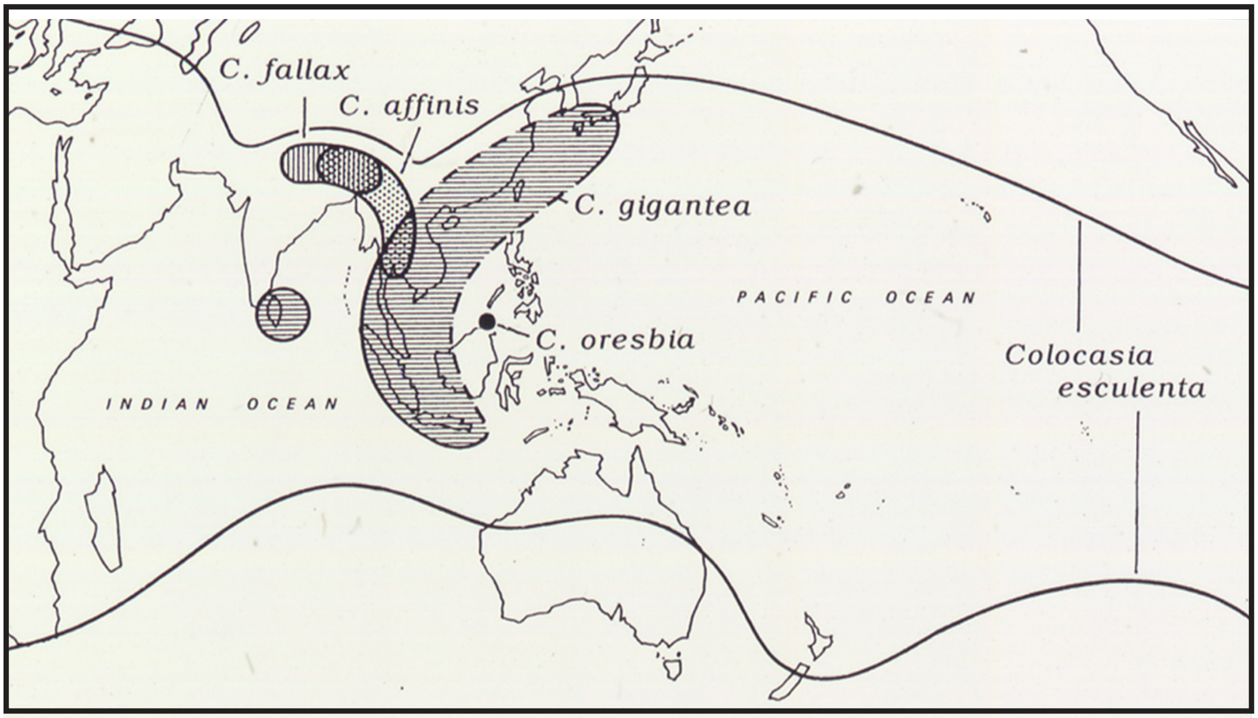
Figure 1. Known distributions of *Colocasia esculenta* (L.) Schott, *C. gigantea* Hook. f. (in wild and cultivation), and other species found only in the wild (*C. fallax* Schott, *C. affinis* Schott, and *C. oresbia* A. Hay). Poorly known species not shown are *C. virosa* Kunth (Bengal) and *C. Mannii* Hook. f. (Assam).



1996). Eyzaguirre (2000) has stressed the need for ethnobotanical research alongside efforts to preserve the genetic diversity of taro and other crops. In my own research on taro, I previously used ecological and genetic approaches to learn about the history of taro. I now believe that ethnographic approaches are also needed, for historical purposes, to help preserve knowledge associated with the crop, and to guide future development of the crop.

Taro is a world crop, and is best introduced with a global perspective. For this I depend on many authors, field informants, and my own observations in Asia, the Pacific, and the Mediterranean.

Origins and Domestication of Taro

Origins and Natural Range

Before the last two centuries of rapid and international transport, taro was the world's most widely cultivated starch crop, ranging from India and Southeast Asia to Northeast Asia, the Pacific Islands, Madagascar, Africa and the Mediterranean (Matthews 1995).

From what we know about the distributions of other species of *Colocasia* (Figure 1), the origin of taro (*C. esculenta*) as a natural species was probably somewhere in the tropical region from India to Indonesia. One widespread natural form or wildtype of taro has been described, and this is distributed from India to China, Japan, Indonesia, Australia, New Guinea and Polynesia (Matthews 1991, 1995, 1997, 1998a; Matthews *et al*. 1992a,b; Matthews & Terauchi 1994). The natural range of wildtype taro is not yet well defined, but is certainly less than its present range. The natural range may extend as far as Australia and New Guinea, or somewhere further east, but not as far as Polynesia because of sea barriers. As a food, medicinal plant, or fodder plant, the geographical range of wildtype taro has been extended by humans, with or without cultivation. No specific places or dates can be recognised for the first use of wildtype taro, and discussion of its natural range is complicated by the possibility that domesticated forms have reverted to wildtype in some areas.

Wildtype Taro and Domestication

Wildtype taro differs from domesticated forms of taro in many ways. It is much more acrid, has relatively small corms (swollen stems that store starch), bears long thin stolons (runners) rather than short, thick and starchy side-corms, and has leaves that are almost entirely green. Wildtype plants are not genetically uniform, but they are very similar in morphology over a large geographicalrange (Matthews *et al*. 1992; Matthews & Terauchi 1994, Lebot *et al*. 2000). Other wildtypes that do not form long stolons may exist at relatively high altitudes in subtropical Himalaya (Yoshino 2001). In northern Australia, wildtype taro is commonly associated with waterfalls and stream banks at low altitudes (below 1000 m) in wet tropical rainforest.

Figure 2. Wildtype taro (green petiole with stolons and small corm) and a domesticated form (purple petiole with larger corm) from a stream on Amami Island, in the Ryukyu Archipelago of southern Japan. The wildtype is locally recognised as a plant that was used until the mid-20th century as pig fodder, after cooking. The plants shown here grew side-by-side on a gravel stream bank, below the site of a former settlement. The wildtype is commonly found in disturbed habitats near past or present settlements. The domesticated form is presumably a garden escape, and was not seen in other locations with the wildtype. (April 2001).

Taro in its natural state is a semi-aquatic tropical herb, and can easily become weedy in disturbed or managed habitats that are warm, wet and open to the sun (Figure 2).

In contrast, domesticated forms of taro are found over a much larger geographical and environmental range, and are very diverse in morphology, eating qualities, maturation speed, and storage characteristics. There are possibly hundreds of tropical, subtropical and temperate-adapted forms of cultivated taro, but no exact figures can be given - partly because there are no fixed criteria for distinguishing cultivars.

Exactly when and where taro was first domesticated is not known, for three reasons. Firstly, the full variation, distribution and natural range of wildtype taros are not yet known. Secondly, most surveys of genetic diversity have been carried out on cultivated forms. In the few surveys involving wild forms, there has been little or no discussion of whether or not they can be recognized as wildtypes, and sample sizes have been small. Thirdly, archaeological evidence for early use of taro is lacking, at least partly because the edible portions of the plant are soft and unlikely to be preserved.

Genetic studies are discussed in more detail in the next section. One tentative claim has been made for the occurrence of ancient taro starch on stone tools in New Guinea, approximately 28,000 years ago (Loy *et al*. 1992). This claim has not yet been verified by other workers, but has helped to open an important new field of archaeological research. Starch residues from many different plant species have been found in archaeological contexts, in various parts of the world, and the search for ancient starch is a small but rapidly expanding field (see Fullagar 1999, Piperno *et al.* 2000).

Genetic Diversity in Taro

Diploids and Triploids

The earliest studies on genetic diversity in taro used simple cytological techniques to count chromosome numbers. Diploids with 2n = 2x = 28 chromosomes, and triploids with 2n = 3x = 42 chromosomes are common, while tetraploids (2n = 4x = 56) are extremely rare and may be weak-growing (n = somatic cell chromosome number; x = basic chromosome number, the number in a single full set). Triploids are believed to arise when unreduced gametes (1n = 2x = 28) from one parent flower meet normal gametes from another parent flower (1n = 1x = 14). Tetraploids are much less likely to arise because they require unreduced gametes from both parent flowers. Early geographical surveys of chromosome numbers revealed that only diploids are common in the Pacific Islands, while diploids and triploids are common in the mainland of Asia. Coates *et al*. (1988) examined chromosome morphology and found diverse cytotypes among diploids and triploids.

More recently, surveys in China have shown that triploids predominate at higher altitudes and latitudes. Similar but less comprehensive surveys have been made in India and Nepal, with similar results. Zhang & Zhang (2000) suggested that triploid taro may have arisen in south and central China during a long period, 4000 to 1000 years BC, when the climate of that region was tropical and thus favorable for flowering by diploid taro. At present, only diploids are found in the extreme south, in Hainan province, while diploids and triploids are common in southern China, and only triploids are found in central, eastern and northern China (i.e. from the Yangtze River area northwards). At altitudes and latitudes that are marginal for diploid taro, adverse environmental conditions may promote the occurrence of unreduced gametes (Zhang & Zhang 2000).

Tahara *et al*. (1999) surveyed isozyme variation in diploid and triploid taro from Yunnan (southern China) and Nepal, and concluded that triploids arose independently from diploid parents in both regions. They suggested that the additional set of chromosomes improved the competitive ability of triploids in unfavorable climates. Presumably two phases of competition were involved, a first phase in the establishment of wild seedlings (assuming that taro was never deliberately propagated by seed), and a second phase of competition with other cultivars, after seedlings were discovered by farmers. Triploid taro are inherently infertile, and diploids cannot breed in unfavorable climates, so this second phase must have involved vegetatively propagated cultivars during human selection for cold-hardy and fast maturing forms at higher altitudes and latitudes.

In the Pacific Islands, the general absence of triploids might reflect a lack of environmental stress during gamete production, the presence of stable genotypes, or a lack of selective advantages for any indigenous or introduced triploids. The few triploids that have been reported (Yen & Wheeler 1968; Matthews 1985; Coates *et al*. 1988) are most likely recent historical introductions from Eastern Asia (from China or Japan to Hawaii and New Zealand for example), or may be earlier introductions from Eastern Asia in the case of the Philippines.

Genetic Diversity and Regional Genepools

Genetic diversity in taro has been surveyed further with tests for ribosomal DNA (Matsuda 2001, Matthews *et al*. 1992a, Matthews & Terauchi 1994), chloroplast DNA (Tahara *et al*. 1999), mitochondrial DNA (Matthews *et al*. 1992a), analysis of randomly amplified polymorphic DNA (RAPD analysis) (Irwin *et al*. 1998, Li, M. *et al*. 2000), and isozymes (Isshiki *et al*. 1995, Lebot & Aradhya 1991, Lebot *et al*. 2000, Li, X. *et al*. 2000, Matsuda & Nawata 1999; Tahara *et al*. 1999; Zhang & Zhang 2000).

All of these approaches, and studies of chromosome morphology, indicate that cultivated forms of taro are very heterogeneous. A number of studies indicate that triploids have arisen independently many times from diverse parents. From the DNA and isozyme surveys conducted by Irwin *et al*. (1998), Lebot & Aradhya (1991), Lebot *et al*. (2000) and Tahara *et al*. (1999), it now appears that more-or-less distinct taro gene pools exist in all the regions where taro may be naturally distributed - the Indian subcontinent, in China and Southeast Asia (Sunda continental region), and in Australia and New Guinea (Sahul continental region). Early domestication involving different gene pools and wildtype populations may have taken place more-or-less independently in these regions (Matthews 1990). Surveys of taro in Southeast Asia and the Pacific Islands indicate that most cultivars in Polynesia have a narrow genetic base derived from New Guinea and the Solomon Islands (Lebot 1999, Lebot & Aradhya 1991, Lebot *et al*. 2000). In these surveys, morphologically similar wild taros were genetically more diverse, and morphologically diverse cultivars were genetically less diverse. Domestication or further selection may still be happening in the various taro genepools, wherever the plants produce flowers and seed (in tropical regions), and wherever new vegetative mutations occur (in all climatic regions).

Vegetative Mutation and Selection

It is likely that much of the visible phenotypic diversity of cultivars in the Pacific Islands is due to vegetative mutation and selection. The diversity of color patterns in the corms and leaves of Pacific cultivars have been noted by many authors. Selection for attractive and ornamental color patterns may have made it easier to distinguish and maintain plants with other less-visible vegetative mutations. More speculatively, it is also possible that synergistic effects promoted unstable colour systems and vegetative mutation generally. In any case, it is clear that measures of overall genetic diversity do not fully measure diversity among the genes that affect agronomic and culinary qualities. Much more work is needed to learn about (i) the full natural range of wildtype taro, (ii) the extent and nature of genetic variation among wild and cultivated taro, (iii) the reproductive biology of taro, and (iv) the role of vegetative mutation in the domestication of taro.

Alternative Scenarios

The evidence so far does not exclude the possibility of taro being cultivated and domesticated in one area first. Ideas about transplanting and cultivating wildtype taro could have been transmitted from one region to another, thus leading to culturally-linked domestication in multiple gene pools. Alternatively, a few already-domesticated plants could have been transmitted - along as yet unknown routes - thus allowing the introgression of important alleles and traits into other regions, with no large or overall impact on genotypes and gene pools in other regions. These and many other scenarios can be imagined, as the complex history of taro begins to emerge.

Morphological and Biochemical Diversity

Forms, Types, and Uncharted Morphological Diversity

Historically, in research literature concerning taro, two main groups of cultivars have been recognized - those that produce a large edible main corm with few side-corms, and those that produce a small or medium-sized main corm that is often inedible, and many small edible side-corms (Plucknett 1983). In fact there are many intermediate and also more extreme forms, including forms with (i) abundant granddaughter side-corms, (ii) multiple elongate corms, or (iii) branched corms that may be the result of different shoots fusing or partial division of a central shoot (as suggested by Yoshino 2001). Distinct types or botanical varieties of taro have been reported but are not universally recognized by botanists. In this paper, I refer to 'cultivars' or 'forms' to indicate plants that vary morphologically.

Lebot *et al*. (2000) suggested that the two main groups of cultivars (referred to as **dasheen** and **eddoe** types) are what most farmers and markets seek, and that intermediate types are not interesting for plant breeders. This might not be true in all locations. The two main groups may represent tropical and temperate extremes in the range of morphological variation in taro, with large-corm types being common in tropical to subtropical regions, and small-corm types common in subtropical to temperate regions. Intermediate types may be common in subtropical regions of India, East Asia, and Southeast Asia, and may be important for plant breeders in those regions.

The actual situation is even more complex than just indicated. Taro has been long cultivated in very diverse regimes of soil, water, temperature, day length, light intensity, altitude and latitude. Most English-language research on taro has been focused on tropical cultivars, outside the continental Asian axes of low-to-high latitude, and low-to-high altitude. The many forms of taro may include some that emerged gradually in one place, in response to very specific environmental circumstances, and others created in single crosses between parents from separate locations (in humanly-created assemblages of cultivars, or cultivars and wild taros, for example). Recognising long-term and adaptive associations between particular forms and particular environments will be difficult because (i) morphological diversity in taro is still uncharted in many regions, (ii) cultivars can be grown in sub-optimum as well as optimum environments, and (iii) taro has an ancient and poorly known history of long-distance dispersal.

Across the full geographical range of taro, very little is known about exactly what forms are grown for what economic and culinary purposes. The needs and preferences of urban and commercial markets do not always coincide with the needs and preferences of rural markets and farmers. Many farmers grow taro for family, friends, and other community activities. Like many other root crops, taro is often associated with informal or non-commercial economic activities, Such activities are generally not recorded in surveys of agricultural production and trade (Horton 1988).

Biochemical Diversity and Culinary Qualities

During the last two decades there has been a rapid expansion in the amount of information available on the biochemistry of taro (Bradbury & Holloway 1988, Maga 1992, O'Hair & Asokan 1986, Sunell & Arditti 1983). Data on starch, sugar, protein, and fat content, amino acid composition, vitamins, and so on have been reported in many countries. Since starchy corms are the main product from taro, there have been detailed studies of starch granule size, gelation, amylose and amylopectin content, and the mucilage that makes corms very slippery when cut. Lipids, proteins and amino acids, and sugars all give rise to volatile compounds when taro is cooked, and these compounds contribute to the flavor. MacLeod (1990) identified nearly all volatile compounds in extracts from cooked taro, and described the flavour as buttery, earthy, and musty/moldy, with odor notes reminiscent of boiled/baked potatoes, cooked rice, and roasted cereal.

Acridity and many other factors may compromise the edibility, digestibility, and nutritional qualities of wildtype and domesticated taro. The following list, from Matthews (2000), represents most of the factors that have been studied.

(i) acridity
(ii) oxalic acid
(iii) cyanide

(iv) alpha-amylase inhibitors
(v) trypsin and chymotrypsin inhibitors
(vi) lectins (major storage proteins)
(vii) mucilage
(viii) tannins and other phenolic compounds

Acridity and other factors are involved in the natural biochemical defenses that help to protect taro against herbivores and micro-organisms. These defenses can act on herbivores, and humans, at the moment of consumption, or later during the process of digestion. The most obvious unfavorable quality of taro for humans is the acridity of raw corms and leaves. According to Bradbury & Nixon (1998), acridity is caused by a protease (protein degrading enzyme) that is attached to raphides, thus forming a functional complex described as 'Nature's poisoned spear'. The raphides are sharp, arrow-like crystals of calcium oxalate, and are abundant in taro tissues. Raphides in taro and other aroids are not always acrid, and the degree of acridity in these plants is not always correlated to the abundance of raphides or calcium oxalate.

Most cultivated forms of taro have some degree of acridity, but wildtype plants are much more acrid, and can only be eaten after very thorough processing. Acridity can cause a severe itching, stinging, or burning sensation in the mouth and throat, followed by swelling and other effects, or a less severe irritation or itching sensation on external skin (on hands and arms for example). The reaction can be immediate (apparently instant) or delayed (a few minutes), weak (tolerable) to strong (intolerable), and short-lasting (minutes) or long-lasting (hours) (author's experiences). Responses to acridity vary, and some people can tolerate more acridity than others.

All the biochemical factors noted above vary among taro cultivars, so there is great potential for modern plant breeders to modify the nutritional and culinary qualities of taro. However, breeding is only one component of crop development. A comparison with the wine industry illustrates this. The modern international wine industry is based to a large extent on two activities, (i) the transfer of grapevine clones to many different locations, and (ii) very close analysis of the precise taste qualities of the grapes and wines produced by each clone in each location, by each grower and wine maker (see Robinson 1996). Wine products are often branded according to place and the particular grapes used. Such distinctions are not taken to the same extreme for most other vegetatively propagated crops. The taste qualities of taro cultivars undoubtedly vary with equal subtlety, according to place, cultivar, and preparation method, but the variation is not understood in great detail. Investment in such understanding is lacking because taro, in general, has a lower social status than wine. In the Pacific Islands, the social status of taro is greater than in most other taro-growing regions, and this may have encouraged (i) wide dispersal of the crop and favoured cultivars, and (ii) more sensitive recognition of variation in culinary qualities, according to the cultivar used, cultivation place, and preparation method.

The phrase 'culinary qualities' embraces many different qualities that affect preparation and consumption. Plant breeders have always given some attention to these qualities, because they are critical for the acceptance of new cultivars by consumers. So far, no effort has been made to relate specific genes in taro to specific culinary qualities or traditional uses, and very little information on traditional uses has been available. Some research institutions have started recording local culinary knowledge, to help guide the preservation of existing taro cultivars, and the development of new cultivars (Eyzaguirre 2000, Sivan 2000).

Ethnographic Research Culinary Knowledge

Descriptions of taro production are common in many areas where the plant is an ancient crop, in Africa, Asia, and the Pacific Islands, but the most detailed accounts come from Oceania, where total production is lowest (because of low total population) but per capita consumption is highest (see Vieth & Chang 1983). In Oceania as a biogeographical region (Green 1991) taro is often an important supplementary or staple crop (see Allen 1971, Barrau 1958,1961, Handy & Handy 1972, Morrison *et al.* 1994, Ohtsuka 1994, Pollock 1992, Sillitoe 1983, Young 1960). Surprisingly, a full description of taro preparation methods and uses has probably never been made in any one location, although Kennedy (1931) did present a relatively detailed description of several taro dishes on one island in Micronesia.

To build up a picture of how taro is used, worldwide, will require intensive ethnographic surveys in many locations, and systematic reviews of the brief and scattered reports that already exist (Matthews 2000). My own efforts so far have been mostly in Cyprus, an high island in the Eastern Mediterranean, and in Japan. Next I briefly introduce taro as a food in these areas, and in the Pacific.

Cyprus, Taro, and Recent Immigrants in the Pacific

In Cyprus only one cultivar of taro is grown, but there are at least nine distinct ways of preparing taro (**skhara**, **vrasto**, **souppa skourdalia**, **tiganites**, **kappamas**, **yiakhni**, **psito**, **moussakas**, Matthews 1998a) (Figure 4). The fermentation of taro starch, and the edibility of leaves (petioles and blades) are not known in Cyprus. All the methods recorded use heat to reduce acridity - by simmering, boiling, stewing, frying, roasting, grilling, and baking (steaming was not reported). For each named dish, the details of preparation varied from person to person and village to village. The range of dishes is not large, compared to the range in Japan (Matthews 1995), but does involve a greater range of methods for applying heat.

Figure 4. Taro stew in Cyprus (**kolokasi yiakhni**), prepared with taro, onion, tomato, celery, lemon juice and pork (Sept. 1996).

Taro is essentially unknown in central and northern Europe, but is likely to have reached Cyprus in ancient times from India or Africa, via the Levant or Egypt. Taro in Cyprus has been integrated into a cuisine that is best described as Mediterranean. One of my main interests in Cyprus was to see how taro is used by people with a cuisine that is close to European. Most Europeans and their descendants have never eaten taro, or do not enjoy it, but do enjoy Mediterranean food. The author of one New Zealand cooking book has described cooked taro as 'a mixture of wood pulp and wallpaper paste' (Law 1978). A small number of Cypriot immigrants are now growing taro in areas near Sydney and selling it in that city, alongside taro produced by Asian immigrants and taro imported from the Pacific Islands (author's field notes, 1998). If Mediterranean-style taro dishes become more well known in the Pacific region, this might expand the market for taro. In contrast to Europe, the appreciation of taro in Asia is much more widespread. For many Asian immigrants in the Pacific Islands, taro is a very familiar food.

Figure 5. Wetland taro (**ta-imo**) in ponds, below a plantation of a tropical coastal cycad, *Cycas circinalis* L., Amami Island, Ryukyu Archipelago, southern Japan (April 2001).

Cultivars and Cuisine in Japan

The islands of Japan span a wide range of latitudes and are exposed to continental and Oceanic weather systems. The islands thus offer very diverse physical environments for agriculture. Apparently tropical forms of taro are common in the Ryukyu Archipelago in southern Japan (Figure 5), and reach their northern limit for cultivation in Kyushu. Temperate forms reach their northern limit in the far north of Honshu, and are also found in the Ryukyu islands. In northern regions, the main agronomic distinction made among taro cultivars is developmental (early verses late maturing). Taro in the north experience a relatively short growing season and are almost all grown in dryland conditions (Figure 6). In Okinawa and other islands in the far south, the main distinction is habitat preference (wetland verses dryland

Figure 6. Farmer with dryland taro, Nigata Prefecture, northern Japan (Oct. 2000).

types). Taro in the south can be grown year round, in a continuous temporal succession of crops, although there is some seasonality. Certain recipes are particular to wetland taro, or ta-imo, and other recipes are common to a range of dryland cultivars, which are grouped together as chinnuku. The wetland or dryland distinction is important throughout most of the tropical Pacific.

There are at least nineteen named and unnamed morphological groups among taro cultivars in Japan (Matthews *et al*., 1992). These groups are believed to be derived from several genetically distinct clonal introductions that changed through vegetative mutation while in Japan. The cultivars vary in the size and shape of central corms and side-corms, number of side-corms, acridity, texture after cooking, and other qualities. Early and late maturing types differ in their culinary qualities and uses; wetland and dryland types also differ. Farmers choose the cultivars they grow for both agronomic and culinary reasons, balancing their personal preferences with commercial aims and the resources available for growing taro (land, labor, and so on).

The overall diversity of cooking methods in Japan is well illustrated in a large encyclopedia entitled Japanese Food Eating Styles (Rural Culture Association 1997). For this publication, elderly people were interviewed by many researchers in all prefectures of Japan, in the 1980s, to record food rituals and recipes known during the first half of the twentieth century. Computer searches of the CD edition have revealed almost 2000 entries on taro (Table 1). This work contains what is probably the largest and most detailed compilation of taro recipes in existence, despite the fact that taro is a minor component in Japanese diets. In this recipe collection, boiling taro in water (with or without other ingredients) is far more common than applying heat in other ways. So far I have only encountered frying as a modern secondary treatment used to enhance flavor after boiling taro. This reflects the general importance of cooking in water for Japanese cuisine.

Taro dishes commonly referred to as **nimono** (boiled materials, Figures 7 & 8) and **miso-shiru** (hot soups made with paste from fermented soybean as flavoring) are most common. These kinds of dishes are not unique to taro, and are found everywhere in Japan. They are mainstay side-dishes, almost always eaten together with rice, and taro is just one of many possible ingredients that can be used. The encyclopedia Japanese Food Eating Styles also mentions many taro dishes just once or a few times. These may include uncommon dishes that are not widely known, and common dishes that have many different names. Specific taro cultivars may be used for specific dishes, but in most cases, taro is not referred to using cultivar names. Dishes in which taro is boiled and then mashed and flavored in various ways appear to be a distinctive component of cuisine in the far southern islands of Japan. These mashed taro dishes - numuni and others

Figure 7. Small child-corms (**ko-imo**) after boiling in a flavoured sauce, and sold as fresh product, in Kyoto, Japan.

Figure 8. Small child-corms (**ko-imo**) after boiling in a flavoured sauce, and sold as stored product in liquid in airless plastic bag in Kyoto, Japan.

Table 1. Taro dishes in eleven northern regions of Japan. The dishes are ranked according to the number of reports found in Japanese Food Eating Styles (Rural Culture Association 1997). Prefectures covered: Hokkaido, Aomori, Iwate, Miyagi, Fukushima, Akita, Yamagata, Niigata, Toyama, Ishikawa, Fukui (information for all the other prefectures has not yet been translated).

Dishes using corms or side-corms	No. reports	Dishes
	47	**nimono**
	15	**miso-shiru**
	7	**mochi**
	6	**zoni, zosui**
	5	**noppei, misoni**
	4 or less	**dango, dengaku, dojojiru, goma-ae, gomoku meshi, imonoko-jiru, kasu-jiru, kiritanpo, mazegohan, nabemone, nanakusagayu, nitsuke, o-hagi, sekihan, soba, suiton, surimi, zubonuki**
Dishes using petiole (or blade if indicated)	5	**itamemono**
	4	**suzuke**
	3	**miso-shiru, sunomono**
	2	**aemono, itamemono (with blade), suiton, zoni**
	1	**makizushi, nimono, nitsuke, shira-ae, tsukudani** (with blade)

Figure 9. Edible taro petioles (**zuiki**) from a cultivar of *C. esculenta* (**akazuiki**), (A) placed in sun to dry before peeling and storage, (B) peeled while fresh and served after pickling in weak vinegar. Nigata Prefecture, Japan (Oct. 2000).

- are usually made using the wetland taro (Matthews field notes 2001).

A few taro cultivars in Japan are recognized as having edible petioles (leaf stems), but this is a minor use and involves few cultivars. In northern areas, a cultivar known as **akazuiki** (red-stem) is the main source of petioles (Figure 9). Using taro leaf-blades is very rare in Japan. A second, taro-like species known as **hasu-imo** (*Colocasia gigantea*) is only used as a source of edible petioles (Figures 10 & 11). **Hasu-imo** is common in rural home-gardens, and is also grown commercially and sold widely within Japan. The leaves of taro are commonly used as a vegetable throughout Asia and the Pacific, while those of **hasu-imo** are mainly used in eastern and southeastern Asia. The inflorescences and stolons of taro are widely but not commonly used, in Asia and the Pacific.

Recent Trends in Japan

Analyzing the data in Japanese Food Eating Styles has only just begun. Initial examination indicates that the diversity of culinary methods applied to taro is positively

Figure 10. Edible petioles (**zuiki**) from *C. gigantea* (**hasu-imo**) as sold in a supermarket in Kyoto city, Japan (July 1996), Only one cultivar of this species is known in Japan.

Figure 11. Edible petioles (**zuiki**) from *C. gigantea* (**hasu-imo**) peeled while fresh and served raw as a vegetable sashime, Kagoshima Prefecture, Japan (Nov. 2000).

correlated with production, at the prefectural geographic scale. In other words, more dishes have been reported in areas that produce more taro. It is not yet known whether or not the areas with greater production are associated with greater cultivar diversity. The relationship between production and cultivar diversity is likely to have changed during recent decades, as taro became a standardized commodity that is sold nation-wide. The main cultivar sold now is an early-maturing temperate form known as **Ishikawa-wase**. The small side corms of this and similar dryland cultivars are generally referred to as **ko-imo** (i.e. child corms) and such **ko-imo** are now imported in large quantities from China (He & Li 2000). In China, this trade has stimulated efforts to add value with new processing techniques.

In Japan, the relatively cheap and abundant supply of one kind of taro product may be encouraging innovation in cooking methods, as people seek ways to make the product more interesting to eat. Taro minestrone and taro pizza are among the more curious inventions. From interviews and field observations, it appears that price competition is leading to greater crop wastage. The mother corms (**oya-imo**) of some cultivars are considered inferior for eating compared to the child corms (**ko-imo**), and are now often discarded because their retail value is too low.

The main commercial varieties in Japan are not at risk of disappearing because of imports, but some local cultivars may be. At present, many cultivars are represented in local and national research collections, and there are still many farmers and home-gardeners who grow local cultivars for their own use. As I write, the issue of cheap imported vegetables and competition with Japanese growers is being actively discussed and is of national concern.

Cultivars and Cuisine in the Pacific Islands

In Australia, New Zealand, and the Pacific Islands generally, taro is now grown, sold, and used by diverse indigenous and immigrant groups. Although recent immigration has expanded the range of culinary knowledge associated with taro, many indigenous peoples in the region have adopted European and American food styles and industries. Traditional foods and culinary knowledge have been lost to some extent, especially in urban areas. In the Pacific generally, local recipes for taro may have been more complex or diverse in the recent past. Standard modern flavorings such as tomato sauce, refined sugar, and iodized salt may have made the use of traditional flavorings less widespread or frequent, though grated coconut and coconut milk remain popular additions in taro cooking. These coconut products are now commercial commodities and are commonly imported and used with taro in Australia and New Zealand. The extensive modern trade in new and traditional foods has led to new ways of using taro in previously isolated areas of the Pacific - most obviously in Hawaii perhaps.

Many different taro cultivars exist in Hawaii (Hollyer *et al*. 1997). These vary in color, texture and sweetness, and different cultivars are favored for different culinary purposes. Taro corms in the Pacific Islands are often eaten in a very plain manner, after being peeled and boiled. Among Pacific connoisseurs of taro, much attention is given to the color, taste and texture of the most simply prepared taro. In this region, any variation in culinary qualities is likely to have been subject to strong selection by taro growers and consumers. Such selection has undoubtedly contributed to the cultivar diversity that now exists, despite an essentially narrow genetic base (see isozyme surveys discussed above).

Conclusions

Genetic diversity and the preservation of culinary knowledge

Ultimately, the survival of genetic diversity in cultivated taro - and any cultivated plant species - will depend on the personal interests and motives of farmers and consumers. For taro, the critical issues are (i) whether or not the plant is actually liked as a food, and (ii) the maintenance, transfer, and development of traditional culinary knowledge. There is clear evidence for much genetic diversity in taro, but only scattered evidence for diversity in culinary knowledge. On current evidence, it is not possible to quantify the overall correlation between these two kinds of diversity. In some situations, there may be no correlation or a negative correlation.

A common problem for the commercial distribution of taro is the great variation in culinary qualities among different cultivars (Matthews 2000). This would not be the case if just one culinary method or rule could be applied to all existing cultivars. As a generalisation, it therefore seems obvious that genetic diversity and culinary knowledge are correlated and interdependent. In areas where taro cultivation has a very long history, such as China and Japan, existing diversity is threatened by shifts to large-scale and standardised production. In other areas such as New Zealand and Australia, where little taro is grown, recent immigration is encouraging the introduction of new cultivars and culinary knowledge. In Hawaii, both trends can be seen - old cultivars have been lost, and new cultivars have been introduced.

Looking to the Future

Despite the many uncertainties, a good way to monitor and preserve genetic diversity and culinary knowledge may be to invest much more effort in ethnographic research. Recording the knowledge associated with specific local cultivars will be helpful for plant breeders, nutritionists, and local cooking writers. All of these efforts will depend on the support and personal interests of growers, cooks and consumers. Research can help, but cultivars and culinary knowledge are much more likely to survive if many different people enjoy growing and using their own plants, and can avoid being too dependent on commercial supply systems.

Taro is mainly produced, sold and bought by people for whom the plant is already familiar (Matthews 2000). This is true in countries where taro is traditionally produced, and also in countries where recent immigrants produce, sell, and use the crop. Specific information on how to use the sold product is rarely available for new buyers. Since most taro cultivars are toxic unless cooked properly, it is difficult for new buyers to cook taro safely and well - cooking books cannot be relied upon for preparing the particular materials that a buyer finds. These problems can be dealt with, in part, by local publication of suitable methods for particular cultivars and markets. It would also be useful to establish and publish principles for dealing with variable and unfamiliar materials. The more conventional approach is for producers and distributors to develop standards and grading systems, and to promote a very limited number of cultivars.

Written knowledge can never represent all knowledge, and can never be a complete substitute for oral communication but it can be a stimulus for innovation, adaptation, and new forms of oral communication. Japan has a long history of agricultural and culinary writing, and writing is an integral part of crop management and the transmission of culinary knowledge in Japan. With this example strongly in mind, it appears to me that genetic diversity and culinary knowledge associated with taro will be best preserved and developed through (i) household production and consumption of the crop, (ii) locally-orientated, small-scale commercial production (which can contribute to large-scale but diversified or mosaic economies), and (iii) continued transfer of culinary knowledge to written media, with special attention to the identification of suitable cultivars for each dish described.

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