The Impact of Taro Leaf Blight in the Pacific Islands
with special reference to Samoa

Danny Hunter\(^1\), Kirifi Pouono\(^2\) and Semisi Semisi\(^2\)

Introduction

The farmers fight against plant disease is a constant battle. It is a fight that has been going on since the beginning of agriculture. Writings in ancient texts describing plant disease epidemics and the resultant suffering and struggles testify to this. Plant disease epidemics have influenced the course of history in countries where they have had a devastating effect and continue to be of great importance especially for those people whose day to day survival depends on their crops. Often they are the difference between life and death. There are examples where plant diseases have resulted in hundreds of thousands of deaths due to the destruction of staple food crops and consequent starvation. This type of impact and suffering is no doubt the most serious impact of plant disease.

Plant diseases impact on us in many other ways. They can result in severe loss of income to the farmer. Worldwide it is believed that crop diseases reduce agricultural productivity by more than 10% which is the equivalent of 500 million tonnes of food per year (Anon, 1998). Not only does the farmer have to cope with reduced levels of production he or she is also faced with the additional costs involved in trying to control the problem. Reduced production levels of diseased crops means increased product prices for consumers. Losses in terms of exports and foreign earnings can be devastating. If attempts at control involve excessive use of pesticides there may be hidden environmental and health costs. Plant diseases can also reduce the level of biodiversity or limit the variety of plants grown in an area. Paradoxically, severe disease epidemics can contribute to the diversity of crops that are grown by farmers as they turn away from monocropping of the affected crop to explore alternative crops.

The devastating impact of plant disease on human affairs is vividly illustrated by the effect of late blight (Phytophthora infestans) of potato in Ireland from 1845-46. At that time the potato plant was the staple food of hundreds of thousands of people. As a result of the blight there was mass starvation and death although other socio-economic factors were also involved. There was a major exodus from the country as

\(^1\) School of Agriculture, The University of the South Pacific, Alafua Campus, Apia, Samoa
\(^2\) Ministry of agriculture, Forestry, Fisheries and Meteorology, Apia, Samoa
desperate people sought refuge in more ‘prosperous’ lands. The lingering impact of the potato famine in Ireland continues to this day and is deeply etched on the psyche of the people of that country. Interestingly, late blight of potato is once again becoming prevalent in some countries. Other plant disease epidemics have been equally severe, such as the Bengal famine of 1942-43 that resulted from Cochliobolus brown spot of rice and which killed a million people.

The impact of a plant disease epidemic on a national economy was vividly illustrated by the arrival of the coffee rust fungus (Hemileia vastatrix) in Sri Lanka (then Ceylon) in 1875. At that time there were around 160,000 hectares of coffee planted and 45 million kilograms exported yearly. Within 20 years production of coffee had virtually ceased and had fallen to 2 million kilograms (Schumann, 1993). The impact of the South American leaf blight (Microcyclus ulei) on rubber in Latin America is a similar scenario. Epidemics of southern corn leaf blight, wheat rust and grape downy mildew have also caused serious widespread economic losses.

Plant diseases like chestnut blight and Dutch elm disease can limit the geographical distribution of some plants and have threatened to eliminate certain plants species from entire continents (Agrios, 1969).

Plant diseases continue to pose a serious threat to food security and national economies worldwide. In the Pacific region the impact of taro leaf blight and the threat it poses to countries not yet affected by the disease illustrate this point clearly. The taro leaf blight fungus (Phytophthora colocasiae) arrived in Samoa in 1993 and immediately had a devastating effect on the country. Taro (Colocasia esculenta) was the principal staple crop at the time and of economic, cultural and ceremonial importance. It was the major export commodity and income earner for many farmers. The impact of this disease in Samoa and elsewhere in the Pacific will be examined in this paper. The influence of taro leaf blight in Samoa continues to this day but the resilience of the country’s agricultural system has ensured that food security has not been seriously affected. However, there have been significant impacts in other areas. There are various initiatives and strategies now in place that should ensure the taro industry in Samoa can slowly recover. These will be examined and discussed. Taro leaf blight continues to pose a major threat to other taro growing countries of the region and they should take note of the lessons that have been learnt in Samoa. Strategies to cope with the possible introduction of the disease are discussed in concluding.
Taro leaf blight and the causal pathogen *P. colocasiae*

Raciborski (1900) was the first person to study the leaf blight disease of taro in Java and was also responsible for naming the causal pathogen. There is limited information on the origin of *P. colocasiae* and the magnitude of the area of origin remains to be delineated (Zhang et al., 1994). Ko (1979) has indicated that Asia may be the centre of origin of *P. colocasiae* given that it is the world’s centre of origin for many wild and cultivated varieties of taro. Prior to this, Trujillo (1967) had also speculated on a south-east Asian origin for the pathogen. One of the indications of the centre of origin of a fungus such as *Phytophthora* is the existence of an A1/A2 mating type ratio of about 1:1 (Zentmyer, 1988). In order to determine if Taiwan was inside the centre of origin Ann et al. (1986) screened 799 isolates of *P. colocasiae*. All behaved as A2 mating types, indicating that the fungus is not indigenous to this area. Interestingly, in Hawaii 114 isolates of *P. colocasiae* examined were found to be A1 mating type (Ko, 1979). This indicates that Hawaii is not the centre of origin for the pathogen. Only A1 mating type has been found in India indicating that it is not the centre of origin (Narula and Mehrotra, 1980). Evidence for an Asian origin of *P. colocasiae* has recently come from China (Zhang et al., 1994), where previous reports had indicated that only the A2 mating type occurred (Ho et al., 1983). Of 280 isolates of *P. colocasiae* obtained from Hainan Island 136 were A1, 102 A2 and 42 A0 mating types. Such findings indicate that Hainan Island is inside the centre of origin of *P. colocasiae*. Only the A2 mating type has been reported in Papua New Guinea (Arentz, 1986).

Based on a possible south-east Asian origin for the pathogen Trujillo (1967) postulated that the disease dispersed into the Pacific region by 3 different routes (Figure 1) (cited by Putter, 1976). To Hawaii via the Philippines or Taiwan, to Micronesia via the Philippines and to Fiji via Papua New Guinea (PNG) and the Solomon Islands. At this time taro leaf blight had been reported as present in Fiji but this now appears to have been a misidentification. The movement of taro leaf blight via PNG and the Solomon Islands would appear to be a separate route and is supported by anecdotal evidence from inhabitants of these countries expressing that the disease only appeared after the Western Pacific Campaign of World War II (Oliver, 1973).

Ooka (1990) speculates that movement on the northern route went from Java to Taiwan, where Sawada reported the disease in 1911. From Taiwan it is believed to have moved to Japan and then to Hawaii
where it arrived in 1920 (Carpenter, 1920). However, the existence of two different mating types in Hawaii and Taiwan may require further examination of this proposed route for the movement of the pathogen to Hawaii. The disease was first recorded in the Philippines in 1916 and movement to Micronesia probably occurred from there. The disease was recorded in Guam in 1918 (Weston, 1918). There have been no studies on the distribution of mating types in the Samoas that could indicate the likely sources of the pathogen although it is widely speculated that the pathogen arrived from Hawaii on taro planting material.

To date, taro leaf blight has been recorded in a number of countries in the Pacific region, most recently in Samoa in 1993. The disease is mainly a foliar pathogen although postharvest storage rots also occur. Initial symptoms of the disease are small brown water-soaked flecks on the leaf which enlarge to form dark brown lesions, often with a yellow margin. Secondary infections lead to rapid destruction of the leaf which may occur in 10-20 days or less in very susceptible varieties. The normal longevity of a healthy leaf is about 40 days. The disease significantly reduces the number of functional leaves and can lead to yield reductions of the magnitude of 50% (Trujillo and Aragaki, 1964; Trujillo, 1967; Jackson, 1977). Inoculum in the form of spores is spread by wind-driven rain and dew to adjacent plants and nearby plantations. The disease can also be spread on taro planting material and the fungus has been reported as remaining alive on planting tops for about 3 weeks after harvest (Jackson, 1977). This is the most likely source of the disease in new countries and the means for its rapid spread within a country once established. Therefore, strict quarantine measures are required as a first line of defense against the disease.

In addition to corm yield losses that arise as a result of the reduced leaf area in diseased plants there is also a corm rot caused by *P. colocasiae*. This is mainly a problem when taro corms are stored for longer than 7 days but not in subsistence economies where corms are harvested and consumed within days.

Fortunately, *P. colocasiae* does not have a wide host range. *Xanthosoma* taro is immune. Although *Alocasia* taro can be infected by the pathogen the ability of the disease to become epidemic on this host is hindered by reduced inoculum levels on disease lesions (personal observation).
Impact of taro leaf blight in the Pacific Islands

Taro is an edible aroid which occurs wild in south-east Asia. Taro is grown as a staple or subsistence crop throughout the humid tropics but is of greatest importance in the Pacific Islands where it accounts for about 20% of the root crop area. Throughout the region there are many ways in which the plant is utilised. In Samoa the corms are baked, roasted or boiled and the leaves are eaten as Palusami. Taro is believed to have originated in the Indo-Malayan region and spread eastwards into the Pacific reaching the Polynesian islands about 2,000 years ago. However, there is now evidence to suggest that most cultivars found throughout the Pacific were not brought by the first settlers from the Indo-Malayan region but were domesticated from wild sources existing in the Melanesian region (Lebot, 1992). There are now thought to be approximately 2,000 taro varieties found in the Pacific region (Putter, 1993; Hunter et al., 1998).

Prior to the arrival of taro leaf blight, farmers in the Pacific would have selected taro varieties for a number of traits but not resistance to the disease. In the absence of this selection pressure taro varieties have reduced levels of resistance. At the turn of the century when the pathogen began to spread into the region it encountered a host plant that was genetically vulnerable. This is the scenario that has been played out recently in Samoa.

There has been little documentation of the impact of taro leaf blight as it has spread from country to country in the Pacific. What has been documented covers mainly Papua New Guinea. What is known is that wherever it has occurred in the region many growers have been forced to abandon taro and rely on other root crops (Jackson, 1993).

The earliest records for the appearance of the disease in the Pacific Islands are for Guam (1918) and Hawaii (1920) which precede the appearance of the disease in the more southern Solomon Islands and Papua New Guinea by a couple of decades. Prior to the arrival of taro leaf blight in Hawaii there were approximately 350 different varieties of taro in the country. Few have survived the disease and today the number of Hawaiian taros is less than 40 (Trujillo, 1993). In Guam, where the disease has been present for a longer period than Hawaii, the disease is considered unimportant today (Wall, 1993). Recent interviews among farmers in Guam have highlighted that there may be as many as 23 varieties of taro on Guam but most are recent introductions with only 6 predating the arrival of taro leaf blight (Manner,
1991). The relatively few traditional taro varieties is believed to be a consequence of the disease (Wall, 1993).

In Micronesia the disease seems to have been brought in during the Japanese occupation of Truk and Pohnpei and taro cultivation appears to be declining rapidly. Taro leaf blight has contributed to significant changes in dietary patterns and cropping systems in Micronesia where earlier this century cassava became the staple instead of taro (Barrau, 1961; Jackson 1993). In Pohnpei, the majority of the taro varieties that existed before the arrival of the Japanese are gone (Trujillo, 1993) and leaf blight has been responsible for the serious decline in taro as a crop plant (Santos, 1993; Raynor and Silbanus, 1993). On Pohnpei taro now ranks behind yams, banana, imported rice and breadfruit as a staple crop (Primo, 1993; Raynor and Silbanus, 1993). Despite heavy rainfall and the long time presence of leaf blight in Pohnpei farmers are still managing to produce taro. Wall (1993) reports that this is a result of the disease having selected more resistant taro varieties and the incorporation of sanitation and traditional mixed cropping systems for the management of the disease.

Taro leaf blight is believed to have contributed to the decline in taro production and its displacement in some areas by sweet potato in Papua New Guinea. It is thought that the disease spread to Papua New Guinea from south-east Asia through Indonesia during the Second World War (Kokoa, 1993). In Bougainville, P. colocasiae was first reported around the close of the war (Connell, 1978). It was the firm belief of the local population that the disease was not present before then. The impact of the disease in some areas was devastating and throughout lowland Bougainville taro was almost wiped out. It has been reported that the epidemic of taro leaf blight on Bougainville resulted in the deaths of about 3,000 people (Putter, 1993) and in most areas sweet potato replaced taro as the main staple. The real impact of the blight is difficult to accurately assess. At the time of the appearance of the disease the Japanese were pillaging many of the local taro gardens. As a result there was a serious lack of planting materials. Many people fled their villages and numerous cases of starvation and malnutrition occurred. It is difficult to distinguish the impact of the disease, if any, from these events. It is possible that the impact of the disease was delayed for a few years following the occupation. At the close of the war people returned to village life. As the Japanese had taken most of the planting material people turned to many of the early maturing sweet potato varieties that existed in the now disbanded Japanese gardens to fill the interim. Later, when taro planting material did become available again it was wiped out by the blight providing yet another set
back for farmers. Unfortunately, the coincidence of the spread of taro leaf blight in Bougainville with WW II makes it difficult to attribute any given change solely to the effects of leaf blight (Packard, 1975).

The disease continues to spread in Papua New Guinea and in 1976 a severe epidemic occurred on the island of Manus and in 1988 the disease occurred in Milne Bay for the first time, destroying the crop (Jackson, 1993).

In the Solomon Islands it is also difficult to focus on the impact that taro leaf blight had on taro production and cropping patterns in the country. Taro leaf blight first appeared in the Shortland Islands in 1946 (Liloqula et al., 1993) and within the next few years had spread to most of the provinces as a result of the increased movement of people and produce in the post war years. What is known is that taro cultivation declined quite drastically in the Solomon Islands at this time being replaced by sweet potato, which was a later arrival in the country. Whether the introduction of sweet potato alone or combined with the effects of taro leaf blight are the reasons for the decline in taro are difficult to ascertain.

**Impact of taro leaf blight in Samoa**

*Introduction and spread of taro leaf blight*

Taro leaf blight was first detected in the Western District highlands of Tutuila Island, American Samoa on 15 June 1993. The disease has severely constrained taro production in the country (Gurr, 1993). Within a year of the introduction of the disease it had caused over 95% reduction in the supply of taro to the public market in that country. In less than one month taro leaf blight was diagnosed and confirmed in Samoa. It was first observed on the the island of Upolu at Aufaga Aleipata and two days later from Saanapu and adjacent districts of Alafou, Samusu, Utufaalalafa, Malaela, Lepa and Aufaga The disease spread rapidly throughout the country badly affecting all local varieties but was most severe on taro variety *Niue* which was unfortunate as this was the variety of choice for commercial production because of its quality and taste.

It is believed that the rapid spread of the disease was encouraged by the movement of infected planting materials around the two main islands, Upolu and Savai’i. At this time there was a major replanting of
taro underway in the aftermath of Cyclone Val and anything up to 10,000 plants could be planted by a single farmer in a one week period (Semisi, 1993). Various factors contributed to the rapid spread of the disease in Samoa. The area planted to taro *Niue* at the time was extremely large and effectively ensured a monocrop situation comprising a highly susceptible variety. There was a continuous and abundant source of taro for the disease because of the practice of many farmers to interplant on old plantations and stagger their cultivation. Combined with the movement of planting material and the ideal weather conditions that exist in Samoa for the disease it is not surprising that the disease reached epidemic proportions.

Taro in Samoa is the traditionally favoured root crop and was considered an essential component of an everyday meal. This popularity is based on dietary and cultural factors but it is also favoured for its considerable productivity in the fertile and high rainfall environment of Samoa (Ward and Ashcroft, 1998). Average yields of 16 tonnes per hectare have been achieved but higher yields up to 25 tonnes per hectare could be obtained on newly cleared forest land (Anon, 1985). At the time of the disease outbreak taro was the major export earner in the country. On top of these factors the returns per work-day from taro were high compared to other crops grown in Samoa due to lower labour requirements. In 1983 the returns from taro were three times higher than from bananas and eight times higher than from coconuts (Anon, 1985). Prior to the arrival of blight over 90% of households in Samoa were growing the crop (Ward and Ashcroft, 1998).

There are few people in the region unaware of the importance of taro to Samoans and their culture. Its significance is eloquently expressed in the following quotation;

*taro is part of our heritage and a binding force for our tradition. We are Samoans, people from the sun, and throughout our ancestral migration, taro has played a vital role. Its uniqueness is reflected in its value for our ritualism, respect and sharing, and its use as one of the major components of our traditional penalty system (Semisi, 1993).*

Taro is a crop with high prestige and significance in the Samoan cultural context with great importance as a presentation on formal occasions. Given its cultural, dietary and economic importance taro was the most important plant in the country. With the arrival of taro leaf blight a disastrous plot was waiting to unfold.
Impact on cropping patterns and taro varieties grown

In Samoa, agriculture is characteristically mixed cropping. Coconuts, cocoa and breadfruit are the important tree crops while *Colocasia* taro and *taamu* (*Alocasia macrorhiza*) have been the main root crops. *Colocasia* was the most important root crop and also provided leaves, an important vegetable component of the diet. The other major crop in Samoa is bananas. Prior to taro leaf blight these were the main commercial crops (Table 1). Less important crops at this time included yams, kava, cassava, sweet potato and leafy vegetables which between them only accounted for 3% of the total cropped area (Ward and Ashcroft, 1998).

By the time of the taro leaf blight outbreak taro dominated the cropping system in Samoa because of the devastation caused to other major crops by cyclones. Crops like *taamu* and yams were grown as reserve foods and breadfruit was consumed when it was in season. Although cassava was grown extensively it was utilised mainly as a livestock feed (Chan, 1994). Sweet potato was largely disliked because of its taste.

One of the first responses of the Samoan Government to the disease was to encourage diversification into other crops and they helped to explore alternative commercial agricultural enterprises (Semisi, 1993; Jackson, 1996). The government also provided assistance through the supply and distribution of planting material. Farmers quickly diversified into a range of other staple crops. Banana production increased significantly as did other root crops such as *taamu*. Yams also increased in importance as well as breadfruit (Jackson, 1996).

There are few figures to support changes in cropping patterns after the outbreak of taro leaf blight but anecdotal evidence tends to indicate that *taamu* and bananas largely replaced the area planted to taro (Chan, 1994) with additional significant areas planted to yams and cassava. By 1995, areas close to villages, which had been relatively unproductive in pre-blight years, had been converted to well managed mixed gardens producing a variety of food and tree crops. Most gardens contained several varieties of banana and breadfruit, two varieties of *taamu*, yams, cassava and other minor crops. Cocoa and coconut were often intercropped within these mixed gardens (Paulson and Rogers, 1997).
Figure 2 illustrates that both *taamu* and banana have replaced taro as the main staple food of Samoans. One other significant change in the aftermath of the outbreak of taro leaf blight in Samoa was the increase in the importance of *Xanthosoma sagittifolium* which has now become commonplace in the Apia market. Given the dislike in Samoa for root crops such as sweet potato and cassava, it is quite fortunate that *X. sagittifolium* is immune to the disease. *Taamu* is infected by *P. colocasiae* but does not suffer from epidemics of the disease for the reason previously outlined.

To date, there has been no study on the impact of leaf blight on the diversity of traditional taro varieties in Samoa. Like a number of other countries in the Pacific the traditional taro varieties in Samoa were highly susceptible to the disease. This situation in other countries of the region resulted in a significant reduction in local varieties. Some farmers still retain planting materials of variety *Niue* and it is likely that other local Samoan varieties have been established in tissue culture.

*Impact of taro leaf blight on the Samoan economy*

The introduction of taro leaf blight into Samoa had an immediate and dramatic impact on the production of the crop. It was estimated that the disease caused a drastic reduction in the availability of the crop by destroying 95% of taro plantations on the islands of Upolu and Savai’i (Pouono *et al.*, 1994). Yields of taro dropped to 2-4 tonnes following the introduction of the disease (Saena Tuia, 1997).

In the twelve month period prior to the outbreak of taro leaf blight 180,191 kg of taro were brought for sale at the local market. During the next twelve month period subsequent to the outbreak of the disease 59,212 kg were brought in for sale. Seventy five percent of this volume was brought in during the first 3 months of the twelve month period when the impact of the disease was still to be realised (Chan, 1994). However, Paulson and Rogers (1997) report that supplies of taro on the local market in June 1994 were only 1% of the supplies that were available in June the previous year.

The reduction in the amount of taro that was supplied to the local market in Apia in the aftermath of the disease is clearly shown in Figure 2. By April 1994 supply to the local market of taro had virtually ceased, declining from a peak of about 23,000 kg supplied in July 1993, which ironically was the month the disease was first diagnosed in the country. The small amount of taro that was being produced at this time was by a few commercial growers who could afford the cost of fungicides and labour for leaf
removal. During this time the supply of other crops such as banana and *taamu* to the local market began to increase.

Prior to the outbreak of leaf blight taro had assumed a position of major importance as an export crop since cocoa and coconut had been badly affected by Cyclones Val and Ofa in 1990 and 1991. By 1990 taro was the dominant export crop in the country (Table 2). Damage caused to food crops and export crops as a result of Ofa and Val were massive (Ward and Ashcroft, 1998). Banana, breadfruit, cocoa and coconut production were severely disrupted. The total cost of damage to the country from Cyclone Val alone was estimated at around US$368 million (Crawley, 1992). The resilience of taro in the face on natural disasters is illustrated by the fact that within one year of both hurricanes taro export levels and prices had recovered to pre-cyclone levels (Paulson and Rogers, 1997).

Despite the outbreak of the disease in 1993 taro exports for the year still totalled about WS$10 million (Table 2). This represented 58% of the country’s total exports, compared to 15% in 1982 and 21% in 1989. The first 3 months of 1994 saw only 60,000 kg of taro exported which was valued at about WS$56,000 (Chan, 1994). This represents about 0.5% of the 1993 export figure. The cost to the country and farmers in terms of lost revenue was substantial and by 1994 and 1995 the export value of taro had fallen to US$59,250 and US$60,750 respectively (Central Bank Bulletin, 1996).

Recent figures from the Central Bank of Samoa indicate that there is the beginning of a slight recovery in the amount of taro being supplied to the local market. Figures for December 1998 show that taro supply had tripled compared to the same period the previous year (Figure 3). Despite these encouraging figures the supply for December 1998 is below 7% of that for the peak supply month in the pre-blight period.

Despite the higher production costs involved for taro in post-blight years, the higher prices that consumers, locally and overseas, are willingly to pay, means that growing taro became more profitable than ever. The willingness to pay high prices for taro when other staples are readily available more cheaply indicates a strong preference for the crop (Chan, 1994). The price of taro at the Apia market continued to rise after the outbreak of taro leaf blight. Prior to the disease outbreak the price per kg of taro was about WS$0.79 (Chan, 1994; Paulson and Rogers, 1997). The observation that farmers at present seem more willing to meet household needs before supplying taro to local markets when prices
are high is another indicator of the strong preference for taro and also means that supply figures to the local market underestimates the actual amount of taro currently produced (Iosefa and Rogers, 1999).

The figures given above from the Central Bank of Samoa indicating an increasing trend in the amount of taro supplied to local markets in Samoa has contributed to a fall of 34% in the price of taro over the one year period since December 1997 (Figure 3).

**Impact on land use patterns**

Three zones of agricultural land use have been recognised in Samoa (Ward and Ashcroft, 1998);

- A coastal zone with an almost continuous canopy of coconut palms. This zone extends inland to varying degrees and frequently supported patches of root crops, cocoa or bananas.

- Inland of the coconut zone was the mixed cropping zone which was dominated by bananas with plantings of cocoa and root crops.

- The third zone which was inland of the mixed cropping zone was the major area, prior to the arrival of taro leaf blight, for taro planting. Plantings of taro were made in newly cleared forest areas with a high content of organic matter. As the economic importance of taro continued to grow the forest edge was continuously pushed further back.

Earlier this century the German and New Zealand administrations encouraged Samoan landholders to undertake commercial agricultural production. As a result there was an expansion of the area under crops such as coconuts, cocoa and bananas (Ward and Ashcroft, 1998). Landholders planted these commercial crops close to village areas already cleared while the traditional taro gardens were planted in newly cleared areas in the forest. After one or two harvests taro was replanted in new clearings and coconuts, cocoa or bananas planted on the old taro forest clearings. This intensification combined with rising population and a greater accessibility to land through new roads pushed the forest edge further inland on customary village land. This was a trend that was to continue in the 1950s with the expansion in cocoa production and the export boom in bananas (Ward and Ashcroft, 1998). Even the downturn in bananas, coconut and cocoa did not halt the rate of expansion.
During the 1970s taro emerged as a major export crop to the growing number of Pacific Islanders living overseas in New Zealand, Australia and the United States. Planting taro for this export market continued to contribute to the rate of forest clearing in Samoa (Paulson, 1994). By 1993 taro had become the dominant export crop with 58% of the total exports. During the 1980s the export of taro continued to rise and many growers planted large areas of taro specifically for export especially in the villages of Aleipata district and Savai’i where there was still access to large areas of uncleared forest land. Consequently, the majority of taro gardens were located inland from the villages and along the forest margins (Ward and Ashcroft, 1998). No one knows exactly the area of taro that was planted by 1993 but essentially farmers were growing taro as a plantation monocrop and a very susceptible one at that. Niue was the favoured taro variety for export and also the local market. Essentially the entire area was planted with this variety.

Land use surveys in certain villages prior to the blight demonstrated that cropping areas near the villages consisted mostly of unproductive tree crops with minimal management although some farmers did have productive mixed gardens in this zone. Most agricultural activity was located in a distant and expanding zone of taro and grassland fallow. Two years after the outbreak of taro leaf blight this zone had been mostly abandoned and most agricultural endeavours had been redirected back to the areas nearest the villages (Paulson and Rogers, 1997).

The collapse of the export taro trade as a result of the arrival of leaf blight has led to some former taro land being abandoned or left to regenerate while other areas have been given over to other crops and cattle pasture (Ward and Ashcroft, 1998). One land use pattern change that has occurred as a consequence of the disease is that farmers who continue to plant taro have gardens close to their villages or houses and in small areas that could be cared for with the help of the family (Ward and Ashcroft, 1998). With the arrival of taro leaf blight there is now a greater need for labour in taro cultivation. This is required for scouting the crop, removal of disease infected leaves and spraying fungicides.

Impact on food and subsistence needs

The traditional diet of Samoa is based primarily on staple foods (meaai aano) consisting of root crops (taro, giant taro, yams) and starchy fruit crops (green banana and breadfruit) (Adams and Sio, 1997). This was supplemented with protein supplied from fish, shellfish and other foods from the sea plus chicken and pork. Taro is one of the richest, most productive and biologically efficient producers of food energy
available (Williams, 1980). While low in protein, taro does provide useful quantities of minerals and vitamins. Prior to the outbreak of taro leaf blight, local consumption of taro was estimated at 0.5 kg per person per day in Samoa, the equivalent of 183 kg per person per year (Chan, 1994).

In addition, the leaves of taro were eaten as an accompaniment to the corms and provided further supplement to the diet as they are nutritionally rich in protein, minerals, and vitamins. Taro leaves eaten as *palusami*, rolled up leaves cooked in coconut cream, are the traditional vegetable in the diet.

In 1991, taro was responsible for supplying about 20% of the overall carbohydrate intake in urban and rural areas of Samoa. This represented about 12% of the total caloric intake. At that time, imported rice contributed about 5% in urban areas and about 3% in rural areas (Galanis and Chin-Hong, 1993; Galanis *et al.*, 1995). This estimate of taro intake, however, may have been underestimated as Hanna *et al.* (1986) estimated the caloric contribution of taro in the diets of Samoans at around 39%.

Although there have been various changes to the traditional Samoan diet in recent years, such as increases in the consumption of imported rice and flour, there is little evidence to suggest that this is directly a result of changes brought about by the devastation of the taro crop. There are other factors such as urbanization, cyclones, and improved rural infrastructure that have contributed largely to this problem. Despite the dramatic decrease in the availability and supply of taro as a result of leaf blight, rural households were producing enough food to meet their immediate household needs from now productive village-based mixed gardens, in fact marketable surpluses of many of these crops ensured low prices (Paulson and Rogers, 1997). By June 1995, most households had sufficient food crops planted to meet subsistence needs. The diversity of staples, especially root crops, in the traditional Samoan diet and the flexibility of the agricultural system has ensured food security and subsistence needs were met in the post-blight years. Traditional crops like banana, root crops, breadfruit, and coconut are intercropped, serve as cash and food crops, have flexible harvest times and can be grown easily without depending on external inputs thus providing a certain resilience against the negative impacts of a disease such as taro leaf blight (Paulson and Rogers, 1997). As well as meeting immediate food needs, there is ample evidence to indicate that most households were meeting their subsistence needs as there was little disruption to social life in the village. Activities that required outlays of cash or household resources continued as before the blight (Paulson and Rogers, 1997).
One major impact the leaf blight may have had on food and health is the reduction in availability of taro leaves for *palusami*. Unfortunately, Samoans are not known for their consumption of fruits and vegetables. Traditionally, vitamins and minerals were supplied in the diet by *palusami* or *poke* (plain baked taro leaves) since fruit was never a significant constituent of the meal (Adams and Sio, 1997). The lack of leaves for *palusami* may have had a significant impact on this aspect of the Samoan diet.

**Response to a disease situation**

*Initial efforts to minimise the disease*

Early efforts to contain taro leaf blight in Samoa included a spraying programme of infected plantings with the fungicides Ridomil MZ and Manzate. Staff from the Ministry of Agriculture, Forestry, Fisheries and Meteorology (MAFFM) carried out routine fungicide spraying of infected plantations. Later, fungicides were supplied free to farmers through village *pulenuu* (village mayors) and application equipment was made available at subsidised prices at the local Agricultural Store (Chan, 1994). At the completion of this initial spraying campaign over WST$600,000 had been spent.

In conjunction with fungicide spraying, quarantine efforts to minimise the movement of planting material, leaves and soil on the island of Upolu and between islands was enforced. A public awareness campaign to inform farmers and the general public was implemented to coincide with the spraying and quarantine programmes. Included was information on disease symptoms, epidemiology including disease spread, disease control and effects on taro production. The campaign utilised radio, television, videos and print media including leaflets and newspaper.

This three pronged response had minimal effect on the spread of the disease. Unseasonal wet weather in the months following the introduction of the disease into Samoa and the fact that planting material was still being routinely moved meant the disease spread rapidly. By the end of 1993 the disease had spread to most of the nearby island of Savai’i (Chan, 1994) and farmers were beginning to diversify with alternative crops. Despite the promotion of a package by MAFFM, with the assistance of the AusAID funded Farming Systems Project (WSFSP), that included fungicide spraying and leaf removal, there were only 200 farmers growing taro in Samoa (Jackson, 1996). Most farmers used to growing taro traditionally
could not afford the extra costs required for fungicides and labour involved in leaf removal and spraying. This necessitated MAFFM and other national and regional organisations to explore alternative strategies for the management of the disease. Some of these initiatives are outlined below.

**Cultural Control**

Various cultural methods have been recommended for the control of taro leaf blight. Removal of infected leaves has been effective during the early stages of disease development in a number of countries. Wide spacing of plants has been reported to reduce disease severity but this appears to have a negligible effect when conditions favour disease development. Other cultural methods that have been recommended include delaying planting on the same land for a minimum of 3 weeks, avoiding plantings close to older infected ones and preventing the carryover of corms or suckers which can harbour the pathogen from one crop to the next (Jackson, 1977). Preliminary findings have indicated that fertilizer treatment may also help the plant cope with leaf blight (Tilialo *et al.*, 1996).

In Samoa a few methods of cultural control have been tested by MAFFM/WSFSP to a limited extent, including the effect of planting time, the role of fertilisation on the incidence and severity of the disease and the effect of leaf removal. Unfortunately these trials have been inconclusive (Chan, 1997).

The effect of intercropping on the incidence and severity of taro leaf blight has been investigated at the University of the South Pacific (USP) (Amosa and Wati, 1995; Hunter *et al.*, 1998). One of the recommendations of the South Pacific Commission seminar on taro leaf blight, held in Samoa in 1993, was to investigate the effect of intercropping on the disease. Initial trials were conducted on taro intercropped with maize. Taro leaf blight was first recorded 80 days after planting in both the intercropped taro and the sole taro crop. However, disease severity was consistently higher in the sole taro crop compared to the intercropped taro.

Innovative farmers in Samoa have also experimented with cultural approaches to the control of the disease including intercropping, varietal mixtures, off-season planting, crop spacing and growing taro in agroecological zones that are less favourable for disease development. A recent survey of farmers in Samoa revealed that almost 60% were occasionally or regularly removing leaf lesions from infected taro
plants (Iosefa and Rogers, 1999). An additional survey carried out by USP has shown that 63% of farmers carry out both leaf removal and chemical spraying (Adams, 1999).

**Chemical Control**

Jackson (1993) reports that the disease can be controlled by spraying copper fungicides. Copper oxychloride applied at a rate of 4.5 kg per 100 litres of water per hectare gave good control of the disease in the Solomon Islands. To date, there have been no trials in Samoa on copper containing fungicides. Early trial work in Samoa concentrated on trials of Ridomil MZ, Manzate and Phosphorous acid (Foschek). Pot experiments demonstrated the superiority of phosphorous acid over Ridomil MZ. Further experiments comparing phosphorous acid formulations (Foschek, Agri-Fos 400 and Foli-R-Fos) found no differences in terms of disease control (Chan, 1997). As a result of MAFFM/WSFSP pot and field experiments a recommendation for fungicide spraying was made for Foschek, alternated with Manzate to minimise resistance problems. Recent indications from surveyed farmers indicate that 30% are spraying with Foschek while only 7% are using Manzate. None of the surveyed farmers were using Ridomil MZ (Iosefa and Rogers, 1999). A similar survey carried out in 1998 at USP also highlighted that 30% of surveyed farmers were using Foschek for leaf blight control (Adams, 1999).

**Introduction and screening of exotic varieties**

Given the susceptibility of local taro varieties to leaf blight MAFFM initiated a programme to screen and evaluate exotic taros. Of those varieties screened in the field PSB-G2, Pwetepwet, Pastora and Toantal were found to be more resistant to leaf blight. Pwetepwet, Pastora and Toantal originated from the Federated States of Micronesia (FSM) and were obtained from the Tissue Culture Unit at Alafua Campus, USP. PSB-G2 was received from the Philippine Seed Board in 1994 (Chan, 1997).

These four varieties were further multiplied and evaluated in trials at USP-Alafua during 1996-1998. A preliminary trial demonstrated that disease severity recorded for each variety was not significantly different. Pastora produced the largest corms followed by PSB-G2, Pwetepwet and Toantal (Hunter et al., 1998). Samoans prefer dry, firm-textured taro and therefore, percent dry weight is one measure of eating quality. Dry matter content of corms was highest for PSB-G2 (37%) and taste tests at USP-Alafua demonstrated that both Toantal and PSB-G2 were most preferred. MAFFM taste tests also rated PSB-G2 highest followed by Toantal (Chan, 1997).
These four varieties have been evaluated by MAFFM using on-farm trials in three different agroecological zones representing three rainfall regimes in Samoa. Generally, these trials demonstrated that PSB-G2 and Toantal had higher severity of disease compared to Pastora and Pwetepwet although recorded differences were not significant. The latter two cultivars also produced the largest corms, although dry matter content was highest for PSB-G2. Those farmers in the very wet zone rated Pwetepwet as most resistant whereas in drier zones PSB-G2 was rated as more resistant. All farmers irrespective of location, rated PSB-G2 superior in terms of quality (Chan, 1997).

A recent impact assessment carried out among farmers in Samoa on the multiplication, performance and use of PSB-G2 has highlighted a number of interesting results (Iosefa and Rogers, 1999). All farmers surveyed expressed satisfaction with PSB-G2 and stated that it performed well and that severity of leaf blight was relatively low. Similar sentiments were expressed regarding the yield and quality of this variety. The most interesting aspect of this survey was the rapid rate of multiplication of PSB-G2 by the farming community. Initially the forty farmers involved in the survey were given 1,002 plants of PSB-G2. Over a two year period this group of farmers had multiplied the number to approximately 74,000 plants. PSB-G2 is amenable to rapid multiplication as it produces runners that can be cut into nodal segments and raised in nursery beds. The authors of this report estimated that if current multiplication rates are maintained over the next two years there would be over 18 million taro plants growing in Samoa.

Additional varieties collected from Palau by Professor Eduardo Trujillo, University of Hawaii are now available in Samoa. Trials in Hawaii have shown that some of these varieties have good levels of resistance against taro leaf blight. Currently the varieties are undergoing multiplication and will be evaluated prior to release to farmers. No doubt they will provide additional taro germplsm that will help to revive the taro industry in Samoa.

Breeding taro for resistance to taro leaf blight

In Samoa, the long-term strategy for the management of taro leaf blight is the breeding of more resistant varieties which together with the introduction of resistant exotic varieties is the most sustainable approach in managing the disease. Breeding for resistance to leaf blight has taken place in the Solomon Islands and Papua New Guinea for a number of years. However, there are two reasons to be cautious when
considering using any resistant material from either of these breeding programmes in Samoa or any other country where the disease occurs. Firstly, there is concern over the source of resistance that has been used in these programmes. There is the possibility that the resistance may be based on vertical resistance genes. If this is the case there are justified concerns as to the durability of resistant germplasm arising from these breeding programmes. Although vertical resistance usually gives a plant complete protection against a particular pathogen and is effective over a wide range of agroecological zones it is not effective when there is a matching strain of the pathogen (Robinson, 1996). For this reason vertical resistance is temporary resistance and there is the risk that it would eventually be overcome in the field with the emergence of new strains of *P. colocasiae*. This problem is minimised when using a horizontal breeding strategy.

Secondly, both Solomon Islands and Papua New Guinea are home to taro viruses that are of major quarantine concern in the region. Alomae, a lethal disease of taro, is present in both countries and is believed to arise from a mixed infection with taro large bacilliform virus (TLBV) and taro small bacilliform virus (TSBV). Both viruses can be transmitted by planting material and there is uncertainty about the seed transmission of both viruses. For these reasons the introduction of taro germplasm from either Papua New Guinea or Solomon Islands to other countries of the region is a risk. An Australian Centre for International Agricultural Research (ACIAR) project will commence in 1999 to address the problem of taro viruses in the region. The objective is to develop reliable virus-indexing methods that will facilitate the movement of taro germplasm internationally.

A taro breeding programme for resistance to leaf blight commenced in Samoa in 1996. Breeding blocks were established at both USP-Alafua and a MAFFM site at Nu’u comprising local and exotic varieties as parent material. Successful crosses were made utilising *PSB-G2, Niue, Pwetepwet, Alafua Sunrise, Toantal, Putemu, Tusitusi* and *Buntafortwe*. Currently a number of progenies from these crosses are in the field and undergoing evaluation for resistance to taro leaf blight. It is planned that future taro breeding for resistance will continue in Samoa and activities in this area are supported by USP, MAFFM, Secretariat of the Pacific Community (SPC) through an Aus AID funded regional project: *Taro Genetic Resources: Conservation and Utilisation* (TAROGEN). At the planning stages of this project it was agreed that future taro breeding in the region should follow a strategy based on horizontal resistance to avoid the problems that may arise with vertical resistance, such a strategy is currently followed in Samoa.
While future taro breeding is important for Samoa, it is equally important for other countries of the region where the disease is yet to strike. Given the taro virus problems that exist in other countries where taro breeding has occurred, Samoa could become an important source of resistant germplasm. Also, the question of vertical resistance does not arise in Samoan germplasm as there is no evidence of immunity to infection among any taro material in the country. Therefore, future resistant germplasm from this source will be based on horizontal resistance genes.

**Conclusions**

The recent introduction of taro leaf blight into Samoa illustrates clearly the devastation that the disease can cause and highlights the vulnerability of isolated taro populations that for years evolved in the absence of the disease (Putter, 1993). While Samoa is a long way from the pre-blght levels of taro production there are encouraging signs that taro is making a comeback. An integrated approach to disease management, utilising host plant resistance, sanitation and fungicide spraying, is helping a number of farmers back into significant taro production. There are still constraints for many farmers who cannot afford to use fungicides or pay for labour required for leaf removal. In the long-term these farmers will benefit from the availability of more improved varieties that arise from breeding initiatives or importation. Improvements in plant resistance to the disease will further reduce the need for fungicide spraying and leaf removal. However, it is difficult to predict at this stage whether Samoa will ever return to the pre-blght situation when there was relatively little requirement for inputs other than some hand weeding.

The scenario that has been played out in Samoa highlights the vulnerability of neighbouring countries to the disease. Food security is now a major issue for governments in the region and the ‘subsistence affluence’ of Pacific island countries is no longer assured or can be taken for granted (Jackson, 1993). There is the risk that other countries, presently free from the disease, will jump at the opportunity to exploit the overseas market for taro and encourage the planting of large areas with popular, but highly susceptible, local varieties like Niue. This could lead to the re-enactment of events that have been played out in Samoa. With this in mind it is important that those countries at risk from the disease have strategies in place to cope with introduction of the disease. These could involve:
Effective and strong quarantine is essential to stop the introduction of the disease to new countries. Both quarantine workers and the general public should be informed about the disease and how it spreads. Although there are examples of successful disease eradications in the region such as black leaf streak and citrus canker from Australia and coffee rust in PNG it is unlikely that eradication will be successful for taro leaf blight. This emphasizes the need for strong and effective quarantine regulations which are observed by all.

In the event that eradication may be an option response must be prompt. It is vital that countries have the resources and contingency plans in place and are able to respond effectively at the first report of the disease. The evidence from Samoa indicates that eradication is difficult. There have been reports that leaf blight has been eradicated from the island of Rota after taro production ceased for ten years. If eradication is an option contingency plans in the Pacific context are discussed by Jackson and Macfarlane (1993).

If taro is an important staple and economic crop inform farmers about the dangers of relying on local cultivars that are susceptible to the disease. With the information now available in the region regarding resistant taro from FSM, Philippines, Palau and elsewhere governments should take steps to ensure that it is available in the event of a disease outbreak. Virus-indexed resistant taro could be imported in tissue culture as a preliminary measure. Governments have the option of promoting and distributing resistant taro to the farmers with the objective of minimising the initial impact of the disease when it arrives. Alternatively, material could be established at research stations and multiplied in the event of a disease outbreak. The latter approach would ensure a slower response. The first approach is constrained by trying to get farmers to accept varieties that have attributes for a problem that does not yet exist and which may not be readily acceptable for home consumption or markets.

All countries at risk from the disease should have access to disease awareness materials that are currently available in Samoa and through SPC for extension staff, farmers and the public. These should be obtained so that awareness programmes can commence without delay. This should be facilitated by regional organisations like SPC and IRETA. Such materials, together with suitable fungicides, should be available in-country if eradication is a serious option as discussed above. They
should also be available, with fungicides and resistant germplasm, to minimise the extent of damage that will occur in the likely event that the disease cannot be contained.

 Governments should encourage diversification as opposed to reliance on a few individual crops to minimise the economic and social impacts of the disease.

References


Table 1. Area Under Major Crops in Western Samoa (1989)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cropping Area (ha)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taro</td>
<td>14,600</td>
<td>23</td>
</tr>
<tr>
<td>Alocasia taro</td>
<td>8,200</td>
<td>13</td>
</tr>
<tr>
<td>Coconut</td>
<td>27,380</td>
<td>43</td>
</tr>
<tr>
<td>Cocoa</td>
<td>8,320</td>
<td>13</td>
</tr>
<tr>
<td>Banana</td>
<td>2,240</td>
<td>3.5</td>
</tr>
<tr>
<td>Breadfruit</td>
<td>1,061</td>
<td>1.7</td>
</tr>
<tr>
<td>Kava</td>
<td>253</td>
<td>0.4</td>
</tr>
<tr>
<td>Yam</td>
<td>245</td>
<td>0.4</td>
</tr>
<tr>
<td>All other</td>
<td>1,201</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>63,500</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 2. Major exports of agricultural commodities (value ‘000 WS$)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa</td>
<td>1436</td>
<td>985</td>
<td>4616</td>
<td>2412</td>
<td>2357</td>
<td>3087</td>
<td>2262</td>
<td>1261</td>
<td>2025</td>
<td>502</td>
<td>-</td>
<td>1000</td>
<td>4000</td>
</tr>
<tr>
<td>Coconut</td>
<td>3924</td>
<td>2760</td>
<td>1397</td>
<td>-</td>
<td>951</td>
<td>-</td>
<td>335</td>
<td>1969</td>
<td>3237</td>
<td>501</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Taro</td>
<td>2136</td>
<td>2224</td>
<td>2371</td>
<td>4223</td>
<td>5284</td>
<td>4262</td>
<td>5274</td>
<td>5236</td>
<td>5900</td>
<td>3500</td>
<td>7000</td>
<td>5500</td>
<td>10000</td>
</tr>
</tbody>
</table>

Fig 1. Postulated routes of spread into the Pacific of Phytophthora cubensis.
Figure 2. Monthly Supply of Taro, Taamu and Banana to the Apia Central Market (1992 – 1996). Source: Central Bank Monthly Reports
Supply and Price of Taro