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# TARO CULTIVATION IN ASIA AND THE PACIFIC

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Prof. Inno Onwueme  
*Agriculture Department,  
University of Technology,  
Lae, Papua New Guinea*

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS  
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## **FOREWORD**

Taro, *Colocasia esculenta* (L.) Schott, occupies a significant place in the agriculture of the Asia-Pacific Region. It is in this region, more than any other in the world, that the crop attains its greatest importance as a staple food. In Oceania particularly, taro plays a critical role in household, community and national food security. Since both corms and leaves are usually consumed, taro supplies much-needed protein, vitamins and minerals, in addition to carbohydrate energy.

The socio-cultural importance of taro in the region is very high. The crop has evolved to be an integral part of the culture, and features prominently in festivals, social gift-giving and the discharge of social obligations. More recently, taro has become a source of income for individuals, and an earner of foreign exchange. Its role in rural development has therefore been increasing, especially with respect to the provision of employment and the alleviation of rural poverty.

Given the importance of taro, activities need to be geared toward its research, development, and available literature. This book is, therefore, a valuable and timely effort to fill some of the information gaps with respect to taro in the Asia-Pacific Region. Apart from a general coverage of the region, it delves into a country-by-country treatment of taro cultivation in 19 of the most important taro-growing countries in the region. The publication will be a useful reference source for researchers, extension workers, growers and entrepreneurs who are interested in taro. The presentation has placed emphasis on clarity and simplicity to permit easy understanding even by persons for whom English is a second language. I recommend this book to all users, and I am fully confident that it will prove valuable as an information resource.

Prem Nath  
Assistant Director-General  
and FAO Regional Representative  
for Asia and the Pacific

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# 1. INTRODUCTION: IMPORTANCE OF TARO

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**

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

	<b>Taro/Tannia</b>	<b>All Tubers</b>
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

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 to 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 worldwide. 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 acidity 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 21°C 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 flowering 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

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 grown 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 Prometryne 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**

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 as 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 *Vavraia*. 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.