- **[1. INTRODUCTION: IMPORTANCE OF *TARO*]**

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Source: *FAO* Database, 1999. The relative importance of *taro* in each of the above countries can hardly be gleaned from the production statistics. **...**
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6. PECULIARITIES OF *TARO* PRODUCTION IN SPECIFIC ASIA-PACIFIC COUNTRIES
Among the root crops in Fiji, *taro* (locally know as Dalo) ranks second only **...**
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4. DISEASES AND PESTS
The characteristics of this and other diseases and pests of *taro* will be **...**
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1. INTRODUCTION: IMPORTANCE OF TARO

1.1 Food Security Importance
1.2 Socio-Cultural Importance
1.3 Taro as a Cash Crop and Earner of Foreign Exchange
1.4 Role of Taro in Rural Development

The term **taro** is used to refer to *Colocasia esculenta* (L.) Schott. It should not be confused with the related aroid *Xanthosoma* spp. which is called tannia. In many parts of the Asia and Pacific region, the name for tannia is a modification or qualification of the name for taro. In Papua New Guinea for example, taro is called “taro tru” while tannia is called “taro singapo”. In Tonga, taro is called “talo Tonga” while tannia is called “talo Futuna”. In some of the world literature, taro and tannia are collectively called cocoyams, while in a place like Malaysia, the local name for taro (keladi) also applies to all the other edible aroids. The ensuing presentation here concerns itself with taro, *Colocasia esculenta*.

1.1 Food Security Importance

Table 1 shows that in 1998, about 6.6 million tonnes of taro/tannia were produced in the world on an area of 1.07 million hectares (the statistics combine taro and tannia). The bulk of the production and area were in Africa, with Asia producing about half as much as Africa, and Oceania about one tenth as much. The major producers in Asia were China, Japan, Philippines and Thailand; while in Oceania, production was dominated by Papua New Guinea, Samoa, Solomon Islands, Tonga and Fiji.

Table 1. Production, Yield and Area for Taro/Tannia in 1998; only the Leading Producers are Indicated

	Production (1,000 tonnes)	Yield (tonnes/ha)	Area (1,000 ha)
World	**6586**	**6.2**	**1070**
Africa	**4452**	**5.1**	**876**
Asia	**1819**	**12.6**	**144**
China	1387	16.8	82
Japan	255	11.6	22
Philippines	118	3.4	35
Thailand	54	11.0	5
Oceania	**283**	**6.2**	**46**
Papua New Guinea	160	5.2	31
W. Samoa	37	6.2	6
Solomon Islands	28	21.9	1
Tonga	27	6.4	4
Fiji	21	14.7	1

Source: FAO Database, 1999

The relative importance of taro in each of the above countries can hardly be gleaned from the production statistics. It is very seriously distorted by factors of land mass and population. For example, a country like China, where rice holds sway, and where taro/tannia is a very minor crop, still manages to show substantial production because of the large land mass involved. A much better gauge of the importance of taro/tannia in each nation’s food basket comes from examining the percentage of total dietary calories that each person derives from taro/tannia. The top of Table 2 presents the top six countries in terms of the percentage of the dietary calories that comes from taro/tannia. Four of the top six countries are from the Oceania. Not even the heavy root crop consumers in Africa such as Zaire (Congo) and Cameroon could match the Oceania countries in terms of dependence on taro/tannia.

Table 2 further shows that Oceania as a whole has a higher dietary dependence on taro/tannia than any of the other continents of the world. The conclusion is obvious from these figures and from all available evidence. No other part of the world can match Oceania in terms of the intensity of production, utilisation and dependence on taro/tannia for food. Even though the above figures are combined for taro and tannia, in most of Oceania, taro is the predominant partner. Most of the cultures of Oceania have evolved on the strength of root crops as the major food source, and in most of them today, taro ranks among the top two or three staple food items. It plays a major role in the "affluent subsistence" which has for centuries characterised agriculture in Oceania.

Table 2. Percentage of Dietary Calories Derived from Taro/Tannia and from all Tubers in 1984 for Various Countries and Continents.

	Taro/Tannia	**All Tubers**
Tonga	18.1	45.0
Samoa	16.0	19.2
Solomon Island	7.7	39.0
Ghana	7.1	43.3
Gabon	4.6	36.7
Papua New Guinea	4.2	32.6
Zaire (Congo)	0.1	56.8
Cameroon	0.5	44.5
Oceania	0.7	7.2
Asia	0.1	5.2
Africa	0.5	15.3
N. & Central America	0.0	2.6
S. America	0.0	6.4
Europe	0.0	4.7
World	0.1	6.0

Source: Adapted from Horton, 1988.

1.2 Socio-Cultural Importance

Taro is postulated to have originated in southern or south-east Asia, and to have been dispersed to Oceania through the Island of New Guinea very many centuries ago. The crop has evolved with the cultures of the people of the Asia/Pacific region. Not surprisingly, it has acquired considerable socio-cultural importance for the people. Among the food crops in Oceania, the adulation and prestige attached to taro is equalled only by yam in certain localities.

The socio-cultural importance of taro manifests itself in several ways:

a) It is considered a prestige crop, and the crop of choice for royalty, gift-giving, traditional feasting, and the fulfilment of social obligations.

b) Taro features prominently in the folklore and oral traditions of many cultures in Oceania and south-east Asia.

c) Various parts of the taro plant are used in traditional medical practice. Examples of this can be seen right from the Malay Peninsula all the way to Oceania.

d) As if to highlight the importance of taro in the countries, both Samoa and Tonga each have a depiction of taro as the main feature on one of their currency coins. Outside Oceania, it is unlikely that taro is given such a glorified place in any other part of the world.

e) The socio-cultural attachment to taro has meant that taro itself has become a totem of cultural identification. People of Pacific Island origin continue to consume taro wherever they may live in the world, not so much because there are no substitute food items, but mainly as a means of maintaining links with their culture. This cultural attachment to taro has spawned a lucrative taro export market to ethnic Pacific Islanders living in Australia, New Zealand and western North America.

1.3 Taro as a Cash Crop and Earner of Foreign Exchange

While a lot of taro is produced and consumed on a subsistence basis, quite a considerable amount is produced as a cash crop. Also surpluses from the subsistence production manage to find their way to market, thereby playing a role in poverty alleviation.

The taro corm is a very awkward market commodity. It is bulky, consisting of two-thirds water. It is fragile and easily bruised. It is perishable and can only store for a few days at ambient temperatures. Yet most of taro marketing takes place in form of the fresh corm, with few suitable processed forms available. The effectiveness of the taro cash crop system is therefore dependent on an adequate marketing structure. Unfortunately, very few of the producing countries have such structures. Fiji, Hawaii, and Cook Islands are examples of where efforts have been made to establish such structures, and quite a few farmers make reasonable money as taro producers.

Where taro can be exported, its production not only provides cash to the farmers but also valuable foreign exchange to the country. This is precisely what has happened in Fiji, Tonga, Cook Islands, Tuvalu, Thailand and, up till 1993, in Samoa. These countries have been able to earn substantial sums from the taro export trade, mainly to Australia and New Zealand. Many other countries would like to participate in taro exportation, but they are deterred by quarantine regulations against one or other of the taro diseases and pests.

1.4 Role of Taro in Rural Development

The taro industry provides meaningful employment to a large number of people, mostly in rural areas. Where taro exportation occurs, then the facilities for cleaning, sorting, packing and shipping the taro provide additional avenues for poverty alleviation and employment generation in the rural areas. Whereas as in Hawaii, processed forms of taro are produced in rural cottage industries, then the role of taro in rural development is even further enhanced.

It is therefore within the Asia/Pacific region that taro attains its greatest importance on earth. Within the region, it is significant as a provider of food security, as a focus of socio-cultural attention, as a cash crop and earner of foreign exchange, and as a vehicle for rural development. This document intends to first outline general principles relating to taro and its cultivation, and then to describe the peculiarities of taro cultivation in selected counties/territories in the region. Countries/territories have been chosen mainly on the basis of the intensity of taro cultivation, utilisation and significance.

2. BOTANY AND ECOLOGY

2.1 Classification and Genetics
2.2 Origin and Distribution
2.3 Morphology and Anatomy
2.4 Growth Cycle
2.5 Ecology and Physiology

2.1 Classification and Genetics

Taro belongs to the genus *Colocasia*, within the sub-family Colocasioideae of the monocotyledonous family Araceae. Because of a long history of vegetative propagation, there is considerable confusion in the taxonomy of the genus *Colocasia*. Cultivated taro is classified as *Colocasia esculenta*, but the species is considered to be polymorphic. There are at least two botanical varieties (Purseglove, 1972):

i) *Colocasia esculenta* (L.) Schott var. *esculenta*;

ii) *Colocasia esculenta* (L.) Schott var. *antiquorum* (Schott) Hubbard & Rehder which is synonymous with C. *esculenta* var. *globulifera* Engl. & Krause.

C. *esculenta* var. *esculenta* is characterised by the possession of a large cylindrical central corm, and very few cormels. It is referred at agronomically as the **dasheen** type of taro. C. *esculenta* var. *antiquorum*, on the other hand, has a small globular central corm, with several relatively large cormels arising from the corm. This variety is referred to agronomically as the **eddoe** type of taro. Most of the taro grown in the Asia/Pacific region is of the dasheen type.

Chromosome numbers reported for taro include 2n = 22, 26, 28, 38, and 42. The disparity in numbers may be due to the fact that taro chromosomes are liable to unpredictable behaviour during cell divisions. The most commonly reported results are 2n = 28 or 42. Germplasm collections of taro exist at various scientific institutions world-wide. These include the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria; the Philippine Root Crop Research and Training Center, Beybey, Philippines; the Koronivia Research Station, Fiji; the Bubia Agricultural Research Centre in Papua New Guinea, and numerous other locations in Oceania.

There are hundreds of agronomic cultivars of taro grown throughout the world. These are distinguished on the basis of corm, cormel, or shoot characteristics, or on the basis of agronomic or culinary behaviour. Examples of taro cultivars in various places are given in subsequent chapters that deal with taro cultivation in various countries.

2.2 Origin and Distribution

Various lines of ethno-botanical evidence suggest that taro originated in South Central Asia, probably in India or the Malay Peninsula. Wild forms occur in various parts of South Eastern Asia (Purseglove, 1972). From its centre of origin, taro spread eastward to the rest of South East Asia, and to China, Japan and the Pacific Islands (some authors have suggested that the island of New Guinea may have been another centre of origin for taro, quite distinct from the Asian centre). From Asia, taro spread westward to Arabia and the Mediterranean region. By 100 B.C., it was being grown in China and in Egypt. It arrived on the east coast of Africa over 2,000 years ago; it was taken by voyagers, first across the continent to West Africa, and later on slave ships to the Caribbean. Today, taro is pan-tropical in its distribution and cultivation. The greatest intensity of its cultivation, and its highest percentage contribution to the diet, occurs in the Pacific Islands. However, the largest area of cultivation is in West Africa, which therefore accounts for the greatest quantity of production. Significant quantities of taro are also grown in the Caribbean, and virtually all humid or sub-humid parts of Asia.

It has been suggested that the eddoe type of taro was developed and selected from cultivated taro in China and Japan several centuries ago, and it was later introduced to the West Indies and other parts of the world (Purseglove, 1972).

2.3 Morphology and Anatomy

Taro is a herbaceous plant which grows to a height of 1-2m. The plant consists of a central corm (lying just below the soil surface) from which leaves grow upwards, roots grown downwards, while cormels, daughter corms and runners (stolons) grow laterally. The root system is fibrous and lies mainly in the top one meter of soil.

In the dasheen types of taro, the corm is cylindrical and large. It is up to 30cm long and 15cm in diameter, and constitutes the main edible part of the plant. In eddoe types, the corm is small, globoid, and surrounded by several cormels (stem tubers) and daughter corms. The cormels and the daughter corms together constitute a significant proportion of the edible harvest in eddoe taro. Daughter corms usually give rise to subsidiary shoots even while the main plant is still growing, but cormels tend to remain dormant and will only give rise to new shoots if left in the ground after the death of the main plant. Each cormel or each daughter corm has a terminal bud at its tip, and axillary buds in the axils of the numerous scale leaves all over its body.

Corms, cormels and daughter corms are quite similar in their internal structure. The outmost layer is a thick brownish periderm. Within this lies the starch-filled ground parenchyma. Vascular bundles and laticifers ramify throughout the ground parenchyma. Idioblasts (cells which contain raphides or bundles of calcium oxalate crystals) also occur in the ground tissue, and in nearly all other parts of the taro plant. The raphides are associated with acridity or itchiness of taro, a factor which will be taken up in greater detail when the utilisation of taro is discussed. The density and woodiness of the corm increase with age.

Occasionally in the field, some taro plants are observed to produce runners. These structures grow horizontally along the surface of the soil for some distance, rooting down at intervals to give rise to new erect plants.

In both eddoe and dasheen types of taro, the central corm represents the main stem structure of the plant. The surface of each corm is marked with rings showing the points of attachment of scale leaves or senesced leaves. Axillary buds are present at the nodal positions on the corm. The apex of the corm represents the plant's growing point, and is usually located close to the ground level. The actively growing leaves arise in a whorl from the corm apex. These leaves effectively constitute the only part of the plant that is visible above ground. They determine the plant's height in the field.

Each leaf is made up of an erect petiole and a large lamina. The petiole is 0.5-2m long and is flared out at its base where it attaches to the corm, so that it effectively clasps around the apex of the corm. The petiole is thickest at its base, and thinner towards its attachment to the lamina. Internally, the petiole is spongy in texture, and has numerous air spaces which presumably facilitate gaseous exchange when the plant is grown in swampy or flooded conditions. For most taro types, the attachment of the petiole to the lamina is peltate, meaning that the petiole is attached, not at the edge of the lamina, but at some point in the middle. This peltate leaf attachment generally distinguishes taro from tannia which has a hastate leaf i.e. the petiole is attached at the edge of the lamina. An important exception to this rule are the "piko" group of taro found in Hawaii; quite uncharacteristically, they have hastate leaves.

The lamina of taro is 20-50cm long, oblong-ovate, with the basal lobes rounded. It is entire (not serrated), glabrous, and thick. Three main veins radiate from the point of attachment of the petiole, one going to the apex, and one to each of the two basal lamina lobes. Some prominent veins arise from the three main veins, but the overall leaf venation is reticulate (net-veined).

Natural flowering occurs only occasionally in taro, but flowering can be artificially promoted by application of gibberellic acid (see later). The inflorescence arises from the leaf axils, or from the centre of the cluster of unexpanded leaves. Each plant may bear more than one inflorescence. The inflorescence is made up of a short peduncle, a spadix, and spathe. The spadix is botanically a spike, with a fleshy central axis to which the small sessile flowers are attached. The spadix is 6-14cm long, with female flowers at the base, male flowers towards the tip, and sterile flowers in between, in the region compressed by the neck of the spathe. The extreme tip of the spadix has no flowers at all, and is called the sterile appendage. The sterile appendage is a distinguishing taxonomic characteristic between dasheen and eddoe types of taro. In eddoe types, the sterile appendage is longer than the male section of the spadix; in dasheen types, the appendage is shorter than the male section.

The spathe is a large yellowish bract, about 20 cm long, which sheathes the spadix. The lower part of the spathe wraps tightly around the spadix and completely occludes the female flowers from view. The top portion of the spadix is rolled inward at the apex, but is open on one side to reveal the male flowers on the spadix. The top and bottom portions of the spadix are separated by a narrow neck region, corresponding to the region of the sterile flowers on the spadix.

Pollination in taro is probably accomplished by flies. Fruit set and seed production occur only occasionally under natural conditions. Fruits, when produced, occur at the lower part of the spadix. Each fruit is a berry measuring 3-5mm in diameter and containing numerous seeds. Each seed has a hard testa, and contains endosperm in addition to the embryo.

2.4 Growth Cycle

Taro is herbaceous, but survives from year to year by means of the corms and cormels. Root formation and rapid root growth take place immediately after planting, followed by rapid growth of the shoot. Shoot growth and total shoot dry weight show a rapid decline at about six months after planting. At this time, there is a reduction in the number of active leaves, decrease in the mean petiole length, a decrease in the total leaf area per plant, and a decrease in the mean plant height on the field. All through the season, there is a rapid turnover of leaves; new ones are continually unfurling from the centre of the whorl of leaves, as the oldest ones below die off. Such a high rate of leaf obsolescence is physiologically wasteful.

Corm formation commences at about three months after planting; cormel formation follows soon afterwards in cultivars that produce appreciable cormels. By the sixth month when shoot growth declines, the corm and cormels become the main sink and grow very rapidly. As the adverse (dry) season sets in, the decline of the shoot accelerates, until the shoot finally dies back. The corm and cormels permit the plant to survive through the adverse season. If they are not harvested, they will sprout and give rise to new plants at the onset of the next favourable season. Where there is no adverse season, the shoot may fail to die back, and instead persist and continue growth for several years.

Flowering, in the few instances where it happens naturally, occurs in the early part of the season.

2.5 Ecology and Physiology

Partly because of their large transpiring surfaces, taro plants have a high requirement for moisture for their production. Normally, rainfall or irrigation of 1,500-2,000mm is required for optimum yields. Taro thrives best under very wet or flooded conditions. Dry conditions result in reduced corm yields. Corms produced under dry conditions also tend to have a dumb-bell shape; the constrictions reflect periods of reduced growth during drought.

Taro requires an average daily temperature above 21ºC for normal production. It cannot tolerate frosty conditions. Partly because of its temperature sensitivity, taro is essentially a lowland crop. Yields at high altitudes tend to be poor. In Papua New Guinea, for example, the maximum elevation for taro cultivation is 2,700m.

The highest yields for taro are obtained under full intensity sunlight. However, they appear to be more shade-tolerant than most other crops. This means that reasonable yields can be obtained even in shade conditions where other crops might fail completely. This is a particularly important characteristic which enables taro to fit into unique intercropping systems with tree crops and other crops. Daylight also affects the growth and development of taro. The formation of corms/cormels is promoted by short-day conditions, while flowering is promoted by long-day conditions.

Taro is able to tolerate heavy soils on which flooding and waterlogging can occur. Indeed, the dasheen type of taro does best when grown in such soils. It seems that under flooded or reducing soil conditions, taro plants are able to transport oxygen (through their spongy petioles) from the aerial parts down to the roots. This enables the roots to respire and grow normally even if the surrounding soil is flooded and deficient in oxygen. In practice, however, flooded taro fields must be aired periodically in order to avoid iron and manganese toxicity under the reducing soil conditions. Poor soils, such as the red soils in certain parts of Fiji, tend to give low yields of taro.

Taro does best in soil of pH 5.5-6.5. It is able to form beneficial associations with vesicular-arbuscular mycorrhizae, which therefore facilitate nutrient absorption. One particularly useful characteristic of taro is that some cultivars are able to tolerate salinity. Indeed, in Japan and Egypt, taro has been used satisfactorily as a first crop in the reclamation of saline soils (Kay, 1973). This definitely opens up the possibility for the use of taro to exploit some difficult ecologies where other crops might fail.

Flowering and seed set in taro are relatively rare under natural conditions. Most plants complete their field life without flowering at all, and some cultivars have never been known to flower. For many years, this characteristic was a great hindrance to taro improvement through cross pollination. However, the problem was solved when it was discovered that gibberellic acid (GA) could promote flowing in taro (Wilson, 1979).

Essentially, plants are grown from corms or cormels to the 3-5 leaf stage in the field, and then treated with 15,000 ppm GA, a process known as "pro-gibbing" (Alvarez & Hahn, 1986). Alternatively, the plants could be multiplied in a seedbed, and pro-gibbed at the 1-2 leaf stage with 1,000 ppm GA. A third method involves leaving taro in the field at the end of the growing season and then pro-gibbing the first leaves that emerge at the onset of the next rainy season. Whichever method is used, pro-gibbed plants produce normal flowers 2-4 months after treatment.

Today, researchers are able routinely to induce flowering of both taro and tannia by the application of GA. Controlled pollination can then be carried out on the flowers that are produced. The resulting seeds, thousands per spadix, are first germinated in nutrient media in petri dishes. The plantlets are later transplanted to humid chambers in the greenhouse. When the seedlings have reached a height of 15-20cm, they can be transplanted to the field. The large genotypic and phenotypic variability resulting from this process affords the plant breeder ample scope for selection.

Another propagative technique which has recently been used for taro is the production of plantlets through meristem tissue culture. Essentially, the technique involves excising the tip meristem of taro, sterilising it, and culturing it in sterile nutrient medium in petri dishes. The cultured meristem first proliferates a mass of callus tissue, from which bits can be taken for subculturing to produce plants with roots and shoots. If desired, the plantlets can later be transferred to pots in the greenhouse, and eventually to the field. The multiplication of taro by tissue culture has several distinct advantages:

a) It provides an extremely rapid means for multiplying elite clones. Starting from one plant, it is possible to produce a million or more plantlets in a year;

b) It affords a phytosanitary method for producing disease-free material. This factor relies partly on the fact that the culture starts with the extreme meristem tip which is as yet free from various disease organisms. This method, for example, has been used successfully to eliminate dasheen mosaic, alomae, and bobone virus diseases from taro;

c) The tissue culture technique provides a handy yet phytosanitary method for international and inter-regional transfer of germplasm;

d) The technique provides an economical, space-saving, and labour-saving method for the preservation of germplasm over long periods of time. Rather than repeatedly growing germplasm collections in the field, they can be stored as tissue culture in nutrient media. Only occasionally (once in several months) does the material need to be re-cultured; and even then, the space, time and labour consumption for the exercise are minimal.

3. GENERAL CULTIVATION PRACTICES

3.1 Planting Material
3.2 Production Systems I: Flooded Taro

[3.3 Production Systems II: Dry-Land Taro](#)
[3.4 Weed Control](#)
[3.5 Fertilizer Application](#)
[3.6 Harvesting](#)

The specific cultivation practices for each of the major taro-producing countries are discussed in subsequent chapters. This chapter seeks to set out some of the fundamentals that guide taro cultivation, and provides a background for a more effective appreciation of the specific cultivation practices in various areas.

3.1 Planting Material

There are essentially four types of planting material that are used in taro production:

i) *Side suckers* produced as a result of lateral proliferation of the main plant in the previous crop;

ii) *Small corms* (unmarketable) resulting from the main plant in the previous crop;

iii) *Huli* i.e. the apical 1-2 cm of the corm with the basal 15-20 cm of the petioles attached;

iv) *corm pieces* resulting when large corms are cut into smaller pieces.

The use of huli (Figure 1) is particularly advantageous because it does not entail the utilisation of much material that is otherwise edible. Moreover, huli establish very quickly and result in vigorous plants. However, huli are best adapted to situations where planting occurs shortly after harvesting, since protracted storage of huli is not advisable.

Where corm pieces are used, it is sometimes advisable to pre-sprout the pieces in a nursery before they are planted in the field. This enables sprouts to appear on the pieces before they are moved to the field. Side suckers and small corms may also be kept in nurseries to develop good sprouts, especially if there is a long time between the previous harvest and the next planting.

The availability of planting material is an ever-present problem in taro production. This is particularly so in places like Tonga where occasional droughts reduce the quantity of available planting material for years after each drought.

Three strategies are currently available for the rapid multiplication of planting material. The first is to use a *minisett technique* analogous to the same technique used for yams. Essentially, small corm pieces 30-50g in weight are protected with seed dressing. They are sprouted in a nursery, and then planted in the field. The resulting small corms and suckers are used as subsequent planting material. The minisett technique can be carried out by the farmers themselves, since the level of technology required is well within their competence.

[Figure 1. The Taro Huli, Used as Planting Material](#)

The second rapid method of generating planting material is through meristem tissue culture. Starting from a single plant, thousands of plantlets can be generated in a few months.

However, tissue culturing requires considerable scientific sophistication. While it is useful for multiplying and distributing elite clones, it has so far not become a routine method for the generation of commercial taro planting material.

A third method of rapid multiplication of taro planting material is the use of the true seed of taro for planting. This currently being tried by the Kauai Agricultural Research Station in Hawaii. Even though one successful taro crossing can produce hundreds of seeds, there are likely to be problems with segregation in subsequent generations, the smallness of the resulting seedlings, and the infrequent nature of taro flowering.

3.2 Production Systems I: Flooded Taro

There are two main production systems used in taro cultivation:

i) Flooded or wetland taro production
ii) Dryland (unflooded) or upland taro production.

Flooded taro cultivation (Figure 2) occurs in situations where water is abundant. The water may be supplied by irrigation, by the swampy nature of terrain, or from diverted rivers and streams. The soil must be heavy enough to permit the impounding of water without much loss through percolation. Apart from rice and lotus, taro is one of the few crops in the world that can be grown under flooded conditions. The large air spaces in the petiole permit the submerged parts to maintain gaseous exchange with the atmosphere. Also, it is important that the water in which the taro is growing is cool and continuously flowing, so that it can have a maximum of dissolved oxygen. Warm stagnant water results in a low oxygen content, and causes basal rotting of the taro.

Figure 2. Flooded Cultivation of Taro

The best situation for flooded taro production is where irrigation water is available, and the water level can be controlled. This requires an initial levelling of the land and the construction of embankments so that water can be impounded. The field is puddled so as to retain water, and is flooded just before or just after planting. The water level is low at first, but it is progressively raised as the season progresses, so that the base of the plant is continually under water. The field is drained occasionally for fertilizer application, but is re-flooded after 2-3 days.

In many production situations, wetland taro is grown without adequate control of the terrain or the water supply. In such situations, taro is grown on stream banks or in low lying marshy areas with hydromorphic soils. The required inputs in these situations are much less than those for the controlled flooding described above. The yield output is also commensurately less.

Growing taro under controlled flooding has several advantages over normal dry-land taro production:

a) The corm yields are much higher (about double)
b) Weed infestation is minimised by flooding
c) Out-of -season production is possible, often resulting in very attractive prices for the taro.

However, flooded taro requires a longer time to mature, and involves a considerable investment in infrastructure and operational costs.

Because of continuous water availability, time of planting is usually not critical in flooded taro production. Planting can occur at virtually any time of the year. Indeed many producers take advantage of this phenomenon by staggering their planting dates in various plots. Thus they can have corms for sale virtually all year round, even during off-season periods when prices are high.

Most flooded taro is grown as a sole crop, rather than intercropped. This is partly because of the intense specialised nature of the cultivation, and partly because very few other crops can sufficiently tolerate the flooded condition to share the field with taro. For the same reason, taro may be gown on the same field for several years (monoculture) before another crop such as rice or vegetable is introduced.

3.3 Production Systems II: Dry-Land Taro

Dryland taro production implies that the taro is not grown in flooded or marshy conditions. Despite its advantages, flooded taro is restricted only to certain locations where the economics of production and water availability permit the system to thrive. By far the largest area and production of taro in the Asia/Pacific region occurs under dry-land conditions. This is also true of global taro production.

Dry-land taro is essentially rain-fed. Sprinklers or furrow irrigation may be used to supplement the rainfall, but the objective is mainly to keep the soil moist, not to get the field flooded.

The rainfed nature of dry-land taro cultivation means that the time of planting is critical. Planting is usually done at the onset of the rainy season, and the rainy season itself must last long enough (6-9 months) to enable the taro crop to mature.

Land preparation for dry-land taro starts with ploughing and harrowing. If the soil is deep and friable, the crop can be grown on the flat; otherwise, ridges are made. Ridges are usually 70-100 cm apart and plant spacing on the ridge is 50-90 cm. Planting in the furrows of the ridges is also practiced. Unlike flooded taro, dryland taro is quite frequently intercropped, although sole cropping is also common.

Planting in dryland taro production involves opening up the soil with a spade or digging stick, inserting the planting pieces, and closing up. Mulching is done to conserve moisture. Manures and composts may be applied after planting, or incorporated into the soil during the initial land preparation.

As indicated above, dryland taro matures earlier than flooded taro, but the yield is lower and the production inputs are also less.

3.4 Weed Control

For flooded taro, weed infestation is minimal, but some aquatic weeds do occur. Some of these are pulled out manually, although in high-technology production systems, herbicides may be added to the irrigation water. In Hawaii, Nitrofen at 3-6 kg/ha has been found to be effective.

For dryland taro, weed control is necessary only during the first three months or so, if crop spacing has been close enough. Thereafter, the crop closes canopy and further weed control is not necessary. In the last two months of the crop's field life, average plant height diminishes and spaces open up again between plants. Weeds may re-appear but their potential for economic damage is very low.

Weed control with hand tools is the most prevalent practice in dryland taro. Care should be taken to confine the tools to the soil surface; taro roots are very shallow and can be very easily damaged by deep weeding or cultivation. Earthing up of soil around the bases of the plants is advisable during weeding, so that the developing corms are protected. Herbicide weed control is possible in dryland taro production. Recommended herbicides include Promtryne at 1.2kg/ha, Dalapon at 3kg/ha, Diuron at 3.4 kg/ha or Atrazine at 3.4 kg/ha.

3.5 Fertilizer Application

The majority of taro growers in the Asia/Pacific region, especially those producing taro for subsistence, do not use any fertilizer. Some even believe that fertilizers diminish the quality and storability of their taro. All the same, taro has been found to respond well to fertilizers and to manures and composts. The specific fertilizer types and quantities recommended vary widely from place to place; they are therefore left till the next section where cultivation practices in various countries are discussed. In general, it is best to apply the fertilizer, compost or manure as a split dose. The first portion is applied at planting, possibly incorporated into the soil during land preparation. This first dose promotes early plant establishment and leaf elaboration. The second dose is supplied 3-4 months later when the corm enlargement is well under way. Splitting the fertilizer dose minimises the effects of leaching which is potentially high in the high-rainfall areas where taro is produced.

Taro is able to form mycorrhizal associations which promote phosphorus uptake. Also, in some flooded taro fields, *Azolla* is deliberately or inadvertently cultured in the field water, thereby improving the nitrogen supply to the taro. This is quite common in flooded taro fields in the Hanalei Valley, Hawaii.

Malnourished taro exhibits certain deficiency symptoms. Potassium deficiency causes chlorosis of leaf margins and death of the roots. Zinc deficiency results in inter-veinal chlorosis, while for phosphorus, a leaf petiole content below 0.23% signals the need to apply fertilizer. Various other nutritional deficiencies and toxicities of taro have been elaborated by O'Sullivan *et al*. (1995).

3.6 Harvesting

For dryland taro, maturity for harvest is signalled by a decline in the height of the plants and a general yellowing of the leaves. These same signals occur in flooded taro, but are less distinct. Because of the continuous and abundant water supply, the root system of flooded taro remains alive and active, and leaf senescence is only partial.

Time from planting to harvest ranges from 5-12 months for dryland taro and 12-15 months for flooded taro. Much depends on the cultivar and the prevailing conditions during the season.

Harvesting is most commonly done by means of hand tools. The soil around the corm is loosened, and the corm is pulled up by grabbing the base of the petioles. For flooded taro, harvesting is more tedious because of the need to sever the living roots that still anchor the corm to the soil. Even in mechanised production systems, harvesting is still mostly done by hand, thereby increasing the labour and cost of production.

Average yield of taro in Oceania is about 6.2 tonnes/ha, while that for Asia is 12.6 tonnes/ha. The global average is about 6.2 tonnes/ha.

4. DISEASES AND PESTS

[4.1 The Taro Beetle]

[4.2 Taro Leaf Blight]

[4.3 The Alomae/Bobone Virus Disease Complex]

[4.4 Dasheen Mosaic Virus Disease (DMV)]

[4.5 Other Diseases and Pests]

Taro production in the Asia/Pacific region is currently under the stranglehold of one pest (the taro beetle) and one disease (the taro leaf blight), both of which are proving to be extremely menacing to the taro industry. Some countries such as Fiji have only the beetle; others such as Samoa have only the leaf blight; others such Papua New Guinea have both; while yet others such as Tonga have so far escaped either of these two afflictions. In most places where they have occurred, the beetle and the blight have posed serious problems for the taro industry. Their presence has resulted in quarantine isolation for some of the affected countries, and their resultant exclusion from the export taro trade. The most dramatic recent example has been Samoa, where the appearance of the taro leaf blight since 1993 has not only wiped out the lucrative taro export trade, but also seriously destabilised the internal food supply.

A third, but slightly less menacing, affliction of taro is the alomae/bobone virus disease complex. The characteristics of this and other diseases and pests of taro will be described in this chapter. Their presence and impact on the taro industry in various countries will be taken up in the sections where taro production is discussed for each country.

4.1 The Taro Beetle

The taro beetles of economic importance are several species belonging to the genus *Papuana* (Coleoptera: Scarabaeidae). These include *Papuana woodlarkiana*, *Papuana biroi*, *Papuana huebneri*, and *Papuana trinodosa*. The adult beetle is black, shiny, and 15-20 mm in length. Many species have a horn on the head.

The adult beetles fly from the breeding sites to the taro field and tunnel into the soil just at the base of the taro corm. They then proceed to feed on the growing corm, leaving large holes that degrade the eventual market quality of the corm. Also the wounds that they create while feeding promote the attack of rot-causing organisms. The feeding activity can cause wilting and even death of the affected plants. After feeding for about two months, the female beetle flies to neighbouring bushes to lay eggs. The eggs are laid 5-15 cm beneath the soil close to a host plant, (Jackson, 1980). The eggs are cylindrical and brown or white in colour. A wide range of plants have been found to be hosts for taro beetle breeding (Sar *et al*., 1997). These include Johnson grass (*Sorghum verticilliflorum*), Elephant grass (*Pennisetum purpureum*), Kunai (*Imperata cylindrica*) and pitpit (*Phragmites karka*). Larvae hatch from the eggs in 11-16 days. The larvae feed on plant roots and dead organic matter at the base of the host plants. The larva moults about three times in its 3-4 months of life, and then pupates. After about two weeks, the adults develop from the pupa and fly to neighbouring taro plots to cause another cycle of damage. The adult lives for 4-8 months.

Not only does the taro beetle have a wide host range for breeding, but it also has a wide host range of crops that the adult feeds on and disfigures. Crops that are attacked include tannia, sugarcane, banana, sweet potato, yams, etc. This versatility of hosts makes the taro beetle additionally destructive, and its control much more difficult. The taro beetle is a pest in taro production in a wide sweep of territory from Indonesia through Papua New Guinea, Solomon Islands, Vanuatu to Fiji and New Caledonia; in short, virtually all of Melanesia and beyond. It was first reported in Fiji in 1984.

Numerous efforts have been made to develop effective control measures for the taro beetle. Mulching with polythene, coconut husk or grass has only been partially effective. The earlier recommendation of lindane for taro beetle control in Papua New Guinea has proved to be environmentally unsustainable. Other insecticides have proved not to be effective; nor has the use of physical barriers such as fly wire or shade cloth spread over the soil. The most recent research efforts are now concentrating on finding an effective biological control. Certain pathogens of the beetle have been identified. These include a fungus (*Metarhizium anisopliae*), a bacterium (*Bacillus popilliae*) and the protozoa V*avraia*. Much of this research is taking place in Papua New Guinea and Solomon Islands, supported by the Pacific Regional Agricultural Programme (PRAP). Hopefully, a biological control measure for the taro beetle will become available before long.

4.2 Taro Leaf Blight

Taro leaf blight (Figure 3) is caused by the fungus *Phytophthora colocasiae*. It was first reported in Java about a century ago, and has since spread to various parts of Asia and the Pacific. The list of countries where it has been reported include Indonesia, Papua New Guinea, Solomon Islands, Hawaii, Samoa, American Samoa, Thailand and the Philippines.

Figure 3. The Taro Leaf Blight Disease

The disease begins as purple-brown water-soaked lesions on the leaf. A clear yellow liquid oozes from the lesions. These lesions then enlarge, join together and eventually destroy the entire lamina in 10-20 days. Free water collecting on older leaves, as well as high temperature and high humidity are conducive to onset and spread of the disease and germination of the spores. The disease can be spread from plant to plant by wind and splashing rain. Spores survive in planting material for three or more weeks. Thus, infected planting material is one common means of spreading the disease over long distances and from season to season. The disease also attacks *Alocasia macrorrhiza*, a common aroid crop in the Pacific region, but the symptoms and yield losses are less severe.

The disease can cause yield losses of 30-50%, and results in lowering of the quality of the reduced harvest. Also taro leaves for human consumption are rare in affected areas. Most countries where the disease has been reported are under strict quarantine isolation.

Various approaches have been used to try to control the taro leaf blight. Agronomic methods that have given partial success include careful choice of planting material, planting at high density, intercropping taro with other crops rather than growing it as a sole crop, and crop rotation. Field removal of infected leaves has also been useful, but it is extremely laborious. In Samoa, control has been achieved by an intensive spraying programme with Ridomil or Manzate, and more recently with phosphorous acid (Foschek). Chemical control is extremely tedious, expensive, and not totally effective. An integrated control approach combining cultural and chemical methods seems to be the best at present. The ultimate solution must lie in the breeding and release of resistant cultivars. The taro breeding programme in Bubia, Papua New Guinea, has already identified several promising lines in this regard.

In some countries/territories, the taro leaf blight is present but causes relatively minor economic damage. This is true of the Philippines, Thailand and Hawaii. In other cases such as Samoa and American Samoa, the disease can be devastating. This situation has led to conjectures about the possibility that various strains of *Phytophthora colocasiae* may exist, and that in south-east Asia in particular, some of these strains may have evolved along with the taro crop (Lebot, personal communication) and may be less virulent. This factor is in addition to differences in the genetic make-up and genetic diversity of the taro crop in each country.

4.3 The Alomae/Bobone Virus Disease Complex

The alomae virus disease is caused by a complex of two or more viruses acting together. The two viruses that are definitely involved are the taro large bacilliform virus (TLBV) which is transmitted by the plant hopper *Tarophagus proserpina*, and the taro small bacilliform virus (TSBV) which is transmitted by the mealybug *Planococus citri* (Rodoni 1995). Neither virus is transmissible by mechanical contact, and their host range seems limited to aroids only. The full-blown alomae disease occurs when these two viruses (and possibly others) are present. Presence of only TLBV alone results in bobone, a milder form of the disease.

Alomae first starts as a feathery mosaic on the leaves. Lamina and veins become thick. The young leaves are crinkly and do not unfold normally. The petiole is short and manifests irregular outgrowths on its surface. The entire plant is stunted and ultimately dies. The symptoms of bobone are similar, but the leaves are more stunted and the lamina is curled up and twisted. With bobone, complete death of the entire plant does not usually occur.

Severe cases of alomae can result in total crop loss, while bobone can cause up to 25% yield loss. However, in many instances, only isolated plants in taro fields seem to be affected by either disease, and in the case of bobone infected plants may recover from the symptoms. The alomae/bobone disease complex has been reported in Papua New Guinea and Solomon Islands. The disease is controlled by pulling out diseased plants in the field, and by careful selection to ensure disease-free planting material. Ultimately, control will have to rely on breeding and disseminating resistant cultivars. Some tolerant cultivars bred through recurrent selection, have been released in Solomon Islands since 1992 (Gunua & Kokoa, 1995).

4.4 Dasheen Mosaic Virus Disease (DMV)

While the alomae/bobone disease is mainly confined to the Pacific, the dasheen mosaic virus disease occurs world-wide. Most taro-producing countries in the Asia/Pacific region have the disease. DMV is caused by a stylet-borne, flexuous, rod-shaped virus that is spread by aphids. It is characterized by chlorotic and feathery mosaic patterns on the leaf, distortion of leaves, and stunted plant growth. The disease is not lethal, but yield is depressed. Control is through the use of DMV-free planting material, field sanitation, and quarantine measures.

4.5 Other Diseases and Pests

Other diseases and pests of taro include:

a) Corm and root rots caused by the fungi *Pythium* spp and *Phytophthora.*

b) Nematodes.

c) The taro planthopper, *Tarophagus proserpina* which not only transmits virus diseases, but can cause wilting and death of the plant in heavy infestations.

d) Aphids.

e) Taro hornworm which defoliates the plant.

f) Armyworms or cluster caterpillars which can also do extensive damage to the leaves.

While these diseases and pests may be considered minor, they can become quite severe in certain locations or at certain times during the cropping season.

5. COMPOSITION AND UTILIZATION

5.1 Composition of the Taro Corm and Leaf
5.2 Acridity in Taro
5.3 Utilization of Taro

5.1 Composition of the Taro Corm and Leaf

The main economic parts of the taro plant are the corms and cormels, as well as the leaves. The fresh weight composition of the taro corm is shown in Table 3. The fresh corm has about two-thirds water and 13-29% carbohydrate. The composition of the carbohydrate fraction is shown in Table 4, indicating that the predominant carbohydrate is starch. The starch itself is about four fifths amylopectin and one-fifth amylose. The amylopectin has 22 glucose units per molecule, while the amylose has 490 glucose units per molecule. The starch grains are small and therefore easily digestible. This factor makes taro suitable as a specialty food for allergic infants and persons with alimentary disorders. However, the smallness of the starch grains makes taro less suitable as a source of industrial starch. The starch in the corm is more concentrated at the corm base than at the corm apex.

Taro contains about 7% protein on a dry weight basis. This is more than yam, cassava or sweet potato. The protein fraction is low in histidine, lysine, isoleucine, tryptophan, and methionine, but otherwise rich in all the other essential amino acids. The protein content of the corm is higher towards the corm's periphery than towards its centre. This implies that care should be taken when peeling the corm; otherwise a disproportionate amount of the protein is lost in the peel.

The taro leaf, like most higher plant leaves, is rich in protein. It contains about 23% protein on a dry weight basis. It is also a rich source of calcium, phosphorus, iron, Vitamin C, thiamine, riboflavin and niacin, which are important constituents of human diet. The fresh taro lamina has about 20% dry matter, while the fresh petiole has only about 6% dry matter.

Table 3. Proximate Composition of the Taro Corm on a Fresh Weight Basis

Component	Content
Moisture	63-85%
Carbohydrate (mostly starch)	13-29%
Protein	1.4-3.0%
Fat	0.16-0.36%
Crude Fibre	0.60-1.18%
Ash	0.60-1.3%
Vitamin C	7-9 mg/100 g
Thiamine	0.18 mg/100 g
Riboflavin	0.04 mg/100 g
Niacin	0.9 mg/100 g

Source: Onwueme, 1994.

5.2 Acridity in Taro

Contact of the raw taro corm with the mouth or skin results in considerable itchiness, acridity and discomfort. Even raw leaves and petioles can cause acridity. The intensity of the acridity varies considerably among taro cultivars, with preference among growers and consumers going to cultivars with low acridity. Also for the same cultivar, environmental stress (such as drought or nutrient stress) during the growing season may result in higher levels of acridity.

Acridity has been attributed to the presence of bundles (called raphides) of calcium oxalate crystals in the taro tissues. Presumably, itchiness arises when the crystals are released and inflict minute punctures on the skin when in contact with it. More recent evidence (Bradbury & Holloway, 1988) suggests that the crystals have to interact with a certain chemical on the raphide surface before acridity is experienced. Fortunately for the consumer, acridity disappears when the taro corm or taro leaf is cooked by boiling, roasting, frying or other means.

Table 4. Percentage Composition of Taro Corm Carbohydrate.

Carbohydrate	%
Starch	77.9
Pentosans	2.6
Crude Fibre	1.4

Dextrin	0.5
Reducing sugars	0.5
Sucrose	0.1

Source: Onwueme, 1994

5.3 Utilization of Taro

By far the largest quantity of taro produced in the Asia/Pacific region is utilised starting from the fresh corm or cormel. They are boiled, baked, roasted or fried and consumed in conjunction with fish, coconut preparations, etc. A favourite and peculiarly Pacific way to prepare taro is to roast it in hot stones (mumu or umu) in dug-out earth ovens. This is quite common when taro is used in feasts and ceremonies.

Taro leaves are used for human food in most producing countries within the region. The leaves are usually boiled or prepared in various ways mixed with other condiments. The high protein content of the leaves favourably complements the high carbohydrate content of the corm which goes with it. Similarly, the stolons of stolon-producing cultivars of taro are often used for human consumption.

Processed, storable, forms of taro are not common in the Asia/Pacific region. Geographically the most widespread are taro chips for human consumption. They are usually made by peeling the corm, washing, slicing into thin pieces and blanching. The pieces are then fried in vegetable oil, allowed to cool and drain, and then packaged. While taro chips are made in most of the countries, their availability is sporadic and quantities produced are small.

Another processed, packaged form of taro is Poi, a sour paste made from boiled taro. Its production and utilisation is quite limited - mainly in the Hawaiian Islands. The details of Poi production are presented when taro cultivation in the Hawaiian Islands is discussed.

Taro flour is available in some places and is used as a thickener for soups and other preparations. To make the flour, the corm is peeled, sliced, and soaked overnight in water. It is then immersed in 0.25% sulphurous acid for 3 hours and blanched in boiling water for 4-5 minutes. The slices are dried at 57-60°C and then milled into flour. In less elaborate village situations, the sliced corms are simply sun-dried and then milled to produced the flour.

Taro peels and wastes are fed to domestic livestock. Efforts have been made in Hawaii to produce silage from the large quantities of taro tops which are left after the corms are harvested.

6. PECULIARITIES OF TARO PRODUCTION IN SPECIFIC ASIA-PACIFIC COUNTRIES

6.1 Taro Cultivation in Fiji
6.2 Taro Cultivation in Samoa
6.3 Taro Cultivation in American Samoa
6.4 Taro Cultivation in Tonga
6.5 Taro Cultivation in Vanuatu

[6.6 Taro Cultivation in Papua New Guinea (PNG)]
[6.7 Taro Cultivation in Solomon Islands]
[6.8 Taro Cultivation in Cook Islands]
[6.9 Taro Cultivation in Tuvalu]
[6.10 Taro Cultivation in Niue]
[6.11 Taro Cultivation in French Polynesia]
[6.12 Taro Cultivation in New Caledonia]
[6.13 Taro Cultivation in Indonesia]
[6.14 Taro Cultivation in Thailand]
[6.15 Taro Cultivation in the Hawaiian Islands (USA)]
[6.16 Taro Cultivation in the Philippines]
[6.17 Taro Cultivation in Malaysia]
[6.18 Taro Cultivation in Japan]
[6.19 Taro Cultivation in China]

6.1 Taro Cultivation in Fiji

Among the root crops in Fiji, taro (locally know as Dalo) ranks second only to cassava in terms of the quantity produced and the hectarage cultivated. For several decades, it ranked second to ginger in terms of root crop export income, but since about 1994, it has surpassed ginger as a foreign exchange earner. This has resulted partly from new markets and higher prices that arose from the demise of the Samoa taro export market.

It is estimated that in 1994, new planting of taro in Fiji amounted to 1443 ha, in addition to 2924 ha of pre-existing taro crop. During that year, 992 ha were harvested, yielding 8810 tonnes valued at Fijian $5.286 million. Local prices ranged from F$1200/tonne for cultivar Tausala-ni-Samoa down to F$500 - 800/tonne for Samoa Hybrid and other cultivars. Mean yield was about 9 tonnes/ha and there were 14028 farmers engaged in taro production. Taro export in 1994 was about 3491 tonnes valued at F$5.5 million. By 1995, harvested tonnage had increased to 16,125 tonnes and mean yields were 10-20 tonnes/ha. About 5187 tonnes were exported in 1995. Most of the exported taro went to New Zealand, Australia and the U.S.A.

Taro, is grown mainly in the wet areas where rainfall exceeds 2500 mm. Cultivation occurs on both alluvial flat land as well as on fertile hillside slopes. On the slopes, the cropping rotation adopted is such that taro follows ginger, and cassava comes in after the taro. Where kava is grown, taro is often used as a nurse crop to provide shade for the young kava plants. The taro is allowed to establish before the kava is put in. Even after this first crop of taro is harvested, a second crop of taro may be grown among the kava in the second year. A small degree of mechanisation (using animal or tractor power) is used in taro cultivation on flat lands, but cultivation on slopes has to rely mainly on manual operations.

Much of Fijian taro is grown in pure stands especially on slopes. Wetland or flooded cultivation occurs in some locations, but the bulk of the crop is upland (not flooded) taro.

Planting is most commonly done with suckers, although corms or corm pieces are occasionally used. Best yields result when planting is done in October/November when the rainy season is just starting. Some amount of off-season planting occurs in March-June.

In conventional planting, the planting material is placed in holes made with sticks, while in mechanized production, the planting material is dropped in furrows that have been opened up by machinery. The conventional system gives higher yields per stand. In general, deeper plantings yield better than shallow ones. Inter-plant spacing is 90 × 60cm in the conventional system, and 100 × 60 cm with mechanical planting.

Subsistence taro farmers in Fiji use hardly any fertilizers, but commercial taro producers apply a variety of fertilizers for improved yields. Nitrogen at 100 kg N/ha is often applied as urea or ammonium sulphate, in split applications at 5, 10 and 15 weeks after planting (WAP). Where necessary, 25 kg/ha phosphorus is applied at planting as superphosphate. If potassium is low, 100 kg/ha is split, with one application at planting and the other at 10 WAP. Compound NPK fertilizer (13:13:21) is recommended at 400 kg/ha, with half applied at planting and the other half at 10WAP. Where available, poultry manure can be used at 10 tonnes/ha, applied two weeks before planting.

Fiji has been free (1996) of the taro leaf blight and the alomae virus disease. The taro beetle is present, but there is no effective control measure. The pest is particularly serious in the Central Division.

Weed control is critical in the first 4-5 months after planting, and this is done manually, mechanically, or occasionally with herbicides.

Harvesting occurs 7-10 months after planting. Maturity is signalled by a reduction in plant size, and some degree of yellowing of the leaves. Sticks, poles or forks are used to dig up the corms. Most of the taro goes for domestic consumption (Figure 4). Where the taro is to be shipped over long distances or exported, then post-harvest handling becomes important. At present, the post-harvest handling simply involves collecting, sorting, cleaning, packing and shipping. A cold temperature (6-8ºC) is maintained when shipping the taro corms for export. Most of the crop is handled and shipped as intact fresh tuber. Little or no processing into dry or preservable products takes place, apart from occasional taro chips available in supermarkets.

Figure 4. Taro Corms on Sale in Suva Market, Fiji

Active research on taro is going on in the country, especially at the Koronivia Research Station. Since 1984 when the first improved cultivar (Samoa Hybrid) was released, at least four more cultivars have been released. A taro germplasm collection of over 60 lines is maintained at Koronivia. The main research emphasis now is to identify or produce cultivars that are drought tolerant, taro-beetle resistant, and can sucker profusely to supply adequate planting material. Apart from these, other constraints that require attention include the ever-present threat that the taro leaf blight may enter the country despite quarantine vigilance, the unavailability of a control measure for the taro beetle, and the instability of the international market for taro. There is also need to improve the availability of planting material, and strengthen the extension network.

The future potential of taro in Fiji looks quite good, both for local consumption and for export. In particular, the decline of interest in rice production on the banks of the Rewa river and its delta, may create an opportunity for expanded taro cultivation.

6.2 Taro Cultivation in Samoa

Up till 1993, taro was the pre-eminent crop in Samoa. It was the major dietary staple (along with bananas and breadfruit) and accounted for over half of the nation's export earnings. It also had considerable cultural significance and featured prominently in homage, feasting, and gift-giving ceremonies. Its importance has been such that it is featured on one of the coins that form part of the country's currency.

The value (in WS$) of taro export from Western Samoa was 5.8 million in 1989, 3.5 million in 1990, and 9.5 million in 1993. Thereafter, the export market crashed as a result of the outbreak of the taro leaf blight in 1993. The total taro export for 1994 was worth only 0.065 million WS$, and the total 1994 taro production was only 3% of that in 1993. Virtually all of the 1994 production was consumed locally. Most of the importing countries have proscribed taro from Samoa, and in any case, the total production is so low that it cannot even meet the internal demand. Table 5 shows the trends in W.Samoa taro production, price and value from 1982-1995.

Much of the taro in Samoa is grown as a sole crop, usually on newly cleared land that has been fallowed for 2-3 years. Occasionally, it is intercropped with yam, pineapple, Alocasia, bananas or cassava. It is also sometimes grown in between rows of tree crops such as coconuts. The most common cultivar of taro grown has been Taro Niue, but since the blight epidemic in 1993 cultivar diversification is being actively pursued.

In most parts of the country, taro can be planted at any time of the year, but in the drier areas, planting is done in September-November when the rainy season is just starting. Spacing varies from dense (about 60 × 60cm) to wide (about 100 × 100cm) depending on the cultivar, the fertility of the soil, the desired size of corms, and the necessity or otherwise to produce suckers for future planting.

Most growers do not use fertilizers, claiming that it gives the taro a poor taste. Manual weed control is the most common practice.

The taro leaf blight is the most devastating disease of taro in Samoa. When it first struck in 1993, attempts were made to control it with Ridomil and Manzate fungicides. Since mid-1994, phosphorous acid (Foschek) has been the preferred fungicide, combined with a very intense programme of field sanitation. Careful choice of disease-free planting material, physical removal of diseased leaf portions, and even intercropping are some of the sanitation and cultural practices being employed to cope with the disease. So far, neither the taro beetle nor the alomae/bobone virus disease are of any economic importance in Samoa, and are probably absent from the country.

The crop is harvested 6-11 months after planting. Most of the crop, whether for export or for local consumption, is handled as the fresh corm. The leaves are a delicacy, and are harvested as needed. The onset of the taro leaf blight, and the use of chemicals to control it, have made leaf consumption a very expensive and environmentally risky practice.

The predominant constraint in Samoan taro production is the taro leaf blight disease. The impact has been so devastating mainly because the country was so reliant on taro for its food and its export earnings, and the taro crop itself had a very narrow genetic base. A deliberate programme of crop diversification is now being implemented. Meanwhile, research continues, especially at the Nu'u Crop Development Centre, into developing blight-resistant cultivars and other control measures for the disease. The solution may ultimately lie in having a concerted international effort to tackle the disease and other taro problems. Recent significant efforts in this direction have included the European Union-supported Pacific Regional Agricultural Programme (PRAP), and taro breeding work at Bubia in Papua New Guinea. Until the blight problem is effectively solved or contained, the future of taro in Samoa will continue to remain shaky.

6.3 Taro Cultivation in American Samoa

The situation of taro in American Samoa has been very similar to that in Samoa. Before 1993, taro was the dominant root crop both in tonnage produced and in hectarage. The taro leaf blight disease was first reported in American Samoa in 1993, before it was reported in Samoa just a few months later. Its impact on the entire taro production system has been similar to that in Samoa. However, there are two important differences. First, American Samoa never had a taro exporting industry even in pre-blight days. So while the blight in Samoa affected both food supplies and export earnings, it only affected food supplies in American Samoa. Secondly, because of its economic structure, American Samoa has been quicker to source alternative food items to compensate for the shortfall in taro production. Taro still remains a food of choice for much of the indigenous population, and the cultural ties to it are still strong; but unless and until the blight problem eases, other (mostly imported) food items will continue to receive increased patronage.

Table 5. Taro Production, Price and Value in Western Samoa from 1982-1995.

	1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Production, × 1000 tonnes	15.16	15.18	16.18	16.50	25.51	26.88	22.22	28.24	25.42	29.02	27.60	30.08	1.20	1.80
Price, WS$/tonne	470	739	538	538	851	941	986	1008	1096	1171	1350	916	3226	
Value, Million WS$	7.1	11.2	8.7	8.9	21.7	25.3	21.9	28.5	27.9	34.0	37.3	27.5	3.9	

Source: Central Bank of Samoa, In: Tekiu (1996).

6.4 Taro Cultivation in Tonga

In Tonga where the tropical root crops dominate the food basket, taro, (locally called Talo-Tonga) occupies a relatively minor place behind yam, cassava, tannia, Alocasia and sweet potato. All the same it has a high cultural significance, and is regarded as a high status crop fit for nobility and for presentations, feasts and obligations.

Drought is a major factor that influences taro production in Tonga, with the total amount produced being depressed in drought years. There is also a corresponding fluctuation in the amount of taro that is exported. Table 6 gives the amount of taro exported from Tonga from 1990-1995. The years 1992 and 1995 were low rainfall years, and the drastic drops in taro export in those years are attributable to the drought. In 1994, 70 tonnes of taro was traded in local markets, and the total area planted to taro was 470 hectares.

Because of the drought problem, most of Tongan taro production occurs in the northerly Vava'u group of islands where rainfall is higher. Each time a drought occurs, it drastically depresses the yield of the growing crop. Worse still, it creates a scarcity of planting material for the next and subsequent seasons. Farmers and extension agents are then obliged to make nurseries using small corm pieces in order to try to generate additional planting material. Invariably, it takes 2-3 years after each drought to build up enough planting material.

Taro in Tonga is conventionally intercropped with yam and plantains (bananas), but more commercial growers often grow it as a sole crop. Sometimes, it follows yam in the rotation, or follows sweet potato which follows yam. With the recent upsurge in squash production in Tonga, it has become fashionable to plant taro after harvesting the squash, to use up residual fertilizer left over from the squash cropping.

There are two preferred periods for planting. The first period, August-November, coincides with yam planting, and permits yam and taro to be planted at the same time. The second preferred time of planting, March-April, has the advantage that harvesting coincides with the Christmas/New Year period when there is a peak demand for taro for home consumption and for export.

Table 6. Taro Export from Tonga from 1990-1995

Year	Taro Export (tonnes)	Area of Taro Grown (ha)
1990	50	
1991	180	
1992	16	
1993	46	189
1994	110	470
1995	50	

The planting material consists of huli, side suckers, or even corm pieces. Spacing varies depending on the cropping systems used. When intercropped with yam, one row of taro is planted after every 3-5 rows of yam. Inter-row spacing is 100-200 cm while within row spacing is 50-100 cm. For taro grown as a sole crop, a spacing of 90 × 60 cm is recommended.

Manual weeding is practiced. Small-scale producers do not fertilize, but commercial producers are encouraged to apply NPK (12:13:18) fertilizer at 50g per plant. The application is made as a side dressing during the first six weeks after planting.

The current most devastating disease (taro leaf blight) and pest (the taro beetle) of taro in the Pacific are not present in Tonga. The alomae/bobone disease is also not present. So the taro producer has to cope only with relatively minor diseases and pests (armyworms, the dasheen mosaic virus disease, taro hornworm, and the stem/root rot).

Harvesting occurs 6-10 months after planting. Average yield is about 7 tonnes/ha, which is considered low. Little or no processing is done, and most of the commodity is handled and marketed as the fresh tuber.

The most serious constraint to taro production in Tonga is the drought, with the resultant low yields and scarcity of planting material. The absence of the taro leaf blight and the taro beetle offers great potential for the taro crop, both for domestic consumption and for export. However, a great amount of quarantine vigilance is needed to ensure that this advantage remains.

6.5 Taro Cultivation in Vanuatu

Like other root crops, taro in Vanuatu is grown mainly for subsistence. In 1994, less than 1 tonne of taro was exported (to New Zealand). Along with yam and kava, taro enjoys a high social and cultural standing in the country.

One very serious problem afflicting the root crop sector, including taro, is that of inter-island transportation within the country. Even in localities where surpluses exist, the logistics of moving the commodity is so daunting that very little trading in taro exists. A partial solution to this problem was the establishment of Vanuatu Tropical Products Ltd. in the mid-1990's. The company buys and bulks root crops (including taro) in cold rooms, and subsequently re-sells them to consumers.

The taro beetle is present, and continues to pose a problem in taro production. However, the taro leaf blight is currently (1997) absent from Vanuatu, meaning that there is potential to step up taro export to make up for the Samoan shortfall.

It should also be nutritionally profitable for the authorities to encourage a greater degree of taro leaf utilization than exists at present.

6.6 Taro Cultivation in Papua New Guinea (PNG)

For decades, taro has been the third most important indigenous staple in Papua New Guinea (PNG), after sweet potato and bananas. It is estimated that 436,000 tonnes of taro are produced annually on an area of 77,000 hectares (Ghodake *et al*., 1993, Sar *et al*., 1997).

Taro is considered to be a very ancient crop in PNG, and there is archaeological evidence of wetland taro cultivation as far back as 9000 years ago in the Kuk/Baisu area of the Western Highlands Province. Not surprisingly, PNG now has the world's largest genetic diversity of taro (Ghodake *et al*., 1993), even though the crop is believed to have originated in the Indo-Malaya region farther to the west. Taro is grown in all the lowland parts of PNG (Figure 5), and it performs best in these lowland locations. However, taro cultivation also occurs in the highlands including the Star Mountain area of Western Province (2,400 m above sea level), and in Chimbu at about 2,700 m above sea level.

Figure 5. Taro Cultivation in Papua New Guinea

As in many of the Pacific Islands, taro has considerable social and cultural significance in PNG. It is quite commonly associated with ritual, gift-giving and traditional feasting.

Cropping systems used for taro production in PNG vary considerably. Most of the crop is produced under normal rain-fed conditions. Taro is usually planted as the first crop in a newly-cleared garden in the shifting cultivation cycle. It may be intercropped with sweet potato, peanuts and various vegetables, or it may be grown as a sole crop. It may also be planted in the spaces between plantation tree crops such as oil palm or coconut. Irrigated or wetland taro production is practiced in some localities such as Sialum, Rabaraba and Kongara districts. Generally, wetland or irrigated taro results in higher yields.

Planting occurs in any month of the year, particularly in the wetter parts of the country. Recommended spacing varies between 50 × 50 cm to 100 × 100 cm. Close spacing results in higher total corm yields per hectare, but the percentage of larger marketable corms is reduced, and of course the total amount of planting material required at the onset is greater. The planting materials used include huli, suckers and occasionally corm pieces. Several cultivars and land races are grown, with Numkoi (or Nomkowec) being one of the most common. Other cultivars in cultivation include Unabuae, Junguluh, and Chakuk.

Most taro growers do not apply any fertilizer. However, the use of 200 kg/ha nitrogen in the form of urea has been recommended. The incorporation of compost, animal waste or coffee pulp have also been found to be beneficial. Weeds are controlled by manual weeding; the use of herbicides is rare.

In the lowland regions, taro is ready for harvest in 7-9 months, but maturity for harvest in the highland regions may not come till 15-18 months after planting. For harvesting, a digging stick or spade is used to loosen the soil around the base of the plant, and the plant is pulled up by grabbing the petiole bases. Average yields are estimated to be 5-10 tonnes of fresh corm per hectare. Virtually all the harvested taro is handled, transported and utilized as the fresh corm.

Taro production in PNG has witnessed a decline in recent years. The major constraints that have caused this decline are:

a) The presence of the taro beetle.
b) The incidence of the taro leaf blight disease.
c) The high labour requirement for taro production compared to sweet potato.
d) The availability of imported food substitutes, especially rice.
e) The presence of the alomae/bobone virus disease complex.

Partly because of these production constraints, taro is more expensive in PNG, on a weight to weight basis, than sweet potato, yam, tannia or cassava. However it is still preferred as a food item over these other root crops.

The presence of the diseases and pests mentioned above means that PNG taro cannot be exported, due to quarantine restrictions. This factor has been a source of discouragement to various entrepreneurs who have shown interest in commercial production of taro for export. For the present and foreseeable future, therefore, all PNG taro production is for domestic consumption, and no export trade in taro is occurring.

It is interesting that despite having all the major taro diseases and pests of the region, PNG taro production has not been wiped out, and manages to plod along. This contrasts with the Samoan situation where only one of these diseases (taro leaf blight) virtually crippled the taro industry. The key seems to lie in the much greater genetic diversity of the taro crop in PNG. This factor has a stabilizing effect on the taro industry, permitting meaningful production to continue (albeit on a reduced scale) in the face of these constraints.

Research is now in progress within the country to try to address some of the constraints indicated above. Much of this research is centred at the Bubia Agricultural Research Station and at the University of Technology, both near to the city of Lae. The areas of research can be grouped as follows:

a) *Collection, conservation and characterization of taro germplasm*: In the mid-1980's, over 600 accessions were maintained at Bubia, but most of these were lost during the early 1990's. The effort was invigorated again in the mid-1990's, and by 1995, there were 841 accessions made up of 407 cultivars, 203 clones from the breeding programme, 201 semi-wild types, and 21 introductions from other countries (Gunua & Kokoa, 1995).

In the late 1990's, there again seems to be a decline in resources to maintain the collection, and by 1997, the number of accessions had again declined to 333. There is some uncertainty as to whether the momentum can be sustained. A much smaller field collection is maintained at the University of Technology, and the possibility of *in-vitro* maintenance of the collection is being investigated.

b) *Taro beetle control*: Since various experiments have failed to produce a reliable or safe chemical control for the beetle, attention has turned to biological control. Initial trials showed that an entomopathogenic fungus (*Metarhizium anisopliae*), a bacterium (*Bacillus popilliae*) and a protozoa (*Vavraia*) each showed promise for the control of the beetle population. Various cultural methods are also being investigated for the beetle control. What is significant about this research is that most countries in the region are relying on it for an ultimate solution to the taro beetle problem. Much of the research has been carried out under the auspices of the Pacific Regional Agricultural Program (PRAP) which also has a similar taro beetle research going on in the Solomon Islands.

c) *Taro leaf blight control*: This has involved a screening of the germplasm collection, and the production of new genotypes through crossing. In 1992, 433 accessions were screened. Three local varieties (K333, K345 and Ainaben) were found to be highly resistant to taro leaf blight, while another 57 varieties were slightly resistant. Through an active breeding programme and using recurrent selection techniques, it is hoped that the researchers will soon release varieties that are not only resistant to the blight, but also tolerant to nematodes and the alomae/bobone disease. Such varieties must also have desirable culinary and agronomic qualities. This taro leaf blight research, centred in PNG, is also of regional importance, since all the countries that have the blight (including Samoa) are anxiously awaiting its outcome.

If the current research attention can be sustained and re-enforced, then the constraints facing taro production in PNG will be drastically reduced. Such a situation, bolstered by the cultural attachment of the people to taro, could yet give rise to a resurgence in taro production.

6.7 Taro Cultivation in Solomon Islands

The situation with taro cultivation in Solomon Islands is very similar to that in Papua New Guinea. Taro has, for centuries, played a prominent part in the diet of the people, and in their cultural affairs, including traditional medicine. However, taro production has witnessed a marked decline in recent years due to essentially the same constraints as exist in PNG (presence of the taro beetle, existence of the taro leaf blight, existence of the alomae/bobone virus disease, and the greater ease of producing other crops such as sweet potato). Nematodes are also a problem. It is only in isolated outlying atoll islands where these diseases/pests are less prevalent, that taro has remained a major staple.

The area under taro cultivation each year is estimated to be 2060ha in the mid-1990's (Liloqula and Samu, 1996). The crop is usually the first to be planted after bush fallow in a shifting cultivation system. It is sometimes grown in pure stand, and at other times intercropped with yam, sweet potato, banana, cassava or vegetables. Huli and suckers are used as planting material. They are inserted into holes that have been opened up using a pointed stick. Shallow planting is done if the farmer intends to generate many suckers for use as subsequent planting materials; but if sizeable ware corms are the target, then deeper planting is done. Spacing ranges from 60 × 60 cm to 90 × 90 cm. Hand weeding is the rule, and there is generally no fertilizer applied.

The taro beetle is the most serious pest. Active research into its control is going on in Solomon Islands under the auspices of the Pacific Regional Agricultural Programme (PRAP), with biological control being actively explored. The taro leaf blight in the most serious disease. The taro leaf blight was first reported in the country in 1947, over half a century ago. Some degree of control has been achieved using Zineb and copper oxychloride, but in more recent times, greater reliance is being placed on using tolerant cultivars which are available.

Harvesting occurs 5-12 months after planting. Most of the crop is consumed in the household where it is produced (subsistence). The amount that leaves the household is marketed as fresh corm. Virtually no export of taro occurs from Solomon Islands, partly due to quarantine regulations against the diseases and pests mentioned above.

The Research Department of the Ministry of Agriculture and Fisheries has recently released some hybrid taro cultivars which are resistant to taro leaf blight. This, combined with the sweet potato weevil problem in the sweet potato crop, has caused a resurgent interest in taro production. However, the culinary quality of the newly-released cultivars is poor. The new interest in taro production can only be sustained through additional research to produce better disease-resistant cultivars and to offer an effective control for the taro beetle.

6.8 Taro Cultivation in Cook Islands

Taro is the pre-eminent root crop in Cook Islands. Firstly, it occupies a larger area of land that any other root crop, as can be seen from Table 7. The islands with the largest taro area in 1996 were Rarotonga (126ha), Mangaia (29ha), Mauke (9ha), Nassau (9ha) and Aitutaki (9ha). The total area occupied by taro in 1996 was 193.7ha. Secondly, taro is by far the preferred staple among the population, and features prominently in the diet. Both the corms and the leaves are used for food, thereby providing a useful balance of energy and protein. Thirdly, taro is intricately inter-woven with cultural life of Cook Islanders, and this has been so for centuries. It is the preferred crop for obligations, gift giving, ceremonies and feasting, and features prominently in the folk lore and traditions. Not surprisingly, there is considerable sentimental attachment to taro production and consumption. Finally, taro features prominently in the export trade of Cook Islands (Table 8), almost to the exclusion of all other root crops. Most of the export goes to New Zealand. There are very few countries in the world where taro occupies such an exalted position in agriculture as does taro in Cook Islands.

Taro is grown in all parts of the country, but the cropping system adopted depends on the location. In the northern islands which are coral in nature, taro is grown in brackish muddy water. The southern islands, however, are volcanic in origin, and here, three kinds of cropping system are used to grow taro:

a) *Paddy fields*: These are fields to which water is diverted from rivers. The water is never allowed to be stagnant, otherwise rot organisms attack the taro base. The huli or suckers used for planting are pushed into the mud to 20-30 cm depth. Inter-plant spacing is 45-60 cm either way. Fertilizer is not added, but vegetation brought up during weeding is incorporated into the mud as organic matter. Every few years, the paddy is replenished by addition of new soil.

b) *Raised beds*: The raised beds are prepared with hand tools in such a way that water constantly flows around each bed and keeps it 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. Inter-plant spacing is 60-100 cm either way. Fertilizer, when used, is applied after the plants have developed two leaves.

c) *Upland taro*: In this case, there is no free-flowing water beneath or around the taro. Clay-loam soil is preferred. After clearing, the huli or suckers are inserted into holes made with spades or digging sticks. Where machines are available, planting is done into machine-made furrows 30 cm deep. Spacing ranges from 100 × 50 cm to 100 × 60 cm. Irrigation, where used, is by overhead sprinklers or by drip irrigation, and the crops receive water every 3-4 days. Fertilizer application is recommended for the first 3-4 months after planting. Nitrogenous fertilizer is applied as soon as the plants establish, and compound fertilizer is applied in the third and fourth months.

Table 7. Area (ha) Devoted to Various Root Crops in Cook Islands in 1988 and 1996.

Crop	1988	1996
Taro	242.7	193.7
Tannia	127.7	23.8
Sweet Potato	115.3	10.7
Cassava	321.9	76.6

Source: Adapted from Manarangi, 1996.

Table 8. Quantity and Value of Taro Export from Cook Islands from 1989-1994.

Year	Quantity Exported (tonnes)	Value of Export (NZ$ × 10^3)
1989	34.6	64.7
1990	8.1	83.4
1991	16.6	49.0
1992	3.0	0.5
1993	1.5	1.7
1994	90.1	135.2

Source: Adapted from Manarangi, 1996.

Taking the country as a whole, most of the crop is grown on raised beds (Table 9), while upland cultivation occupies the least area. Upland cultivation is increasing in popularity in Rarotonga where irrigation water is available. In general, the best quality taro, in terms of local culinary preference, are those from raised beds and paddy fields. Taro from upland fields is the least preferred.

For all the production systems, hand weeding is often practiced. Herbicides are sometimes used on raised bed or upland systems, but never for paddy. The recommended herbicides are gramoxone (paraquat) and glyphosate.

Harvesting occurs at 6-12 months after planting, and is always done with hand-held digging sticks or spades. Average yields are estimated to be 10-14 tonnes/ha. Harvested corms are kept in moist sacks for transportation, or under dripping water, and can keep for up to two weeks. Longer-term storage is effected by peeling the corms, cutting into required sizes and freezing. Taro is marketed both as fresh unpeeled corms and as peeled frozen corms. Frozen taro can be cooked directly, or thawed before cooking.

Cook Islands has so far been spared the scourge of either the taro beetle or the taro leaf blight. This has permitted both the domestic and export trade in taro to flourish unfettered. Active research on taro is going on at the Totokoitu Research Station. Introduced cultivars that have been tested and released include Kerekere and New Caledonia, which are high yielding, as well as Veo Tarona which is very good tasting. The main exported cultivars are Alafua Sunrise, Old Niue and New Niue. Some research is also looking into the use of *Azolla mexicana* to boost fertility and yield in the paddy production system for taro. One problem that needs some attention is the high cost of collecting the taro from different islands before shipping overseas. Perhaps some amount of pre-processing in the outer islands could reduce shipping costs. Given the present research attention, quarantine enforcement, the unique place of taro in the diet, and the sentimental attachment of the people to the crop, the future of taro in Cook Islands looks set to continue to be quite rosy.

Table 9. Area (ha) of Taro Growing under Different Cropping Systems in Cook Islands in 1988 and 1996.

	1988	**1996**
Upland	38.62	16.3
Paddy	69.14	51.2
Raised Bed	135.34	126.17
Total	**243.10**	**193.67**

Source: Adapted from Manarangi, 1996.

6.9 Taro Cultivation in Tuvalu

Taro is a relatively minor crop in Tuvalu, where *Cyrtosperma chamissonis* (Giant Swamp Taro) is the dominant root crop. However taro occupies a high social and cultural significance, just like *Cyrtosperma*.

Taro cultivation is confined to certain families in the outer islands. Production is mainly in wet lands in huge pits (Pulaka pits) that have been dug down to the water lens. Green composting is an essential aspect of the cultivation practice, and the size of the corm produced is considered an important factor. Dalo Kena, one of the most popular local cultivars, can yield up to 15 tons/ha in a 10-month growing period. One major pest is the taro plant hopper. This is being controlled on the capital island of Funafuti and on Vaitupu using a predator, *Cytorhinus fulvus* (Lausaveve, 1995).

6.10 Taro Cultivation in Niue

Niue is a small, low-lying island with no hills or rivers, and heavily, dependent on collected rain water. Taro has been a traditional crop among its people, and is of considerable culinary and cultural importance. Some taro is also being exported, mainly to New Zealand. In the 1994/95 period, about 235 tons of taro were exported to New Zealand (Tongatule, 1995), which is substantial considering that there are only about 3,000 people on Niue.

The taro production system relies basically on shifting cultivation. Sole cropping of taro, not intercropping, is the rule. About 50% of the growers use fertilizers, and about 90% of them use chemical weed killers. There are no serious diseases and pests. Average yields are estimated at 2-10 tonnes/ha. There is a large number of cultivars grown, among which **Fate fa tea** and **Fate fa ivaiva tea** are among the most popular.

6.11 Taro Cultivation in French Polynesia

Taro production in French Polynesia has shown a steady increase in the past decade, especially on the island of Tahiti (Table 10). Part of the impetus for this increase has come from the very attractive prices which have encouraged the use of greenhouses for taro production.

Table 10. Trends in Taro Production (tonnes) on the Various Island Groups of French Polynesia from 1991-1994.

	1991	**1992**	**1993**	**1994**
Tahiti-Moorea	241	245	317	347
Windward Is.	165	138	186	174
Austral Is.	82	75	85	141
Marquesas Is.	11	10	13	19
Total	**499**	**467**	**601**	**655**

Source: Adapted from Wong, 1995.

The main cultivars grown are Veo, Manaura, Veo Manaura, Amoa and Ute Ute. The entire production is consumed locally, and there is no export of taro. Very little research is currently being done on taro, but there is need to identify salt-tolerant cultivars to permit further expansion of production especially on Tuamotu. With the present high prices for taro, and good demand, the future of taro production in French Polynesia looks assured.

6.12 Taro Cultivation in New Caledonia

New Caledonia has had a long history of taro cultivation dating back for centuries. Taro, with yam, has been the traditional basis of kanak agriculture, with taro symbolising the female and yam symbolising the male. Most of the work on taro gardens was also done by women. Taro cultivation in earlier times occurred on elaborately constructed terraces in various parts of the

New Caledonia mainland. Both dry land and flooded or irrigated cultivation practices were employed. Shifting cultivation was used, relying on bush fallow to restore soil fertility. Many of these historical taro terraces have now been abandoned, but can still be seen all over the countryside.

Today most of taro cultivation in New Caledonia is on the wetter eastern side where the annual rainfall ranges from 2,000-2500 mm, and where the dry season is shorter. The western side is too dry, and the dry season (August to December) too long. Taro on the eastern side is grown mainly as a rain-fed crop by subsistence farmers who usually intercrop it with yam. Some cultivation also occurs in marshy areas on Loyalty Island, and with the use of irrigation around Noumea.

Normally, the crop is planted between October and December, at the start of the hot rainy season. By May, the plants begin to decline in size, and harvesting occurs June-September. This harvesting period roughly coincides with the coolest part of the year (August-September). Because of this cool dry weather, mature corms in the ground do not deteriorate rapidly, so that harvesting can be spread out over an extended period without much harm. Preferred cultivars include **Mateo rose** and **Wallis** which can give yields over 20 tons/ha.

One species of the taro beetle (*Papuana huebneri*) is present in New Caledonia, but up till the mid-1990's, damage was within tolerable limits and no particular control measures were in place (Varin & Verner, 1994). The dasheen mosaic virus disease is also present, but the taro leaf blight is absent. There have been reports of the **loliloli** physiological disorder, caused by continued vegetative growth after the corms mature. It is characterised by soft spongy corms of low density. The hard rot physiological disorder is also present.

Active research on taro is currently going on at the CIRAD research centre in Noumea. Areas being investigated include variety introduction and evaluation, varying the time of planting so as to achieve out-of-season production, weed control, and control measures for diseases and pests.

New Caledonia does not export taro, and probably is a net importer of taro. As such, all the taro that is produced is consumed internally. However, taro prices have been quite good (approximately US$3.3/kg in the mid 1990's), and this has served as a stimulus towards greater production.

6.13 Taro Cultivation in Indonesia

On a national basis, taro is a very minor crop in Indonesia. It is much less important than rice, maize, soybean, cassava, peanut, mung bean or sweet potato. It is not surprising, therefore, that there are very few statistics available on Indonesian taro production and utilization.

Despite its obscurity at the national level, taro is of considerable regional importance in many parts of Indonesia, especially the Provinces of Irian Jaya and Maluku, the island of Mentawai in West Sumatra, and some parts of Java. Indeed, in some districts, taro assumes a pre-dominant importance as a staple, a cash crop, and an object of intense cultural attachment. For example, in the Ayamaru sub-district of Sorong in Irian Jaya, studies have shown that taro can contribute as much as 64 % of the total food of the household, and up to 48% of the total household net cash income (Rochani, 1994).

Taro is most often grown near streams, ponds or in low-lying wet areas. Shifting cultivation is practiced in many locations. Cultivars in use include Talas sutera, Talas bogor and Talas semir in West Java, Talas bentul in East Java, and Awiyah Yumana Mboh, Awiya Yahya, Awiyah Toboh etc. in Sorong District. Propagation is by means of huli or side suckers. Weeding is done one month after planting, and again 1-2 months later (Dimyati, 1994). Most farmers do not use fertilizers, but for those that do, compound fertilizer is applied shortly after planting, and again in the third month after planting.

The taro leaf blight is present, and is one of the major constraints to taro production in Irian Jaya. It was first reported in 1975 and has since become endemic in most parts of the province. Experiments using saprophytic micro-organisms have shown that *Pseudomonas fluorescence, Bacillus subtilis,* and *Gliocladium flimbriatum* can control the fungus *in vivo* and *in vitro* (Matanubun and Paiki, 1994). However, this potential for biological control has not been effectively tested at the farmer level. Other suggested control measures include spraying with fungicide metalaxyl, or growing the taro as an intercrop. The taro beetle is also present both in Irian Jaya and in the rest of the country, but there is no effective control measure.

Harvesting occurs 6-8 months after planting. Most of the harvested crop is used for subsistence in the household. Both corms and leaves are used for food. A small amount of the production is marketed locally, but there is no export trade in taro from Indonesia.

Serious research into taro production began in Irian Jaya in 1957. Since then, the research has continued with increasing vigour, mainly under the auspices of the Root and Tuber Crops Research Centre which was established in Manokwari in 1988. The Centre's activities include conservation of taro genetic resources, development of taro cropping systems for different ecologies, and finding control measures for the taro leaf blight and the taro beetle.

Nationally, Indonesia is expected to continue to be part of the rice culture of Asia, and taro will remain a minor crop. However, with increasing emphasis on decentralised development, it is expected that crops such as taro, which only have regional importance, will receive progressively greater attention.

6.14 Taro Cultivation in Thailand

Like Indonesia, food crop agriculture in Thailand is dominated by rice. Taro is a minor crop, and is eaten mainly as a dessert or snack. However, it is grown as a lucrative cash crop for export. The area and production of taro in Thailand from 1987 to 1996 are shown in Table 11. The largest area and production occur in the northern part of the country. In the 1988-1995 period, Thailand exported approximately 300-500 tonnes of taro each year, valued at US$120,000-200,000 per year. Most of the export went to Hong Kong, Japan and Malaysia.

Taro production in Thailand has been successfully integrated into the rice production system. Taro is grown on the same land after harvesting rice. Planting occurs once the rice crop has been harvested. Alternatively, rice is followed by vegetables, after which the taro is then grown. The main taro crop is planted in February/March, while some upland taro is also planted in July/August. For planting, the land is tilled and harrowed, and soil amendments such as lime or burned rice husk may be added during tillage. The soil is made into raised beds. Each bed is 4-5 m wide, with 1 m space between beds. The furrows between the beds serve for irrigation and for drainage. Preferred varieties include Chiang Mai, Surin, Srisaket, Petchaboon, and Ubon. Average yield is about 13 tonnes/ha.

Table 11. Area and Production of Taro in Thailand from 1987 to 1996.

	1987	1988	1994	1995	1996
Area (ha)	1,810	2,131	2,724	3,776	2,487
Production (tonnes)	22,233	32,061	40,973	49,000	33,039
Average yield (tonnes/ha)			14.57	12.45	13.20

Source: Adapted from Ratananukul (1991), & data from Dept. of Agricultural Extension, Bangkok.

Huli are sometimes used as planting material, but most commonly, a nursery of cut cormels and corms is prepared to produce planting material. The cut corm pieces are kept moist and covered with rice straw. After 3 weeks, they are transplanted to the beds in the field. Rows on the bed are 0.5 m apart and within-row spacing is 0.5 m. A spacing of 100-120cm × 30cm may also be used. Double rows are sometimes used in the upland areas. Irrigation is provided, and side suckers are regularly removed so as to encourage the development of large corms. As the corm itself develops, earthing-up is done frequently to ensure that it remains covered with soil.

Farmyard manure may be placed in the planting holes at 300-500g per hole. A split application of NPK (13-13-21) fertilizer is often done, first in the first month of planting, and then again two months later. The total amount of compound fertilizer for the crop is about 80kg N, 80kg P_2O_5, and 130kg K_2O. Minor insect pests are controlled with insecticides, and leaf spot is controlled by clipping infected leaves. The taro leaf blight is present, but its economic damage is not serious. The taro beetle is absent. Harvesting occurs at 6 months after transplanting. The corms are graded and packed for export. The premium price is paid for large corms.

The Pichit Horticultural Research Centre has a collection of some taro cultivars, but very little taro research is taking place in the country. However, the fact that much of Thailand's taro production is export-driven means that production has already moved from a subsistence footing to a commercial one. As long as the export market prices remain stable, taro production in Thailand is likely to continue to strengthen.

6.15 Taro Cultivation in the Hawaiian Islands (USA)

For centuries, taro was a predominant staple for the indigenous Polynesian people of Hawaii. It played a major role both as a food item and as an object of cultural identification and pride. Both leaves and corms were consumed and used extensively in gift-giving and cultural functions.

Today, taro remains an important agricultural commodity in Hawaii, and continues to attract considerable cultural attachment from the indigenous population. Most of the corms produced are processed into "Poi", a sour-tasting taro paste. It is made by pressure-cooking the corms, washing, peeling and mashing them. The paste is then passed through strainers and packaged. During storage for a day or more, *Lactobacillus* spp. ferment the product, causing it to become more acidic and the pH to drop from about 5.7 to 3.9.

Poi is packaged and sold commercially in stores. The other major product made from taro corms is taro chips. These are also packaged and sold commercially, and have the advantage of having a reasonably long shelf life. There is a virile cottage industry built around the making of taro chips. One such family concern is based in Hanapepe and produces the "Taro Ko Chips" brand of taro chips.

Taro leaves are a valued delicacy ("luau") of the Hawaiian diet, and constitute an important part of the traditional diet. Taro tops left after harvest are used for silage for livestock feeding.

In past centuries, the total land area devoted to taro in Hawaii was much greater than it is today. Much of the decline in area has been due to land pressure as a result of urbanisation and use for other agricultural purposes. By 1972, the area under taro in Hawaii was only 185 ha and production was about 4,000 tonnes (de la Pena, 1990). Since then, further declines in production and area have occurred.

Table 12. Taro Production and Area in Hawaii

Year	Area (ha)	Production (tonnes)
1972	185	4,000
1983	150	2,472
1984	150	2,868
1985	162	3,118
1986	158	2,878
1987	162	2,818
1996	246	

Table 12 shows that even though the taro area has declined over the past few decades, it now holds steady at 150-250 ha each year. Most of the decline has been in the area of taro used for making Poi, while the area used to grow taro for chips has actually increased slightly. Overall, the total amount of taro that is made into chips in Hawaii is only about one tenth of that which is used to make Poi.

Two production systems are used for taro cultivation in the Hawaiian Islands:

a) Flooded or wetland taro
b) Upland or dry land taro, grown as an unflooded, rain-fed crop.

Flooded taro cultivation occurs mainly on the island of Kauai, while dry land taro cultivation is on the "Big Island" of Hawaii. Flooded taro is normally grown in monoculture, i.e. not rotated with other crops. However, upland taro is usually rotated with ginger on the island of Hawaii.

For flooded taro, machines are used to plough the field and build embankments so that water can be impounded. The field is also puddled, to reduce the loss of water through percolation. The typical planting material is the huli. Planting can be done at any time of the year, and indeed many farmers stagger their plantings so that they have different plots ready for harvest at different times.

Planting is done by inserting the huli by hand into the loose puddled soil, or by use of mechanical planters before flooding. As the crop grows, the water level is gradually raised to keep the base of the plant submerged. However, the water is kept flowing at all times, otherwise its oxygen content becomes low and rot organisms attack the taro. Weeds are usually not a serious problem, but when necessary, appropriate herbicides (eg. Nitrofen) are added to the irrigation water. Flooded taro responds well to fertilizer, up to about 1,120 kg/ha of either nitrogen or phosphorus. The field is drained in order to fertilize it. After fertilising, the farmer waits three days and then re-floods the field. *Azolla* grows on its own in many of the flooded fields, thereby providing additional fertility. Most growers make little or no effort to manage the *Azolla*.

Upland taro cultivation of taro in Hawaii begins with mechanical land ploughing and harrowing. The crop may be planted on ridges, furrows or on the flat (de la Pena, 1978). The planting material may be huli, or quite commonly, small unmarketable corms. Cultivars preferred for upland planting are **Lehua Maoli**, and **Bun Long**. Bun Long is particularly favoured for the making of chips because of the low acridity of its corm. The leaves are also very much preferred for “luau”.

Upland taro is fertilized, first by broadcasting and incorporating the fertilizer into the soil during land preparation; and then side-dressing at 2, 4, and 6 months after planting.

The taro leaf blight disease is present in Hawaii, but it is never severe, probably because of the relatively dry weather. The taro beetle is absent.

Upland taro matures in about 12 months, while flooded taro is ready for harvest in about 15 months. However, flooded taro yields are higher than upland taro. In Hawaii, yields of 37-75 tonnes/ha have been recorded for flooded taro, while upland taro yields about half as much.

Taro cultivation in Hawaii represents the highest level of technology and intensity of cultivation of the crop on earth. The flooded taro cultivation, especially in the Hanalei valley (Figure 6), consistently returns some of the highest yields in the world.

It is true that the area and production of taro in Hawaii, having declined from earlier peaks, have remained stable in the past few years. Further declines are unlikely because of the specialist niche market which Hawaiian taro serves. This market rests on two strong groups of clientele:

(a) The North American tourists keen to sample taro products as part of their Hawaiian cultural experience;

(b) The indigenous Hawaiians eager to consume taro as a reminder of their culture which they are so keen to preserve.

Active research on taro is going on at the Kauai Agricultural Experiment Station. Hawaiian taro production is already on a fully commercial footing, and storable processed products (Poi and chips) are already being made from taro. All the requisites are therefore in place to sustain the taro industry far into the future on the Hawaiian Islands.

Figure 6. Taro Fields in the Hanalei Valley, Hawaii

6.16 Taro Cultivation in the Philippines

The Philippines has the largest area devoted to taro in Asia proper, apart from China. In 1996, about 34,000 hectares of land were devoted to taro, producing about 117,000 tonnes (FAO, 1997). Still taro is a relatively minor crop in the Philippines. The food basket is dominated by rice and maize, with the root crops as a group coming lower in the order. Even among the root crops, greater quantities of sweet potato and cassava are produced compared to taro (locally called Gabi).

There are two main production systems for taro in the Philippines. Dryland/upland is the most common and is used in most of the subsistence production. Wetland/lowland cultivation occurs, but it is restricted to certain regions, and is usually operated on a commercial or semi-commercial basis. Yields are generally low throughout the country, usually averaging less than 5 tonnes/ha.

Planting is done in holes or occasionally in furrows. Interplant spacing is 80-100cm either way. Taro is often intercropped with bananas and upland rice. A considerable amount of taro is grown in home gardens, mainly for the leaves. Usually, 3-4 cultivars may be found growing in the same garden.

Harvesting is done 8-13 months after planting. Both taro corms and taro leaves are utilised for food in the Philippines. Some stolon-producing cultivars are grown for the stolons which are used for food. Most of the corm harvest is marketed as the fresh product, although some amount goes into the making of taro chips. Kalpao is one of the recommended local varieties (Pardales & Villanueva, 1984), but more recently, cultivar Iniito has become the most popular. It has purplish flesh, is fairly tolerant to the taro leaf blight, and is strictly for upland cultivation. Other cultivars include Dalwangan, Monoy, Binisaynon, Pinalawan etc. In some remote localities, taro corms and leaves are used in traditional medicine, evidence of the long association of the people with the plant (Pancho, 1984).

The taro leaf blight is present in the country, but does not result in serious economic losses. The taro beetle is practically absent, although one species of *Papuana* has been reported in the country.

Since about the mid-1990’s, a taro export trade has sprung up in the Philippines. The export goes mainly to New Zealand, and the main operator for now is the Dole Company. Some taro research takes place at the Philippine Root Crop and Training Center in Beybey, on Leyte.

6.17 Taro Cultivation in Malaysia

Malaysia is one of the areas where taro is said to have originated. Not surprisingly, records of taro use as a food crop date back more than 2,000 years (Ghani, 1984). Today, taro features not just as a food item but also as a prominent item in traditional medicine and folklore. Locally it is called keladi, although other aroids and even yams are similarly called. Numerous wild relatives of taro occur, especially in the Malay Peninsula.

The long-term association notwithstanding, taro is today a minor crop in Malaysia, becoming significant only if and when the rice crop fails. Total taro hectarage throughout the country is probably about 1000ha. The main consumers of taro in Malaysia are the ethnic Chinese population. Numerous cultivars are in cultivation. Short season (4-6 months) cultivars include Keladi Pinang and Keladi Tongsan. Longer-season (9-12 months) cultivars include Keladi

China, Batang Hitam and Keladi Nibong Merah. There are even cultivars that do not produce corms but which are grown mainly for their edible leaves and petioles.

6.18 Taro Cultivation in Japan

Taro was introduced into Japan over 2000 years ago. In the twentieth century, there has been a decline in its production and consumption as sweet potato and Irish potato increased in prominence. Table 13 shows that both the area of taro cultivated in Japan, and the per capita consumption have both declined since the early part of the twentieth century.

Table 13. Area Planted of Taro in Japan, and Per Capita Taro Consumption Each Year for Various Periods in the Twentieth Century.

Years	Area Planted (ha/yr)	Per Capita Consumption (kg/yr)
1907-1911	58,142	24.6
1923-1924	52,818	21.9
1925-1944	56,529	20.3
1945-1965	30,708	5.3
1966-1972	37,000	5.3
1973-1985	30,000	

Source: Adapted from Nishiyama (1984).

Today, taro is grown in Japan not as a staple, but mainly as a vegetable. In this regard, it ranks fourth in terms of area planted, behind radish, cabbage and Chinese cabbage. It is grown mainly for the petioles and leaves, and to a lesser extent for the corms and cormels. Since the 1970's, the area of taro cultivated in Japan has remained fairly steady at between 20-30 thousand hectares. Average yield is approximately 13 tonnes/ha.

Most of the taro grown in Japan is of the eddoe type. Because of the temperate conditions, short-season cultivars are preferred, and even then, most of the cultivation occurs in the warmer southern parts of the country. The cultivation strategy is basically geared towards getting the maximum amount of growth during the short growing season available.

Before planting in the field, small suckers are first raised in nursery beds for 1-2 months until they sprout and attain the 3-leaf stage. The sprouted seedlings are then transplanted to the field as soon as the average field temperature reaches 15ºC or more. This usually occurs in May. Field spacing can range from 75 × 30 cm to 100 × 30 cm. Plastic mulch is often used to cover the soil as a means of attaining warmer temperatures early in the season, and also for weed control. Compound NPK fertilizer is commonly applied, and the addition of lime during field preparation is also recommended. It is suggested that deep planting hinders the enlargement of the underground parts, so the initial planting is kept shallow, and earthing up is done two or three times as the taro grows (Nishiyama, 1984). Nematodes can be a problem, but can be controlled by rotating with other crops.

Taro leaf petioles (locally called "zuiki") are consumed as a vegetable delicacy in Japan. The corms and cormels are also utilized. The cool ambient temperatures permit post-harvest storage of corms and cormels in the field. However, they should not be allowed to get cooler than 6ºC. For this reason, they are covered with earth during field storage. The colder the outside temperature, the thicker the layer of earth should be.

Taro is a very minor crop in Japan, and will remain so for the forseeable future. The major constraint to its production and expansion is the temperate condition which predominates in the country, and the attendant shortness of the growing season.

6.19 Taro Cultivation in China

China produces about 1.39 million tonnes of taro per year. The area of taro harvested each year is approximately 82,000 hectares, and the average yield is about 16.8 tonnes/ha.

The area devoted to taro in China may appear large, but is indeed quite small when compared to the total land area of the country. In reality, China devotes a smaller percentage of its total land area to taro than does any of the countries in the foregoing discussion. Similarly, the per capita consumption of taro in China is smaller than that of any of the foregoing countries. It is not surprising therefore that taro is a relatively insignificant crop in Chinese agriculture.

Taro cultivation in China shares many of the same characteristics with taro cultivation in Japan. Most of the production is confined to the warmer southern and coastal parts of the country. In the cooler regions, the growing season is too short for any meaningful production.

While the taro may be planted directly in the field, the practice of pre-sprouting the suckers in nursery beds is also quite common. The crop is planted out in the field early in the spring. Rice straw and plastic mulches may be used to warm the soil early in the season and to control weeds. Fertilizers are frequently used.

Taro and petioles are harvested from the field as needed, for use as vegetables. The corm and cormel are harvested before any frost occurs on the field. Most of the corm and cormels are utilized fresh, since there is very little processing of taro into dried forms. Only occasionally, the taro may be made into chips, or incorporated into ice cream.

Taro is likely to continue as a minor crop in China, used mainly as a vegetable. It will remain insignificant in the face of rice as the dominant staple.

7. THE FUTURE OF TARO

7.1 Present Constraints in Taro Production
7.2 Research Priorities
7.3 Future Perspectives

7.1 Present Constraints in Taro Production

From the foregoing presentation, it is clear that there are several constraints that limit the scope of present-day taro cultivation and production. The major ones, especially as they apply to the Asia/Pacific region are as follows:

i) *The Taro Leaf Blight Disease*: This disease automatically precludes the development of a taro export trade in many countries, and in some cases threatens the internal food supply. Research must continue in order to develop resistant cultivars, or to identify effective control measures.

ii) *The Taro Beetle*: At present, this is the most serious pest of taro in the region. There is no effective control measure at present, and it may yet take several years before the biological control measures being developed can be tested and disseminated to farmers.

iii) *Laboriousness of the Production System*: Taro production at present is very labour intensive. Even in high-technology production systems, such as in Hawaii, there is still a great deal of manual labour required, especially for harvesting. In the rest of the region, the labour required is even greater, coupled with even lower yields.

iv) *Scarcity of Planting Material*: Like most of the other tropical root crops, the planting material for taro is bulky, making it expensive to transport over long distances. It is also perishable, and cannot be stored over a long time. The net effect of these two factors is that the availability of planting material is frequently a limiting factor in taro production. This is particularly so in countries like Tonga where droughts every few years have the effect of reducing the available planting material for several years afterwards. With planting material being so scarce, it is not surprising that some farmers use whatever planting material they can get. All the preaching by extension agents about discriminating against disease-carrying or low-yielding cultivars is only partially heeded.

v) *Post Harvest Handling and Marketing*: At present, the bulk of taro produced is handled and marketed as the fresh corm. The corm itself has a high water content, and cannot be stored for more than a few days at ambient temperatures. Post harvest losses are therefore heavy, and transportation costs are high. The development and use of processed forms is a partial solution. Frozen taro, Poi, and taro chips are examples. However, for a commodity that has so much cultural and sentimental baggage attached to it, there is likely to be rejection of forms that do not retain the traditional patterns of culinary preparation, presentation and consumption. Marketing channels also need to be improved, as an incentive for farmers to produce taro for cash.

vi) *Limited Taro Research and Extension*: The amount of research currently being done on taro is very little especially in countries where it performs mainly a subsistence function. A similar neglect of the crop is found in the extension services, so that the technical knowledge base of the producers is very low. Given the smallness of the national economies particularly in Oceania, there is a challenge for cross-national bodies to spear-head and sustain research into the problems of taro. They can also take steps to strengthen the extension services.

7.2 Research Priorities

Most of the above constraints in the taro production system can be effectively tackled and possibly solved through research. The major research priorities at present are:

i) *Control of the Taro Leaf Blight*

It is amazing how very little research is being done on this problem at present. The most promising effort so far is the breeding and selection work going on at Bubia, Papua New Guinea. Yet even this work is very seriously hampered by lack of equipment and personnel (especially since the senior breeder left in 1996). The technological breakthrough which gives promise for this work is that taro flowering can now be induced reliably by use of gibberellin, as already discussed in the section on taro botany. With this method, thousands of new genotypes have been produced, and there is hope that through recurrent selection, good quality resistant cultivars can be identified, tested, and distributed.

ii) *Taro Beetle Control*

The most active research on this problem is taking place in the Solomon Islands and Papua New Guinea. The project is supported by the European Union under the Pacific Regional Agricultural Programme. The search for chemical and cultural control methods having proved unsatisfactory, attention has now turned to biological control. Good progress has been made since the mid-1990's. However, the future of the project is now (1998) uncertain, since the external funding support may be withdrawn. This would be quite unfortunate because the taro beetle remains a very serious problem in the region and there is yet no satisfactory control measure. Again the breeding programme is on the lookout for lines that may show tolerance to the taro beetle, although given the versatility of the beetle in terms of host range, the prospects might be less bright than expected.

iii) *Taro Germplasm Conservation.*

Within the region, there is a very large pool of taro germplasm (on farmers' fields, in research stations, and in the wild). Many of these genotypes are being lost daily for various reasons. There is a need to conserve and characterise the taro in the region. Such a collection would not only insure against further genetic erosion of the germplasm, but would serve as a source of desired genotypes for various countries in the region. The foundations for such germplasm conservation have been laid at the Papua New Guinea University of Technology and other locations where protocols for taro tissue culture have been developed. Hopefully, this will permit *in vitro* maintenance of the germplasm to complement accessions that are maintained in the field.

A factor related to taro germplasm conservation is the need to broaden the genetic base of the taro industry in various countries. The destabilising effects of a narrow genetic base have already been mentioned with respect to taro cultivation in Samoa. With effective conservation and characterisation of the region's germplasm, countries seeking to broaden their taro genetic base will have a source for desirable new genotypes.

Quite recently (1998), a project called the Taro Network for South-east Asia and Oceania (TANSAO) has been launched. It is supported by the European Union, and aims to assemble and characterize the taro gene-pool in the region, as well as determine the genetic diversity of *Phytophthora colocasiae* which causes the taro leaf blight. However, only six countries are directly involved (Thailand, Philippines, Vietnam, Papua New Guinea, Malaysia and Indonesia); and the work is strictly concerned with plant genetic resources. It is hoped that the more taro-dependent countries of Oceania may derive some down-stream benefits from the project. One of such benefits might be the ultimate broadening of the genetic base of the taro crop in each country, using the core sample of cultivars generated by the project as a starting point. Broadening of the taro genetic base is particularly needed in Oceania.

iv) *Improved Production Practices*

There is still a lot of taro production that relies on age-old, traditional production methods. Research into various agronomic practices is needed in order to improve productivity. In particular, simple methods for rapid generation and multiplication of planting material need to be explored. More effective low-technology methods of multiplying planting material need to be devised. At the other end of the technological spectrum, it may be possible, for example, for tissue culture to be explored as a method for routine commercial production of planting materials. Also, as new cultivars are produced and released, there is need to establish, through research, the best agronomic practices with respect to spacing, water requirements, weed control, fertilizer, maturity, etc.

v) *Post-harvest Handling and Utilization*

The aim here should be to find ways to minimise post-harvest losses. New culinary forms of preparing and presenting taro should be explored, as well as development of storable processed forms.

All the above research priorities need to be addressed in order to sustain the taro industry in the Asia/Pacific region. Research is expensive and money is scarce; most of the countries are not likely to support taro research without much inducement. One type of inducement is for the authorities to understand the importance of taro both in food security and in the cash economy. This will lead them to establish the appropriate policy framework within which taro production and promotion can occur. Also, the more taro can be placed on a cash crop footing, the easier it will be to acquire the resources to support research into the crop.

7.3 Future Perspectives

Taro is an ecologically unique crop. It is able to grow in ecological conditions which other crops may find difficult or adverse. There are at least three such situations:

a) Waterlogged and hydromorphic soils.

b) Saline Soils: Some taro cultivars can tolerate salinity, and can grow in 25-50% sea water. Such saline conditions would prove lethal to most other crops.

c) Shady conditions: Taro has long been known to be shade tolerant. Onwueme and Johnston (1998) have recently shown that part of the physiological basis for shade tolerance in taro is the ability to maintain a reasonably high stomatal density even under shade. Shade tolerance in taro enables it to grow well as an intercrop between tree crops (e.g. coconuts), because it can profitably exploit the diffuse light reaching the plantation floor.

Because the above ecological conditions are difficult for other crops, there is less likely to be competition with taro in exploiting them. So, the place of taro in these ecological conditions is reasonably assured. This is in addition to its cultivation in normal field situations.

In the root crop cultures of Oceania, there is a great sentimental attachment to taro. This attachment will continue to propel and fuel taro cultivation far into the future. It will also continue to ensure a vibrant internal and external market for taro.

Even the rice cultures of south-east Asia have well appreciated that the field production system for taro is very similar to that of rice. Land that has been prepared for flooded rice is equally suitable for flooded taro. Thus, taro fits well as an alternative crop in the rice-based cropping systems.

The problems that beset taro production in the Asia/Pacific region are numerous, and have been discussed above. However, given adequate research effort and the appropriate policy framework, most of the problems can be easily surmounted. Taro can then continue to perform its age-old functions of providing food security, boosting the economy through internal and external cash earnings, and playing a critical role in the socio-cultural life of the people.

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