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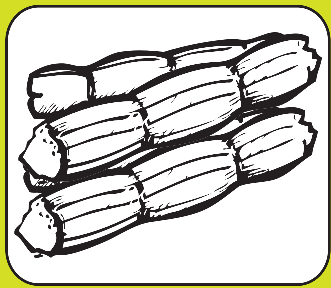

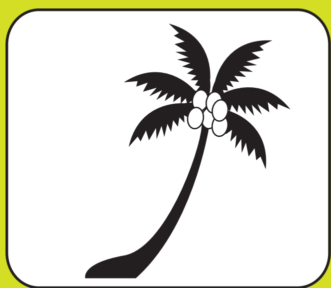

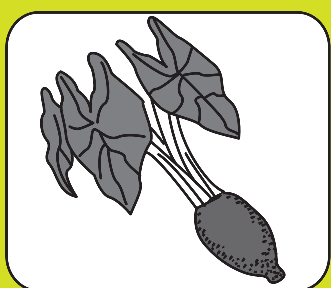

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RESEARCH PAPER

Occurrence and distribution of aibika (*Abelmoschus manihot* (L.) Medik.) collar rot and Fusarium rot in Morobe Province, Papua New Guinea

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ABSTRACT

Aibika (*Abelmoschus manihot* (L.) Medik.) is a popular leafy vegetable in Papua New Guinea (PNG) and many other Pacific countries. It is grown in backyards for subsistence, or on larger farms for cash income. Cultivation is relatively easy requiring minimum care during the growth period. However, there are a number of insect pests and diseases found on aibika, although most are not of economic importance. Collar rot caused by oomycetous pathogen *Phytopthora nicotianae*, however, is a serious disease that can destroy entire aibika plantings in a field. Its symptom is wilting that eventually leads to death. Another pathogen, *Fusarium* sp., often associated with color rot, also causes serious damages on aibika.

A survey conducted in 52 sites in three districts of Morobe Province (Nawae, Huon, and Markham) of PNG demonstrated that wilting and death of aibika was a serious problem in the areas. Presence of collar rot alone was confirmed in nine sites (17.3%), and recorded together with *Fusarium* in four sites (7.7%). Fusarium alone was recorded in two sites (3.8%), while, in other 27 sites (51.9%), the diseases were either absent or not evident. The disease occurrence was widespread but unevenly distributed in Morobe Province. Observations indicated an association of rotting and the pathogens with wet conditions. Breeding for varietal tolerance should mitigate the problem.

Key words: Aibika, bele, collar rot, *Fusarium*, Morobe Province, Papua New Guinea, *Phythophthora nicotianae*, slippery cabbage

1.0 INTRODUCTION

Aibika (*Abelmoschus manihot* (L.) Medik.) is a popular leafy vegetable grown in Papua New Guinea (PNG) and other Pacific countries. Its origin is thought to be China. However, Pacific countries are a major centre of diversity of aibika. The vegetable is called by many different names in different countries. In Solomon Islands, it is called slippery cabbage, while in Vanuatu, it is called island cabbage. In Fiji, the local name is bele. Aibika is also grown in parts of Malaysia and the Philippines.

Aibika plays a vital role for health in rural communities in PNG. It has high nutritional values with protein, minerals, and vitamins, and contributes to 4-12% of the energy requirements (Preston *et al*. 1998). In PNG, Sowei and Osili (1993) reported an annual income of PGK 243,792 (approximately USD 240,000) from 609.48 tonnes of aibika in 1993 in the PNG local market. No information is available on any export sales, if any occurred at that time. It is one of the most important crops in PNG for food security and as a means of income generation for smallholder farmers.

There are about 15 species of aibika worldwide. In PNG, there is a wide range of cultivated and wild species (Sowei and Osilis 1993), where they grow quickly and easily in the lowland areas (Muthappa and Bull 1986). Aibika can tolerate a range of soil types with best growing soils in sandy loam and clay loam, but a poor growth is observed in highly alkaline soils of coral atolls. It can be cultivated in seasonally dry lowlands with an annual rainfall of 1000-2000 mm and in the wet lowlands with a rainfall of >2000 mm. It is also cultivated in higher altitude areas (>2000 m above sea level) with a rainfall of >2000 mm (Paofa and Kambuou 2006). It stays productive for one to several years when planted in rich fertile soils and with high level of tolerance to pests and diseases.

A number of insect pests and diseases have been recorded on aibika with minimal to greatly affecting its growth and quality in terms of appearance of leaves. Jassids have been reported to be the most serious and devastating insect pest (Sutherland 1985a). Among the diseases, collar rot has been reported to be a serious disease of aibika (Preston *et al*. 1998; Muthappa and Bull 1986). *Phytophthora nicotianae* is the causal agent of collar rot of aibika, and can be devastating to the crop depending on the variety they infect and the weather. Muthappa and Bull (1986) reported that yellowing of mature leaves, wilting of younger foliage and the growing tip and defoliation are symptoms of this disease. Infection starts at the collar region of the stem and slowly progresses down towards the roots where it eventually destroys the entire root systems.

There are differences in disease severity among varieties, and it has been observed that wounds in tolerant varieties can heal under high humidity conditions within 24 hours of infection (Pett and Woruba1994). With highly susceptible varieties, the plant is eventually killed.

There have been studies on germplasm (Kambuou *et al*. 2004), agronomic evaluation (Sowei and Osilis 1993), and entomological studies (Sutherland 1985b) of aibika. Although some studies have been conducted on collar rot pathogenicity (Muthappa and Bull 1986), its occurrence and distribution in PNG has not been so far recorded. Therefore, we conducted a survey at 52 sites in three districts (Huon, Markham and Nawae) in Morobe Province in 2011 and 2012 to determine its occurrences and distribution. During the survey, it became clear that *Fusarium* often concurrently associates with *Phytophthora*, forming a disease complex. Therefore, we included in this report the incidences of Fusarium wilt as well.

2.0 MATERIALS AND METHODS

2.1 *Method of Survey*

A survey questionnaire was prepared to standardize the questions asked on site, which included variety of aibika planted, growers' preference if any, pests and disease problems observed, control of pests and diseases used by growers, economical benefits, and other associated problems with growing and marketing of aibika.

The survey sites were randomly selected, stopping at sites where aibika was observed from roads. With the cooperation of growers, all or most information on the questionnaire form were recorded. Information on diseases was recorded when observed by the survey team. Where disease symptoms were observed by the survey team, information was obtained to the best knowledge of the growers.

Disease samples were collected and observed under light microscope in National Agricultural Research Institutes (NARI) Biotechnology Laboratory to identify and confirm the casual agents. The interview questionnaires and responses from interviews were analyzed by using the SPSS statistics package (version 20.0.0, 2011, USA).

2.2 *Surveyed sites*

Fifty-two sites in three districts of Morobe Province (Huon, Markham and Nawae) were covered in the months of July, August, and September, 2011, and in March, April, and May of 2012. Weather (rainfall and temperature) was not considered at the time of survey. Global positioning system (GPS) data were collected for most sites. A few sites had the same readings as they were not far apart. All GPS data were mapped to show the occurrence and distribution of both collar rot and *Fusarium* (Fig.1). All the information gathered were analyzed by using SPSS statistics package.

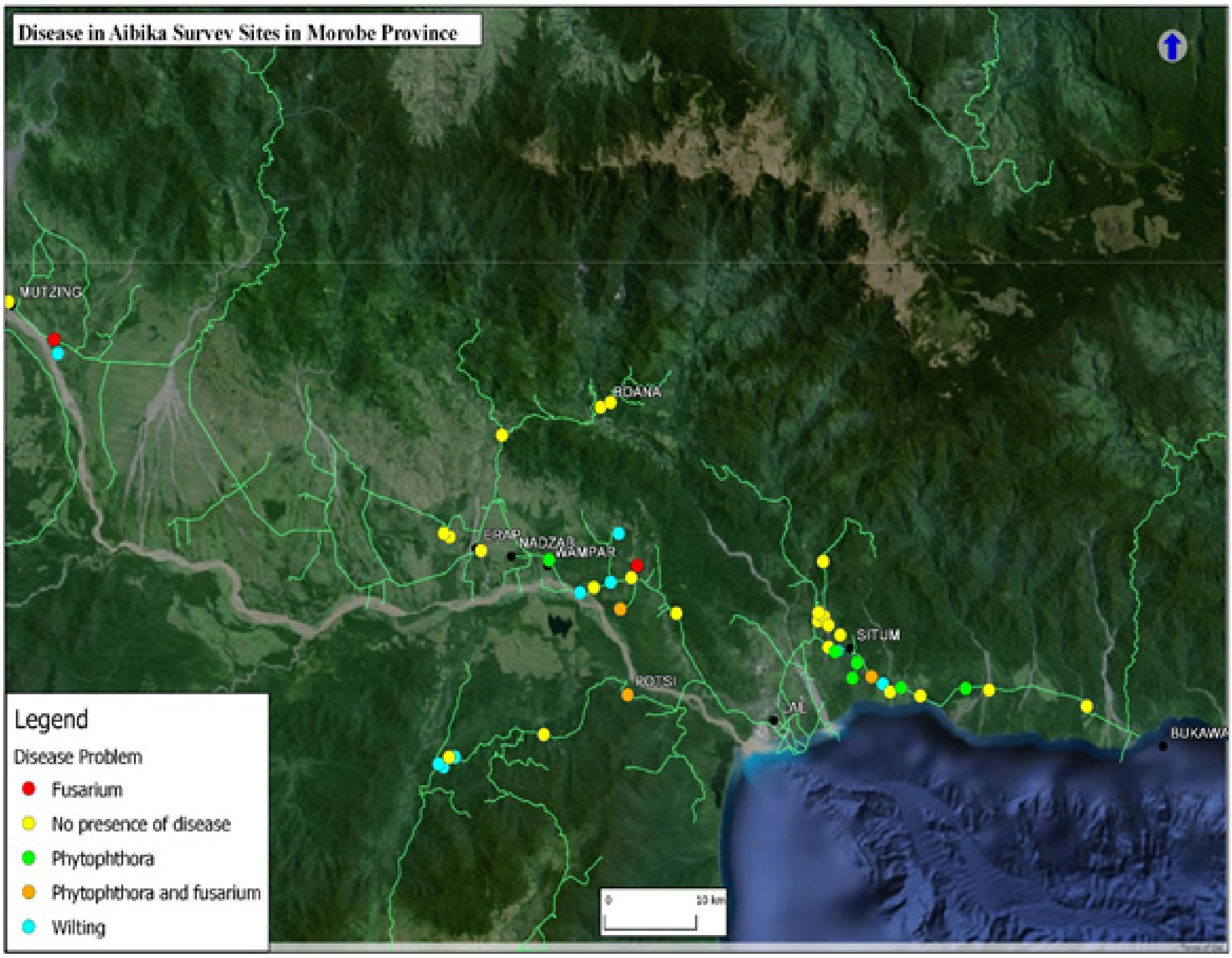

Figure 1. Map showing the occurrence and distribution of *Phytophthora* collar rot and *Fusarium* rot of aibika at 52 sites in 3 districts of Morobe Province. Green circle: site where only *Phytophthora* was present, red circle: site where only *Fusarium* was present; orange circle: site where both *Phytophthora* and *Fusarium* were present; yellow circle: site where no disease was present; blue circle: site where wilting was observed but no sign of pathogen was evident.

Due to accessibility and logistic difficulties, the areas were not uniformly covered. About 33% of the sites sureveyed were from the Markham district. These included 25% sites between Wara Kalap, 14 mile, to Nadzab and 7.7% sites in the Mutzin area. Nawae distrcit included Situm and the Nawae Blocks, which made up 19.2%, another 17.3% sites were in Bukawa, and the areas from Erap to Boana station covered 19.2%, totalling to 55.6% of the sites. The Huon district, which included areas from Wampit to Potsi and Gabensis, made up 11.5% of the sites (Table 1).

Table 1. Number of sites surveyed in the geographical areas

Area	District	Number	Percentage
Wara Kalap-Nadzab	Markham	13	25.0
Mutzin	Markham	4	7.7
Wampit-Potsi	Huon	6	11.5
Situm-Nawae Block	Nawae	10	19.2
Bukawa	Nawae	9	17.3
Erap-Boana	Nawae	10	19.2
Total		52	100.0

2.3 *Gender of participants*

No preference on gender was considered for persons interviewed during the survey. The questionnaire was answered by those who were available and could participate. Almost half of the participants were males (44.6%) and just over half (55.8%) were females (Table 2). Chi-square test (p=0.405) shows that gender participation is not significantly different.

Table 2. Number and percentage of males and females interviewed

Gender	Number*	Percentage
Male	23	44.2
Female	29	55.8
Total	52	100.0

*Chi-square test; p=0.405

3.0 RESULTS

3.1 *Diseases recorded and description of disease*

Twenty-five sites described rotting as a major problem leading to aibika death. Nine farmers (17.3%) confirmed the presence of collar rot alone, two farmers (3.8%) mentioned *Fusarium* alone, and both diseases recorded on same plant in four sites (7.7%). The other 10 sites could not be confirmed with actual presence of either pathogen. However, growers described rotting as a major problem causing death of their aibikas.

These observations were made during the rainy seasons and it was apparent that collar rot was associated with wet period of the year. No disease was recorded at 27 sites out of the 52 (51.9%). The growers expressed no knowledge of diseases and the survey team did not observe any disease at the time of survey (Table 3).

Table 3. Symptoms and/or signs of wilting observed in the survey sites

Symptom/sign	Frequency	Percentage
Collar rot alone	9	17.3
Fusarium wilt alone	2	3.8
Both collar rot and Fusarium wilt	4	7.7
Wilting, identity unknown	10	19.2
No disease	27	51.9
Total	52	100.0

Symptoms of these two diseases as observed were yellowing and wilting of leaves with whitish cotton-like appearance for collar rot, and orange spores for *Fusarium* (Fig. 2).

The collar rot sporangiospores observed under the microscope were taken from whitish cotton type fungi growing mainly on the stem of the plant (Fig. 3a). *Fusarium* sporangiospores were observed from the powdery growth, usually present at the base of the stem (Fig.3c).

(a) (b) (c)

Figure 2. Symptoms of collar rot and Fusarium rot of aibika. (a), (b), and (c): Early symptoms of wilting of leaves of aibika. Inset of (b) shows mycelia of Phytophothora. (d) Severe wilting with leaf loss. The stem is covered with Phytophthora mycelia. (e) Death of plant with total leaf loss. (f) Dead plant due to co-infection with Fusarium and Phythophthora.

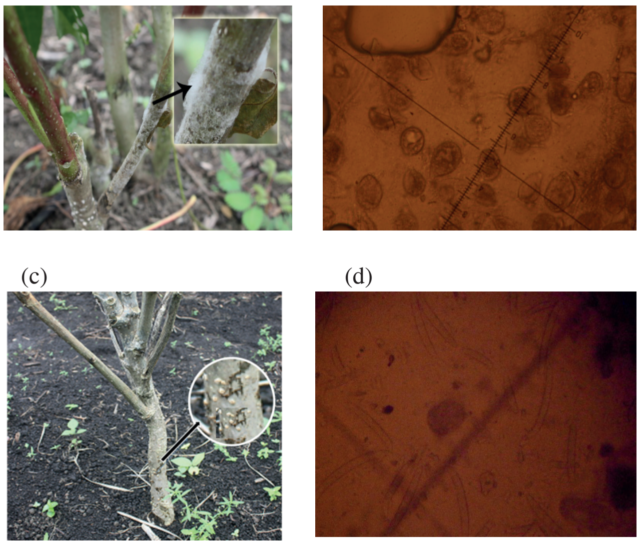

Figure 3. Micrographs showing *Phytophthora* and *Fusarium* spores. (a) *Phytophthora mycelia,* (b) *Phytophthora sporangia* from the plant in (a), (c) *Fusarium mycelia,* (d) *Fusarium* spores from the plant in (c).

3.2 *Occurance and distribution*

Collar rot (Phytophthora) and Fusarium rot were observed in the Nawae and Markham districts, with only one respondent reported Fusarium in the Wampit-Potsi area of Huon district. The problem of wilting described by the growers was a problem recorded throughout the three districts. All the six sites from Erap to Boana in the Nawae District showed no damage from the diseases (Table 4, Fig. 1). Most farmers associated the disease occurrence with rains, while only two farmers reported the disease occurring with no references made to weather (Table 5). The chi-square test of independence or probabilities shows that the diseases recorded occurred with high probability due to the rain or wet periods as reported by the farmers.

Table 4. Symptoms and/or signs of wilting observed in each survey area

Area	Symptom/ sign*					Total
	A	B	C	D	E	
Wara	3	1	1	4	4	13
Kalap-Nadzab						
Mutzin	0	0	1	1	2	4
Wampit-Potsi	0	0	1	2	3	6
Situm-Nawae	4	0	1	2	7	14
Blocks						
Bukawa	2	1	0	1	5	9
Erap-Boana	0	0	0	0	6	6
Total	9	2	4	10	27	52

Table 5. Weather condition when the first symptoms/signs were observed by farmers

Symptom/sign	Weather*			Total
	Wet	Dry	No disease	
Collar rot alone	9	0	0	9
Fusarium wilt alone	2	0	0	2
Both collar rot and Fusarium wilt	4	0	0	4
Wilting, identity unknown	8	2	0	10
No disease	0	0	27	27
Total	23	2	27	52

*Pearson chi-square test of independence, p=0.000, p<0.01

3.3 *Control methods practiced*

A number of control practices were adopted by farmers to reduce the effect of these pathogens (Table 6). This included removal of infected plants, burning of infected plants, and planting alternative crops. However, 25% of the respondents were not making any attempt to control the diseases.

Table 6. Control measures taken by growers for wilting of aibika

Control measure	Frequency	Percentage
Removal of infected plants	8	15.4
Burning of infected plants	1	1.9
Planting alternative crop	3	5.8
No control measure taken	13	25.0
No disease	27	51.9
Total	52	100.0

3.4 *Aibika losses due to diseases*

Across the three districts, five sites (9.6%) mentioned that they lost varieties as a result of diseases, while in another 3 sites, affected plants died out but varieties/types were not lost. In 17 sites, no losses occurred as a result of the diseases (Table 7). Within the districts, the highest loss of varieties due to the diseases was in the Huon district, while there was no losses in the Erap to Boana area area of the Nawae district. Only minor losses occurred in the Markham, Situm, and Bukawa areas of Nawae districts.

Table 7. Severity of losses due to the diseases

Severity	Frequency	Percentage
Loss of entire planting/ varieties	5	9.6
Loss of some planting	3	5.8
Disease present but no loss	17	32.7
No disease	27	51.9
Total	52	100.0

4.0 DISCUSSION

Our study demonstrated that the main cause of aibika loss in the survey areas was the infection by *Phythothora* and/or *Fusarium*. The mycelia of both pathogens appear cottony on the stem and often coexist on the same plant, forming a disease complex. The disease appears to correlate with climatic conditions. In Markham and Nawae districts, collar rot was present in areas where there was high rainfall or the water table. Farmers associated wet periods and flooding or water-logging with the wilting and deaths of aibika. In contrast, there were no recorded diseases from the areas in Erap to Boana of Nawae district. This could be due to the dryer and cooler climate. It was reported that cool and dry weather conditions are not conducive to *Phytophthora* and *Fusarium* infections (Muthappa and Bull 1986).

Studies show that the incidence of collar rot is high in areas with high rainfall and inadequate drainage (Pett 1995 cited in Preston *et al*. 1998) and *Fusarium* spp. incidences are also high during the wet periods. Microscopic observation of samples collected from survey sites confirmed the presence of these pathogens. On the other hand, dry climate appears to be unfavourable for the development of aibika rot caused by *Phytophthora* and *Fusarium*. In our study, the occurrence of the disease was widespread across the three districts, but showed uneven geographical pattern (Fig. 1), reflecting the wide climatic differences within the survey areas.

Although farmers had some control measures, the populations of the pathogens were not likely to be reduced, as practices of replanting the same aibika in the same area only increased the disease severity. And once favorable conditions such as rains, water-logging, and flooding occur, the intensity of infection appears to increase. Because *Phytophthora* and *Fusarium* are soil borne, they can survive well in the soil until favorable conditions arise. This is the main knowledge lacked by the farmers. However, most farmers realized the persistence of the pathogens on their aibika plants.

A number of farmers reported certain types of aibika (varieties) to be tolerant to wilting. These farmers selected and planted rot-tolerant aibika varieties, although the selection was based on trials and errors. Studies have shown differences among varieties regarding the tolerance to the color rot pathogen. Pett and Woruba (1994) observed that the wounds caused by inoculating the fungi can heal under high humidity conditions within 24 hours of infection. Tolerance could be the only means to mitigate the impact of *Phytophthora* and *Fusarium* on aibika. Screening of aibika germplasm collections for these pathogens is thus warranted.

Page (1986 cited in Preston *et al*. 1986) reported two nematodes (*Meloidogyne incognita* and *M. javanica*) cause favorable conditions for collar rot infection. However, no soil samples were collected and analyzed for nematodes in our survey to test this possibility. This must be investigated in future studies.

Phytophora and *Fusarium* are major pathogens that pose serious threat to food and nutritional security in PNG and other Pacific countries. Unless their occurrence and distribution is carefully assessed, and resistance is identified, these pathogens can cause devastating losses. In other crops such as sweet potato (*Ipomoea batatas*) and taro (*Colocasia esculenta*) (Singh *et al*. 2012), development and introduction of tolerant varieties to various pests and diseases have contributed the increased yield. Breeding of aibika for enhanced lines should be seriously considered.

5.0 CONCLUSION

The occurrence of *Photophthora* and *Fusarium* rot in aibika was widespread but unevenly distributed in the survey areas, with high incidence in areas with high rainfall. It appears that there is varietal tolerance against these two pathogens. Development of tolerant aibika varieties will reduce the loss due to the diseases.

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RESEARCH PAPER

The pathogenic haemoparasite of cattle *Theileria oreintalis* Ikeda is not present in Fiji

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ABSTRACT

The pathogenic haemoparasite of cattle *Theileria orientalis* Ikeda is present in Australia and New Zealand. The tick *Haemaphysalis longicornis* Neumann, is a competent host for *T. orientalis* and is abundant in Fiji. Consequently the Fijian Ministry of Agriculture recommended suspension of live cattle imports from countries with *T. orientalis* Ikeda until the status of Fiji could be determined. To determine the status of Fiji with respect to *T. orientalis* Ikeda the Ministry conducted a targeted survey of the two subpopulations of recently imported cattle. Samples of whole blood were tested using a specific polymerase chain reaction (PCR) nucleic acid detection test for *T. orientalis* Ikeda and a generic PCR test for *Theileria* species in New Zealand. The PCR tests were all negative for *T.orientalis* Ikeda strain and also for generic *Theileria* species. Epidemiologic analysis using assumed minimum prevalence 0.1, test sensitivity 0.9 and test specificity 0.99 demonstrated that the two subpopulations were free from *T. orientalis* Ikeda with probability of greater than 99.9 % and 95 %, respectively. Therefore it is highly unlikely that pathogenic *T. orientalis* Ikeda strain is present in cattle in Fiji, but it could become established since the vector *H. longicornis* is abundant.

Key words: *Theileria orientalis* Ikeda, freedom, polymerase chain reaction (PCR), Fiji.

1.0 INTRODUCTION

In 2014 the Ministry of Agriculture planned to import live dairy cattle from New Zealand, but the pathogenic haemoparasite of cattle *Theileria orientalis* Ikeda became established in New Zealand in 2012. Consequently the Ministry recommended interim suspension of live cattle imports from countries with *T. orientalis* Ikeda until the status of Fiji could be determined.

The *T. orientalis* parasites are apicomplexan protozoans with a two host lifecycle. The piroplasm stage infects the erythrocytes of cattle and the sporozoites develop in the salivary gland of ticks. The tick *Haemaphysalis longicornis* Neumann, is a competent host for *T. orientalis* (Riek 1982; McFadden 2014), and *H. longicornis* is widely distributed throughout East Asia, Australasia and the Pacific Islands including Fiji (Hoogstraal *et al.* 1968).

Up to seven strains of *T. orientalis* have been described, but only three strains are commonly recognized parasites of domestic cattle: the non-pathogenic *T. orientalis* Chitose and *T. orientalis* Buffeli strains and the pathogenic *T. orientalis* Ikeda strain. The non-pathogenic *T. orientalis* Chitose is widely distributed throughout East Asia and Australasia, whilst *T. orientalis* Buffeli occurs worldwide (Kamau *et al.* 2011). The pathogenic *T. orientalis* Ikeda has a more limited distribution. It has been associated with disease in East Asia, in Australia from 2005 (Kamau *et al.* 2011a) and in New Zealand from 2012 (Bingham 2013; McFadden *et al*. 2013; McFadden *et al.* 2014).

The widely spread Chitose and Buffeli strains are not considered to be pathogenic because they rarely cause anaemia unless the host animal is debilitated by another disease (Izzo *et al.* 2010). However, in New Zealand the Chitose strain has been found occasionally in anaemic animals that did not have an identifiable concurrent disease (McFadden *et al*. 2011).

The pathogenic *T. orientalis* Ikeda has been associated with severe disease in otherwise healthy cattle. In New Zealand many infected animals developed severe immune mediated haemolytic anaemia. The clinical manifestations of anaemia were exercise intolerance, decreased milk production, reduced growth rates and reduced fertility. In herds newly infected by *T. orientalis* Ikeda the mean prevalence of anaemia was 33 % (range 10 to 88 %) and mortality was up to 15 %. Surviving animals remained anaemic for some months (Lawrence *et al.* 2014).

To date, there is no evidence *T. orientalis* Ikeda is present in Fiji. The Ministry of Agriculture has not received any reports of clinical disease in cattle that could be attributable to haemolytic anaemia, and no cattle have been imported into Fiji from Australia or New Zealand since *T. orientalis* Ikeda was discovered in those countries (Sian Watson, Biosecurity Authority of Fiji, *pers. comm.* June 2014).

Nevertheless the Ministry of Agriculture is concerned that pathogenic *T. orientalis* Ikeda could become established in Fiji if infected cattle or infected ticks were imported. In order to determine the status of Fiji with respect to *T. orientalis* Ikeda the Ministry conducted a targeted survey of cattle imported since 2009. Here we present evidence that Fiji remains free of *T. orientalis* Ikeda.

2.0 MATERIALS AND METHODS

To trace back cattle imported since 2009, the Ministry of Agriculture obtained information from the Biosecurity Authority of Fiji regarding import permits issued since December 2009. Representative sampling plans for the subpopulations of imported cattle were devised.

Because there were two epidemiologically separate subpopulations of interest, two sampling plans were devised. One sampling plan was representative of 210 imported Friesian cattle on the islands of Viti Levu and Vanua Levu. The sample comprised 49 animals on two government stations, and included 44 imported animals plus five offspring which were run in the same mob. The other sampling plan was representative of four Wagyu cattle on an offshore island. That sample comprised the four imported animals plus seven progeny and one other animal that were run together in the same mob.

The sample size was 100% of animals from each of the two subpopulations. Epidemiological analysis was performed using the following parameters:

assumed minimum prevalence 0.1, test sensitivity 0.9 and test specificity 0.99. Epidemiological calculations were carried out using Survey Toolbox version 1.0 (Cameron 1999).

A sample of whole blood in ethylenediaminetetraacetic acid (EDTA) was taken from each of the animals into a vacutainer, transported on ice, refrigerated at 4° C and air freighted chilled to New Zealand.

A specific polymerase chain reaction (PCR) nucleic acid detection test for *T. orientalis* Ikeda and a generic PCR test for *Theileria* species were performed by New Zealand Veterinary Pathology Ltd., Palmerston North using methods adapted by the Ministry for Primary Industries for investigation of theileriosis in New Zealand (Kamau *et al.* 2011b; Eamens *et al.* 2013).

3.0 RESULTS

The PCR tests conducted on the samples from both subpopulations, from the government stations (49) and from an offshore island (12), were all negative for *T.orientalis* Ikeda strain and also for generic *Theileria* species.

Epidemiologic analysis demonstrated that from the subpopulation on the government stations representing the Friesian cattle imported from New Zealand in 2011 the probability of observing zero positive tests from 49 samples from an original population of 210 with a disease prevalence of 0.1 is p=0.00034. Therefore it is with a probability of greater than 99.9 % that this group of animals was free from *T. orientalis* Ikeda.

From the subpopulation of Wagyu cattle on an offshore island the probability of observing zero positive tests from 12 samples from an original population of 4 plus offspring (total 12) with a disease prevalence of 0.1 is p=0.031. Therefore it is with a probability of greater than 95 % that this group of animals was free from *T. orientalis* Ikeda.

4.0 DISCUSSION

The haemoparasite of cattle *T. orientalis* Ikeda strain is common in East Asia and recently became established in Australia and New Zealand. Although the vector *H. longicornis* is abundant in Fiji, there have been no cattle imported from Australia or New Zealand since the Ikeda strain established in those countries. Furthermore there have been no reports of disease attributable to haemolytic anemia which would raise suspicion that *T. orientalis* Ikeda is present in Fiji.

It was hypothesized that Fiji would still be free from *T. orientalis* Ikeda strain unless it had been recently introduced in live animals. Since all imports of cattle have been from New Zealand and Australia a trace back was conducted to identify the cattle most recently imported from Australia or New Zealand i.e. those at slight risk of being infected.

Two subpopulations of cattle were identified, and in the interests of economy the investigation targeted those subpopulations of animals in the first instance. A representative sample of animals from each subpopulation was tested by PCR and the results were negative. These findings provide strong evidence that *T.orientalis* Ikeda strain has not been introduced into Fiji.

When determining what constituted a representative sample it was estimated that the likely prevalence of *T. orientalis* Ikeda in an infected herd would approach 100 % if it were present in Fiji. The reasoning is that once an animal has been infected by *T. orientalis*, the animal remains infected for life and becomes a source of infection for ticks. The tick *H. longicornis* is abundant in Fiji and is active all year round. Therefore if an infected animal were imported it would rapidly infect numerous ticks, which in turn would infect numerous cattle, creating an amplifying cycle of infection. In addition, the cattle in the subpopulations of interest had remained on the same properties for many years, thus there had been ample opportunity for a high prevalence of infection to build up if *T. orientalis* Ikeda were present.

For the epidemiological analysis, a very conservative estimate of prevalence of disease at the minimum level found in New Zealand of 0.1 (Lawrence *et al.* 2014) along with conservative parameters for the diagnostic test of a sensitivity of 0.9 and a specificity of 0.99 were used. Results demonstrated that the probability of freedom from infection in the two sampled subpopulations were 99.9 % and 95 %, respectively. These results give confidence in the finding that *T. orientalis* Ikeda strain is absent from Fiji.

Interestingly the PCR tests for generic *Theileria* species were also negative. The non-pathogenic Chitose and Buffeli strains of *T. orientalis* have been recognized in Australia since 1910 (Seddon and Albiston 1966) and New Zealand since 1984 (James *et al.* 1984). The cattle populations in Fiji are largely derived from animals imported from Australia and New Zealand, therefore it is possible that the non-pathogenic strains are present in Fiji. Further research would be necessary to determine whether the non-pathogenic *T. orientalis* Chitose and Buffeli strains are present in Fiji.

In conclusion, this study indicates it is highly unlikely that pathogenic *T. orientalis* Ikeda strain is present in cattle in Fiji. Nevertheless, the abundance of the tick *H. longicornis* means that *T. orientalis* Ikeda could become established if it were imported into Fiji.

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REVIEW

Land use trends and agroforestry in Fiji Islands

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ABSTRACT

Agricultural development in Fiji evolved around sugarcane plantations. Currently it is diversifying, expanding and intensifying according to the market demands and opportunities. However causes environmental hazards like soil erosion on hilly regions, uncontrolled use of agrochemicals, soil fertility decline, and soil and water pollution.. Agroforestry provides one of the best alternatives to increase yields on hilly terrain, diversify land production, maintain ecological systems and sustain other rural industries. However, applied agroforestry systems are still limited in space and diversity in Fiji .Strategic long term planning with diverse well implemented and integrated programs is therefore necessary.

Key words: Tropical agroforestry, land tenure, land reform, land use planning, Pacific Islands, Fiji.

1.0 INTRODUCTION

Agroforestry is defined as the deliberate incorporation of trees into, or protection of trees within, an agro ecosystem in order to ensure its short and long term productivity, cultural utility, and ecological stability (Thaman and Clarke 1990). Agroforestry systems incorporate new economic opportunities with different benefits, markets, and production risks than commodity farming (Gold *et al.* 2004), serving as a model for integrative land use management systems currently being developed in response to global concerns.

The prospects for regular availability of tree products can also reduce farmers' risk in the event of crop failures. Forty years ago they were promoted by western aid organizations working on marginal lands, a decade later low intensity indigenous cultivation systems were adopted, and new criteria were identified for successful land use management strategies after decades of environmental damage (Turner 1980). Sustainability, stability, and equality have joined increased production efficiency as objectives for agriculture (Conway 1987), in forestry they mean the yield optimization of different products and uses rather than maximizing wood production of only one species (Garrett and McGraw 2000). Future concerns will focus on fossil fuels substitution. The article discusses the historical, geographical and socioeconomic background of Fiji Islands to recommend directions on research and development of agroforestry systems.

2.0 GEOGRAPHY AND LAND USE EVOLUTION

Almost 70% of the land area of Viti Levu and Vanua Levu islands (87% of total Fiji Islands area) is steep mountainous terrain (Ushman 1984) (Fig. 1). Viti Levu covers over half the total land area of Fiji and is home to roughly three quarters of the population. Both islands are steep and volcanic and have a tropical climate with wet areas being in the south-east and center are covered with dense vegetation and forest, while the drier west is savannah grassland. Mangrove forests dominate the coasts. Only 16% of the land is used for arable farming in valleys, river deltas and coastal plains. Patterns of crop planting are determined by variations in rainfall. Mean monthly temperature ranges from 23°C in July and August to 27°C in January. The humid south-eastern shorelines of the big islands receive 3,000 mm of rainfall each year, increasing to 5,000 mm inland (FMS 2015).

The islands have formed from volcanic materials and sedimentary rocks, deposited towards the eastern margin of an ancient massive oceanic plate or platform. Extensive volcanic eruptions in Rotuma, Koro, and Taveuni islands raised limestone reef and alluvial terraces (Leslie 1997).

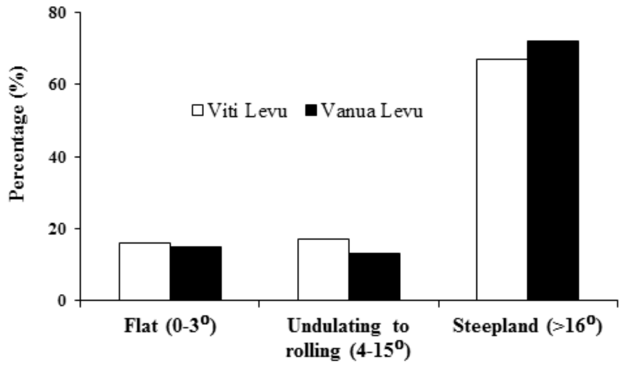

Figure 1. Slope and LUC classes. Source: Twyford and Wright 1965.

Nine of the eleven soil orders are represented in Fiji (Leslie 1997); they are histosols (saturated or peaty soils), Andisols (young, from volcanic parent materials), Oxisols (oxides or Fe and Al, strongly weathered), Vertisols (clayey soils), Ultisols (strong weathered with an argillic horizon), Mollisols (dark coloured surface horizon, high in organic matter and bases), Alfisols (weak to moderately leached with an Argillic horizon, low organic matter in the topsoil), Inceptisols (weakly altered from parent material by leaching and weathering), and Entisols (very young soils with little development of soil horizons). Coastal soils are young and sandy while developed soils are on flat and stable remnants of old plains and terraces. Soils from non-acidic rocks have deep red mottled profiles and iron oxide concretions in the upper horizons. Profiles from acid rocks are high in wet areas, tend to be yellow, mottled red, clayey and not well drained. Crops grown are prone to nutrient deficiencies. Coarse textured shallow soils in low atolls have low capacity to retain water or nutrients and availability of trace elements is low due to soil alkalinity (Asghar *et al.* 1986).

The total area of Class I soils covers only

355,902ha (19.4% of Fiji) with22% in Viti Levu and 15% in Vanua Levu and is suitable for cocoa, mango, dalo and sugar cane without modification. Class II soils comprise of 193,277ha (10.5% of Fiji), of which 8% are in Viti Levu, 13%, in Vanua Levu and 43% in Taveuni but require minor soil conservation works. Soils considered as Class III amounts to c. 587,002 ha with 42% in Vanua Levu and 29% in Viti Levu (Fig. 2). The largest class (IV) with 702,391ha (38.25% of Fiji) is considered unsuitable for agriculture (Leslie and Ratukalou 2002).

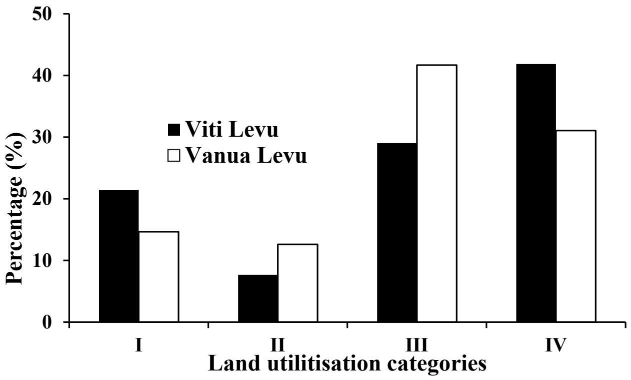

Figure 2. Major land utilization classes (%). Source: Twyford and Wright (1965).

In the early 1800s most of the land area was under forest (Leslie and Ratukalou 2002). Large fires were reported in the 19th century, burning for as long as a week. Ecosystems were modified by tillage, mounding, permanent clearance of forest, control of fallow cover, drainage, irrigation, ponding, exclusion of livestock, weeding, prevention of erosion, and deliberate fertilization. Currently a complex mosaic comprising fern lands, open grassland, reed grass and largely man-induced savannah revert to forest cover in a slow and steady succession process if the land is under fallow.

Fire-maintained fern-grass savannas are common on infertile, eroded, or truncated red soils (*Talasiga*) with few casuarina and pandanus trees. Kirch (1991) grouped major agricultural subsystems into shifting cultivation, intensive dry field cultivation, irrigation and drainage, arboriculture, and animal husbandry. Common current vegetation is a mixture of introduced mission grass (*Pennisetum polystachyon*), wire grass (*Sporobolus* spp.), and thickets of guava scrub (*Psidium guajava*), with remnant trees of ironwood (*Casuarina equisetifolia*) and vadra or screw-pine (*Pandanus tectorius*). Typical trees in the range 150-365masl include baka (*Ficus oblique*), vau (*Hibiscus tiliaceus*), koka (*Bischofia javanica*), ivi (*Inocarpus edulis*), vesi (*Intsia bijuga*) and vaivai (*Serianthes vitiensis*) (Kuhlen 1994).

Intensive, highly productive and sustainable systems developed in pre-colonial times provided techniques and basic principles for farming difficult environments (Denevan 2001). Yams, more important in the past than now, were planted on terraces facing the tradewind and enforced with bamboo shoots to retard soil erosion (Twyford and Wright 1965). Traces of terraced gardens were found in 39 localities in the Sigatoka valley (Parry 1987). Typical garden sizes were of 0.5-50ha range with most common width measuring 4-10m. Nineteen century terraced gardens of the Rewa and Navua deltas are now largely abandoned. Aerial photos show their once intricate hydrological system. Streamside terraced gardens at 200-365masl in the Nakauvadra valley are stone-faced with some walls of over two meters in height and over a meter of fill beneath the garden soil (Kulhken 1994). Before colonization land had to supply all family needs, the gardens were of larger size than today, available tools limited cultivated areas and administrative units were much smaller than today.

3.0 LAND TENURE AND AGRICULTURAL DEVELOPMENT

Large quantity and variety of traditional food crops grown in Fiji were identified as a "hidden strength" of the economy (ADB 1996). Land extensions devoted to agriculture are larger in Western and Northern regions (Fig. 3). The Agriculture industry had a growth of 3.4% in 2013 driven by increase in sugarcane, yaqona, taro, and coconut production. Sugarcane output increase (25.8%) was due to improved supply and milling efficiency (Reserve Bank of Fiji 2015), recovering from a decline by 26.2% in 2012 year (Reserve Bank of Fiji 2013). The Forestry industry recorded also a growth of 10.9% in the same year due to increases in pine and mahogany production (FBoS 2014). The state Fiji Sugar Corporation manages the sugar industry, making contracts with growers and processing sugar cane at four mills. Sugar is grown in the drier north eastern side of the islands by around 22,500 farmers, each cultivating 4-5ha on average producing up to 400,000 tons per year

(Reddy 2003). Mostly, Indo Fijians lease land from native clans (*mataqali*) over 25% of the total territory (Crocombe 2001). Land distribution among ethnical groups is unequal and the leases generally of short term.

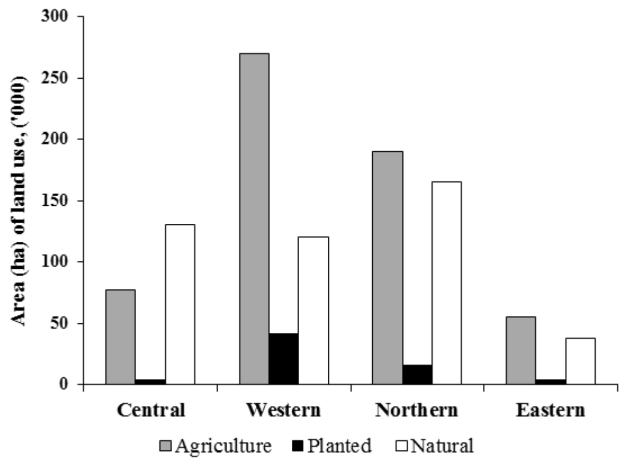

Figure 3. Main types of land use per division in Fiji. Source: National Agricultural Census, MAFFA (1991).

Since the mid 1990s, squatter settlements in Fiji have been expanding at a phenomenal rate, largely due to the non-renewal of agricultural land leases (Thorton 2009). Customary tenure that provided in the past for elements of taxation as contribution in labor, food or service to the community, is now ineffective due to the patterns of inheritance, the increasing distance to the land (Crocombe 2001), and its inability to provide permanent use rights to farms larger than 3ha (IBRD 1965) that constitute 40% of the total farms in the country. Land distribution among ethnical groups is unequal and the leases generally of short term, this confusion may fuel deforestation since one of the most visible ways to place a stamp of ownership is to clear the land, even if the opened space is not used productively (Smith *et al.* 1995).

A second national issue relates to production decline was that, sugarcane production fell by 42% once the land reverted to Fijian ownership, due to late planting and poor cultivation practices (Prasad 1984); however, most native Fijians do not have real access to land (Crocombe 2001). Although the predominant view is that long term leases encourage the buildup of permanent structures and planting of perennial crops (Ushman 1984), they are not necessarily essential for first-best investment incentives, and rental markets are hardly ever pro-poor (Ciamarra 2004). The common view is that future strategies will have to increase land yields in accordance with its capability, and assist on setting up crop processing factories and marketing (Leslie and Ratukalou 2002).

Many rural households produce both food and cash crops, and also earn additional income from fishing. Wet areas produce coconuts, ginger, cassava, taro, kava, bananas and breadfruit; areas with intermediate rainfall produce vegetables, cocoa, passion-fruit and maize, and in minor scale sorghum, tobacco, sweet and Irish potatoes and turmeric. Dry areas produce rice (upland and irrigated), mung beans, pigeon peas, yams, citrus fruit, pineapples and mangoes. Over 40,000 households rely mainly on coconut sales (copra) (Thaman 1994). Bamboo is used for fishing poles, housing and rafts; other preferred trees with high demand for handicrafts are vesi (*Intsia bijuga*), nawanawa (*Cordia subcordata*), and mulomulo (*Thespesia populnea*) are scarce due to over exploitation. Common livestock are poultry, goats, pigs and cattle.

Ethnic Fijians live in nuclear villages, households are often economically inter-dependent (Chandra, 1983). The Fijian word for land (*vanua*) also refers to the people attached to it. Indo-Fijians live independently of each other with no economic inter-dependence between households. Sixty nine per cent of the population lives on Viti Levu while Vanua Levu and Taveuni contribute 20% and the eastern islands 10%. Farm size varies as follows: 2.81ha Western, 2.54ha Central, 11.29ha Northern and 3.09ha Eastern Districts (Macfarlane 2008). Smallholder systems, in some cases with several households per farm, can be of subsistence, semi-commercial or highly commercial. Changes in land holdings reflect the fluctuations in land demand associated with household formation, growth and maturity. A source of inequality in farm sizes is the successive subdivision of land at the death of the owner (Chayanov 1966).

The country implemented a Framework for Evaluating Sustainable Land Management (FESLM) and a Decision Support System (DSS) to assist on organizing land use in accordance to its real capability. The FESLM aims to enhance production (productivity), reduce the level of production risk (stability), protect the natural resources (protection), be economically viable (viability), and socially acceptable (acceptability) (FAO 1993). Its performance is monitored by checking crop yields, nutrients balance, forest regeneration capacity, soil cover maintenance, soil and water quality and quantity, net farm profitability, and participation. The DSS assists decision making and sustainable land management at farm, village, watershed, and regional scales by integrating socioeconomic and biophysical data with indigenous knowledge (Rais *et al*. 1997).

4.0 AGROFORESTRY SYSTEMS: PRESENT AND FUTURE

Contour hedgerow is the principal agroforestry method of soil conservation with annual crops (Young 1997). They aim to reduce run-off, increase infiltration and reduce soil loss through the effect of the barrier, maintain soil organic matter through leaves and root residues, and lead to a progressive development of terraces by accumulation of soil upslope of hedgerows and stabilization of rivers by stems and roots (Young 1997). Trees or perennial crops are planted as a barrier along the contours of a slope, and agricultural crops are planted between them (McDonald *et al.* 1997).

Depending on the species, trees improve soil fertility and modify the microclimate under their canopy both favorably and unfavorably. The magnitude of change depends on canopy and root characteristics, age, size and trees density. The productivity of an agroforestry system depends on: (1) the complementary of resource use by the components, (2) the efficiency of nutrients cycling, and (3) the net value of harvested tree products relative to the net value of crop products (Rao *et al*. 1998). Tree desirable characteristics include a supply of viable seed, fast growth, nitrogen fixation and copious biomass production for use as mulch, fodder, and fuel wood. Selected shrubs and tree should: i) be adapted to the local soil and climate conditions, ii) have low demand for nutrients and be nitrogen fixing, iii) contribute to soil conservation and biodiversity, iv) be culturally accepted by farmers and v) provide economic products. For this, some areas of research are the study of literfall and associated processes, net primary productivity, carbon sequestration, microbial competition, root competition, albedo-reflectance changes at the landscape level, silvopastoral systems, economics, pharmaceutical products and conservation biology (Gordon *et al.* 1997).

In the mid-1970s the Native Land Trust Board identified land growing cane as 'arable', irrespective of slope (Leslie and Ratukalou 2002). The land use section of the Ministry of Agriculture developed a farming model for steep slopes in which three hedgerows (kava, pigeon pea, pineapple, vetiver grass) are placed 20m apart. The vetiver grass hedge is planted at the bottom of the slope acting as a riparian strip to protect gullies. It is more effective in controlling soil erosion than pineapple barriers or farmers practice (Fig. 4). Vetivar grass is commonly used as thatch or handicrafts raw material; however farmers concern is its uncontrolled propagation which led to the removal of old hedgerows established in sugar cane farms 40-50 years ago (Craswell *et al.* 1998).

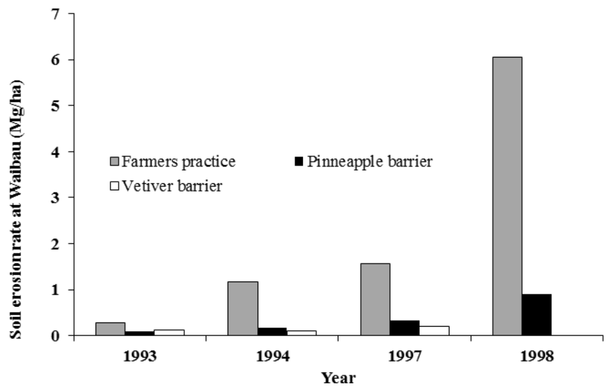

Figure 4. Soil erosion rates at Waibau plots, Naitasiri, Fiji with a slope range of 24-29°. All treatments were cropped with cassava. Source: (IBSRAM 1996; Ratukalou 1998).

Cash crops (melon, tomato, sweet potato, bean, yam, chilies, and papaya) are grown in Sigatoka valley. The farmer may space hedgerows closer at will (Nakalevu *et al.* 2000). The benefits of the hedgerow treatments at the early years after establishment do not outweigh the costs to the farmer, unless the species planted on the contour is a cash crop such as pineapple (Pratap *et al.* 1996). Sloping agricultural land technology (SALT) combines soil conservation and food production. Basically it grows crops in 3-5m wide bands between contoured rows of nitrogen fixing trees; which are thickly planted in double rows to make hedgerows. They are pruned to about 75cm when reaching 1.5-2m, and the tops placed in the alleyways to serve as fertilizer (MBRLC 2012).

Silvopastoril systems are intensively managed production systems. Their commercial viability is influenced by land ownership patterns, soil conditions, climatic factors, proximity to timber and livestock markets, and transportation infrastructure (Sharrow *et al*. 1996). They may outperform pastures and forests as carbon sinks. Sharrow and Fletcher (1994) estimated that Douglas Fir trees associated with pastures in Western Oregon accumulated approximately 740 kg $ha^{-1}yr^{-1}$ more carbon than forest, and 520 $ha^{-1}yr^{-1}$ more carbon than pastures during the 11 years after planting. Increased tree growth of 5 to 10% can be achieved when proper timing, intensity, duration, and class and type of livestock are applied to young conifer forests where palatable understory grasses or shrubs are competing with trees (Sharrow *et al*. 1996).

Economic risks decrease because livestock and forest components require different inputs, share few common diseases and pests, and sell into different markets; in addition, trees can have a climate-stabilizing effect on livestock, resulting in less energy consumption and lower mortality. Recent tree introductions with increased importance in Pacific islands agroforestry systems are Albizzia sp., Cassia sp., *Gliricidia sepium*, a range of eucalyptus or gum trees, caribean pine (*Pinus caribaea*), big-leaf mahogany (*Swietenia macrophylla*) and jambolan (*Syzygium cumini*) (Thaman 1994). Leaves and pods from *Leucaena leucocephala*, *Gliricidia maculata*, *Erythrina* species (drala) and *Calliandra calothyrsus* contain high amounts of crude protein ideal as animal feed, especially useful in dry seasons (Singh 2001); when intercropped with coconut palms, *L. leucocephala* and *G. maculata* control weeds, improve soil structure and copra yields. Fodder is obtained by cutting at 50-150cm height every two months, and fuelwood by pruning every 3-4 months (Rosa 1993).

Kellas *et al.* (1995) reported greater pasture production at 10.5m and 18m from the tree line compared with the open pasture system. However, production tended to decrease with increasing tree density (Kellas *et al.* 1995). When water deficits occurs understory competition affect tree growth and quality (Peri *et al.* 2002). While trees grown in bare ground grew higher than trees grown with understory competition, they also had poor stem quality affecting the net revenue at harvest. Mahogany (*Swietenia mahogani* L.) is large, fast growing timber specie which does not fully utilize solar energy and land resources at early stages of the life cycle. Datta and Dey (2009) successfully transplanted five weeks old chilli seedlings into four years mahogany plantation at 5x3.5m spacing. Tissue cultured bananas and sweet potatoes are planted with Mahogany, Vesi, and Dakua trees in the boundaries of Labasa farms in Vanua Levu (http://agroforestrypacific.blogspot.com); and turmeric is being intercropped with cocoa plants. *Santalum yasi,* a shrub with semi parasitic behavior and highly demanded essential oil was observed with 16 host trees in Viti Levu farms (Goswami and Singh 2014). Coniferous trees are of easy site adaptability and rapid response to intensive management, their conical crowns allow more light to reach the forest floor and are less likely to be browsed by livestock (Sharrow and Fletcher 1994).

Major interactions in hedgerow intercropping that affect crop yields are related to soil fertility, competition, weed control, and soil conservation particularly on sloping lands. Hedgerow intercropping might increase the yield of the closest crop rows on the sheltered side (Huxley *et al.* 1994) and in short periods of time, control soil erosion (Banda *et al*. 1994; Kiepe and Rao 1994) and reduce soil evaporation when pruned foliage is used as mulch (Tian *et al*. 1993).

5.0 CONCLUSION

Agroforestry systems provide ways to manage scarce natural resources that balances environmental stewardship, financial feasibility and social responsibility. Although the islands have great potential to develop them enhancing agricultural yields and controlling soil losses, basic research on socioeconomic impacts, native and exotic tree species, symbiotic and allelopathic relationships, and appropriate low input technologies need to be implemented. Unsolved land tenure issues discourage long term investments on land development, however, planting delays and/or overextended fallows ultimately restitutes soil fertility. The re-establishment of appropriate time-tested systems of edible aroid cultivation like irrigated terraces, drained swamps, forest taro production and the intensification of relatively new SALT techniques are needed in hilly areas. Ambitious agricultural plans like the ones described in the Fiji 2020 Agriculture Sector Policy Agenda (MoA 2014) may need to stress the importance of research and extension, the opening of new markets for organic products, prices stability, and transparent land rights that will prevent both land misuse and overuse, and encourage long term investments. Future land reformation plans will have to be implemented step by step according to local conditions, facilitate productivity, overcome the legacy of colonial tenures, and reestablish a more effective organizational structure within groups of joint landholders.

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SHORT NOTE

Rationale for suspension of live cattle imports from Australia and New Zealand to prevent introduction of the pathogenic blood borne parasite *Theileria orientalis* Ikeda to Fiji: qualitative risk assessment.

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ABSTRACT

The pathogenic blood parasite of cattle, *Theileria orientalis* Ikeda strain is not present in Fiji; however, it recently became established in Australia and New Zealand where it causes significant disease. The tick *Haemaphysalis longicornis* Neumann, is a competent vector and is widespread in Fiji. Consequently, if cattle infected with *T. orientalis* Ikeda were imported into Fiji the parasite would become established. A qualitative risk analysis of live cattle importation was performed. It was concluded that it would be very difficult to source uninfected cattle from New Zealand or Australia. There is insufficient validation data available to use the currently available polymerase chain reaction (PCR) test to ensure animals are free from infection. The parasite could cause significant disease if introduced into Fiji and it would be impossible to eradicate. Consequently it is recommended to continue precautionary suspension of live cattle imports from countries where *T. orientalis* Ikeda is present.

Key words: *Theileria orientalis* Ikeda, risk assessment, Fiji

1.0 INTRODUCTION

In 2011 the Ministry of Agriculture imported 210 dairy cattle from New Zealand to Fiji. In 2014 the Ministry planned to import another shipment of cattle from New Zealand; however, in 2012 a pathogenic blood parasite of cattle, *Theileria orientalis* Ikeda strain, was identified for the first time in New Zealand. It quickly became established and caused significant disease (Bingham 2013).

The *T. orientalis* parasites are apicomplexan protozoans that cycle between two hosts: cattle and ticks. Cattle harbour the piroplasm in blood erythrocytes and the sporozoites develop in the salivary gland of the tick *Haemaphysalis longicornis* (Riek 1982; McFadden 2014).

The tick *H. longicornis* is widespread in the Pacific Islands, including Fiji (Hoogstraal *et al.* 1968). Consequently, if cattle infected with *T. orientalis* Ikeda were imported into Fiji the parasite would become established, with potentially serious adverse consequences for the cattle industries.

It was presumed that Fiji was free of *T. orientalis* Ikeda because no live cattle have been imported since the parasite was found in New Zealand. Furthermore, there have been no reports of clinical disease in cattle (haemolytic anaemia) that could be attributable to infection with the parasite.

Nevertheless, because there was a remote possibility the parasite could have been introduced into Fiji, the Ministry of Agriculture Animal Health and Production Division conducted trace back and testing of recently imported cattle. Specific PCR tests demonstrated that Fiji remains free of *T. orientalis* Ikeda (McLachlan and Angus, in press). The Ministry of Agriculture had to decide whether to continue with plans to import live cattle from New Zealand or to recommend suspension of live cattle imports from countries where *T. orientalis* Ikeda is established. Here we outline the rationale for recommending suspension of cattle imports from Australia and New Zealand.

2.0 RISK ASSESSMENT

Fiji has long established and well developed livestock industries which make significant contributions to the national economy and employment. The largest livestock industries are dairy and beef cattle (Anon 2009).
Fiji enjoys enviable animal health status. The major exotic pandemic infectious diseases are not present, nor are many less serious diseases such as Bovine Viral Diarrhoea, Infectious Bovine Rhinotracheitis and Johnes Disease (OIE 2014), whilst *Fasciola hepatica* infection is rare.

Nevertheless tuberculosis and brucellosis have had severe impacts on the dairy industry. The costs incurred include the resources expended on control, the loss of culled animals, restrictions on animal movement, constraints on sale of livestock and a shortage of breeding stock.

When conducting Import Risk Assessment veterinary authorities must address two considerations: 1. the risk that a disease could be introduced and whether practical steps could be taken to decrease the risk. 2. the impact of the disease should it arrive, including likely effects on the livestock industries and the feasibility and cost of control measures.

The likelihood of introducing the parasite *T. orientalis* Ikeda with cattle imported from New Zealand is assessed as being high. By 2014 *T. orientalis* Ikeda strain had become widespread in the known range of *H. longicornis* in New Zealand. The range of *H. longicornis* largely overlaps with the distribution of the dairy cattle population. Therefore non-selective purchases of dairy cattle would almost certainly include infected animals.

Consideration was given to sourcing animals from outside the traditional tick range; however, the structure of the modern dairy industry means there is extensive movement of cattle for grazing. Indeed a large proportion of the dairy animal population moves into or out of the tick range each year. In addition, the tick range appears to be larger than previously recognized. Cases of clinical theileriosis have occurred in areas previously thought to be tick free (MPI 2014).

Whilst there may be some remaining uninfected herds, they are generally small closed herds which do not offer large numbers of cattle for sale. It was concluded that it would be very difficult to source uninfected animals. Moreover once the animals were moved off the farm of origin for pre-embarkation processing they would be at risk of infection.

The New Zealand Ministry for Primary Industries has developed a PCR test for *T. orientalis* Ikeda in house, and used it to confirm infection in animals that met the case definition for *Theileria* associated disease : anaemia (PCV < 0.24) and piroplasms present on a smear (McFadden and Vink 2015). It is one author's experience (ADM) that a few individual animals which displayed the strongly regenerative anaemia characteristic of *Theileria* associated disease were PCR negative, even when herd mates were positive.

This finding indicates that the sensitivity of the PCR is less than 100% at the individual animal level in diseased animals. Although the PCR was used appropriately in New Zealand to confirm infection in herds with animals displaying clinical disease, the test may be of limited use for identifying individual infected clinically normal animals. If the PCR test were used to in attempt to identify uninfected animals for export to Fiji from New Zealand, there would be a significant risk of introducing false negative animals i.e. animals that are infected but which give a negative test result.

Moreover we are not aware of any data regarding the ability of the PCR to detect *Theileria* sp. infection in clinically normal animals. Because the diagnostic performance of the PCR has not been determined and the PCR has not been validated as a diagnostic test, its utility for testing populations of normal animals for infection remains unknown. Consequently it is impossible to determine how the PCR can be used validly as part of an import protocol.

If *T. orientalis* Ikeda were introduced into Fijian cattle it is impossible to predict how severe the disease manifestations would be. Nevertheless inferences can be drawn from the Australian and New Zealand experiences. The *T. orientalis* Ikeda strain was found in Australia after sporadic occurrences of clinical anaemia in New South Wales and Queensland. Since the mid-2000s there have been ongoing reports of clinical anaemia associated with *T. orientalis* Ikeda infection which has been styled Theileria Associated Bovine Anaemia (TABA) (Izzo *et al.* 2010).

When the disease was first found in New Zealand, based on the Australian experience, the authorities at first hoped that the disease would be mild and sporadic. However, unlike Australia, the infection spread in classic epidemic fashion modified by seasonal peaks in incidence. Of concern is that the clinical disease has been more severe than expected (Lawrence *et al.* 2014).

The reason for the greater severity of disease in New Zealand than Australia is unknown. In New Zealand the disease has higher incidence in dairy cattle whereas in Australia mostly beef cattle were involved initially. However, there are recent reports of more severe disease in dairy cattle in Victoria (Moroz 2012).

An untested hypothesis has been advanced that the severity of disease may be correlated to the tick population density, hence the ongoing parasite challenge. If this hypothesis is correct, because the tick population density is higher in Fiji than in Australia or New Zealand, we could anticipate the manifestation of disease in Fiji might be severe.

In Fiji the tick breeds year round. Moreover, unlike New Zealand and Australia, Fiji has abundant roaming dog populations which effectively spread ticks around. Consequently *T. orientalis* Ikeda could become widely established in a short time. Nevertheless the scattered distribution of cattle populations may mean that endemic stability might not be achieved, hence the spatial and temporal incidence of disease is unpredictable. It must be acknowledged that the foregoing is conjecture. It would be helpful if more information were available from East Asia where the parasite is endemic.

3.0 CONCLUSION

Fiji's dairy industry has struggled with brucellosis and continues to struggle with tuberculosis, losing breeding animals slaughtered as part of control programmes. We envisage that the dairy industry could ill afford another infectious disease.

Because *T.orientalis* Ikeda could not be eradicated once introduced into Fiji and the likelihood of severe effects on the cattle industries is high, the Ministry of Agriculture recommends continued precautionary suspension of live cattle imports from countries where *T. orientalis* Ikeda is present.

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SHORT NOTE

A Golden Anniversary for Soil Science in Fiji

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2015 represents the golden anniversary of the publication of a most significant document for soil science in Fiji. ***The Soil Resources of the Fiji Islands***, 2 Volumes, by Ian T. Twyford and A. Charles S. Wright was published in 1965 by the government printer in Suva. This was the result of intensive field work with accompanying laboratory studies and a detailed inventory of land use in the colony (as it was then) in the 1950s and early 1960s. The publication consisted of a descriptive and interpretative volume (Volume 1, 570 p) and an accompanying set of maps (Volume 2). The set was originally sold for 7 guineas (£7-7-0).

Volume 2 contained a set of 8 soil map sheets produced at a scale of 1 inch to 2 miles (1: 126,720), 8 land classification sheets, a soil map legend, a land classification map legend, a general soil pattern, a generalised land use map, a geological map, a rainfall and climate environmental map, a map of alienated land in Fiji, a landslope map and a population distribution map. These two volumes thus presented an extensive body of information on the soils of Fiji providing the country with one of the best resource statements of any developing country at that time. The information was widely used for land use and other resource decision making for about 30 years until new soil maps and accompanying information was produced following new soil mapping and related research in the 1980s.

This new information was produced in a collaborative effort coordinated through the Land Use Section of the Fiji Department of Primary Industries, and led by a senior soil surveyor (D.M. Leslie) seconded using NZ Ministry of Foreign Affairs and Trade support. Substantial support came from the New Zealand Soil Bureau DSIR (now part of Landcare Research Manaaki Whenua), along with financial and technical inputs from Australia and USA. Collaboration involved the University of the South Pacific, the Sugar Research Centre of the Fiji Sugar Corporation (now the Sugar Research Institute of Fiji), Fiji Pine Commission. Queensland DPI, South Pacific Applied Geoscience Commission (SOPAC) and the Secretariat of the Pacific Community (SPC).

The new information includes a set of 48 soil maps at scale of 1:50,000 covering the whole country, an accompanying set (Leslie and Seru, 1998) of Soil Taxonomic Unit Description Sheets for each of the 220 soil series identified, a monograph summarising the key features of the soils of Fiji (Leslie, 1997), detailed soil survey reports of the Fiji government agricultural research stations (and the Tutu station on Taveuni), and a user friendly interpretative manual for managing Fiji soils (Leslie, 2012). Fiji once again has one of the best soil information databases for strategic land use planning and management.

Over the last 50 years significant changes have occurred in the Fiji economy with a move away from heavy dependence on sugar and other agricultural commodities as the main foreign exchange earner. Tourism, mining and forestry have become more important, but there is still a heavy dependence of soil related activities for export earnings and local economic activity. Domestic production of food is still of critical importance and a degree of subsistence living is still found in more rural areas.

This dependence on soil resources is expected to continue far into the future and the knowledge base that should be used for land use and related decision making is now readily available.

Activities based on Twyford and Wright have helped Fiji in achieving many of its development goals, and the future well-being of its citizens will continue to involve good use of the soil resources.

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SHORT NOTE

Evaluation of promising tomato varieties

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ABSTRACT

Six varieties of hybrid tomatoes were evaluated at Taiwan Technical Mission demonstration farm in Sigatoka Research Station in 2014 arranged in a RCBD design with three replications. These varieties were AVRDC No. 10, AVRDC No. 5, Raising Sun No. 2, King Gang, Moneymaker and Bright Pearl. There was no significant difference in the yield per hectare recorded amongst the different varieties. However, Moneymaker recorded the highest yield of 36.69 t ha^{-1} and AVRDC No. 5 recorded the lowest yield of 30.78 t ha^{-1}.

Key words: tomatoes, yield, varieties.

1.0 INTRODUCTION

Sigatoka in the western side of Viti Levu continues to see an increase in the number of small and medium scale vegetables producers. Growers are producing vegetables for sale and distribution through various marketing chains. Tomato is one of the most frequently grown vegetable crops in the region and serves as a leading product for many local roadside stands and produce auctions.

It has been observed locally in the Sigatoka region that growers tend to use hybrid varieties. While many older varieties are available, locally generated performances data would encourage growers to switch to these varieties. This trial is a continuation of our work, where our goal continues to be to evaluate hybrid tomato varieties available to local growers in an effort to identify those that are best suited to production in our region.

2.0 MATERIALS AND METHODS

Seeds of six tomato varieties were sown into 50 cell flats on June 12th. Seeds were germinated and were transplanted in the greenhouse at the Taiwan Technical Mission demo farm in Sigatoka. Tomato varieties consist of AVRDC No. 10, AVRDC No. 5, Raising Sun No.2, King Gang, Moneymaker and Bright Pearl. Both determine and indeterminate varieties were included.

Prior to transplanting poultry manure of 1,000kg per 1,000m^2 was applied and rotovated. Fertilizer NPK 15-15-15 (40kg ha^{-1}) was broadcasted at the time of planting. Side dressing of Urea water at 500g per 200 liters of water was applied every 15 days after planting. Seedlings were transplanted into raised beds covered with black silver plastic on July 5 at a plant spacing of 0.8m between rows and 0.8m within the rows.

The size of each plot was 14.4m^2 (1.2m × 1.2m) with 12 plants per row in a bed. Plots were arranged in a randomized complete block design with three replications of each variety. After transplanting, plants were grown in accordance with accepted commercial practices and were trellised using bamboo. Kocide fungicide and malathion both at the rate of 16g in 16 liters of water were applied every two weeks until the first harvest.

Individual plots were harvested between 1st and 30th September. Following harvest, fruit from each plot were graded as marketable and non-marketable depending on the shape and physical damage. All fruits were counted and weighed. Data were then compiled and subjected to appropriate statistical analysis. Following harvest, data were compiled and subjected to an analysis of variance. Mean values were separated using the Duncan's Multiple Range Test (DMRT).

3.0 RESULTS AND DISCUSSION

There was no sign of disease from transplant to the first harvest and plants were harvested after every 3 days in a week beginning on September 1st and ending on September 30th (8 harvests). Some plants were infected with Curly Top Virus and were uprooted.

Table 1. Mean Performance of Varieties

Varieties	No. of fruit per plant	Weight per fruit (g)	Weight of fruits per plant(g)	Plot yield (Kg/14.4m^2)	Yield per hectare (Ton/Ha.)
AVRDC No.10	12.4b	180a	2,219a	44.38a	30.82a
AVRDC No.5	13.5b	164ab	2,216a	44.33a	30.78a
Raising Sun No.2	22.2a	106e	2,344a	46.87a	32.55a
King Gang	15.5b	149bc	2,313a	46.27a	32.13a
Money-maker	20.1a	131cd	2,641a	52.82a	36.68a
Bright Pearl	20.8a	115de	2,219a	47.86a	33.24a

In a column, means followed by the same letter are not significantly different at the 5% level by Duncan's multiple range tests (DMRT).

The highest number of fruits (22.2) was recorded for Raising Sun No.10 and the lowest (13.5) for AVRDC No.5 (Table 1). There were no significant differences noted in the size of fruits for the AVRDC No.5, King Gang and AVRDC No.10. AVRDC No.5 and AVRDC No.10 are bigger and round in shape whereas King Gang fruits shape is flat. Money maker shape is oval while Bright Pearl is also oval with smaller size fruits.

AVRDC No.10 had the highest weight per fruit (180g) followed by AVRDC No. 5 (164 g) and King Gang (15.5 g) while Raising Sun No. 2

recorded the lowest (106 g). Moneymaker had the highest weight of fruit per plant (2,641 g) followed by Raising Sun No.2 (2,344 g) and King Gang (2,313 g) however, they were not significantly different between each other. Moneymaker recorded the highest yield per hectare (36.68 t ha^{-1}) which AVRDC No. 5 recorded the lowest yield of 30.78 t ha^{-1}). However, there were no significant difference in yield between tomato varieties.in.

4.0 CONCLUSION

Even though there were significant difference noted amongst the different varieties, Money marker recorded the highest yield and is recommended for farmers in the Sigatoka valley. This evaluation trial will be repeated in the offseason to further determine the performance of these varieties under such conditions.

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SHORT NOTE

Influence of Mucuna (*Mucuna pruriens*) fallow crop on selected soils properties and taro yield in Taveuni, Fiji

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SUMMARY

Soil fertility decline remains one of the most serious problems facing agriculture in the tropics. In many developing countries nutrient depletion already threatens food production and food shortages are again a problem. Methods for controlling soil degradation and improving productivity are well known but economic and political factors determining the acceptability of improved practices have limited their adoption. In spite of criticisms, the 'green revolution' methods of greater fertiliser use with responsive crop varieties have mostly ensured that food production has kept pace with the rapid population growth of the past decades. Nevertheless, the economic problems determining the costs of importing, manufacturing and distributing fertilisers, key factors in countering soil fertility decline and ensuring yield improvement, have not been solved. Crop production cannot be sustained unless nutrient removals are balanced by replenishment, and soil erosion is controlled.

Currently, more than 95% of the human population increase is in the tropics, which puts existing agricultural systems under stress. In order to produce sufficient food and to curb land degradation, productive cropping systems need to be developed. The sustainability of cropping systems is largely affected by the judicious management of the soil chemical fertility. This has been recognised for many decades, but there is a need for hard data on soil changes and nutrient management strategies in order to improve our understanding of agricultural systems and to design sustainable cropping systems in the tropics. Soil productivity decline, nutrient mining and sustainable land management in the Pacific has focused on low external input agriculture by subsistence farmers. With growing interest in reducing excessive synthetic chemical inputs in farming, the importance of cover crops as determinant of productivity has been recognised in many countries. Cover crops provide a lot of benefits for agricultural soil, such as supplying soil organic matter, preventing wind and water erosion, adding biologically fixed nitrogen, scavenging soil residual nutrients, suppressing weeds and breaking pest cycles. However, these benefits can be greatly improved by selecting the most suitable species and rotation.

This has been the focus of this research considering the constrained economic climate under which an average farmer operates. The comparative effects of mucuna (*Mucuna pruriens*) fallow and farmer's natural fallow (mostly grasses and creepers) was evaluated on continuously cropped taro soils. The mucuna fallow was introduced since natural fallow systems tend to take a longer time to restore soil productivity. The fallow cover crops were grown for durations of 6 and 12 months for evaluation of changes in soil properties. A separate fallow trial was established for duration of 6 months after which, a crop of taro was planted to investigate any fallow effects on the yield of taro.

Biomass production (dry matter basis) under mucuna fallow treatment significantly ($P<0.05$) out-yielded that of grass fallow treatment in both 6 and 12 month fallow durations. At both fallow durations mucuna fallow crop significantly accumulated ($P<0.05$) higher levels of plant N,

P, K and Ca as compared to grass fallow crop. As the fallow duration increased, the dry matter production also increased in both the fallow systems.

Under the 6-month fallow duration, lime application to grass fallow resulted in significant increase ($P<0.05$) in soil pH (from 5.3 to 5.6); however, the same application to mucuna did not. Under the 12-month fallow duration, both the fallow types that were applied with lime resulted in significantly ($P<0.05$) higher soil pH. However, there were no significant differences ($P>0.05$) in pH between 6 and 12-month grass fallows applied with lime treatments but both the 6 and 12-month grass fallows treated with lime had significantly ($P<0.05$) higher soil pH than the control (grass fallow). In contrast, there were significant differences ($P<0.05$) between 6 and 12-month mucuna fallow treated with lime. Under the 12-month fallow duration, both the fallow types that were applied with lime resulted in significantly ($P<0.05$) higher soil pH.

Total soil organic carbon levels significantly increased ($P<0.05$) as the fallow duration increased from 6 to 12 months but there were no significant ($P>0.05$) differences amongst the two fallow types at both the durations and additional applications of lime and rock phosphate. Changes in Olsen available soil P over time with different fallow types, fallow duration and application of lime and rock phosphate were not significant ($P>0.05$). There were significant differences ($P<0.05$) in total nitrogen levels between 6 and 12 month fallow duration across all the treatments but there were no significant differences ($P>0.05$) between the fallow types, lime and rock phosphate application. Total nitrogen levels significantly increased ($P<0.05$) with increase in fallow durations across both the fallow types.

Calcium levels significantly ($P<0.05$) increased with the application of lime under both the fallow durations and fallow types. Magnesium levels remained fairly constant across all the treatment combinations except under 6 month mucuna with no additional application of lime and rock phosphate where it was recorded to be lowest. Potassium levels significantly ($P<0.05$) increased with the increase in the length of the fallow duration across all treatments but there were no significant differences between any treatments within the 2 durations. Soil bulk density significantly increased ($P<0.05$) with the length of the fallow duration across all treatment combinations but there were no significant difference amongst all the treatments at the same fallow duration. Furthermore, significant associations ($P<0.05$) were found to exist between soil pH and earthworm population; bulk density and earthworm population; exchangeable calcium and soil pH; and, total organic carbon and earthworm population.

Taro grown under mucuna fallow significantly ($P<0.05$) out-yielded (11.8 t/ha) those grown under grass fallow systems (8.8 t/ha). Overall taro grown under mucuna fallow type had 33.5% higher yield than taro grown under grass fallow type. Significant differences ($P<0.05$) found in yield components of taro grown under different fallow types include taro leaf area, plant height, leaf number and leaf length. Significant associations ($P<0.05$) were found to exist between yield of taro and leaf area ($r = 0.75$), leaf number ($r = 0.52$) and leaf length ($r = 0.32$) while plant height ($r = 0.28$) only marginally correlated with yield.

The gross margin analysis of taro grown under mucuna and natural fallow systems revealed 52% higher returns from taro grown under mucuna fallow. This is mainly due to significantly greater taro yield obtained under mucuna fallow. In addition, weed suppression in taro grown under mucuna was significantly greater ($P<0.05$) than that grown under natural fallow of grass.

From this study, it was evident that mucuna fallow offers benefits for sustainable crop production systems. Mucuna fallow significantly increased ($P<0.05$) taro yield, farmers' profit margin and reduced weed numbers as compared to traditional grass fallow. Mucuna fallow had significantly higher ($P<0.05$) biomass production and accumulated higher levels of N, P, K and Ca. Secondly, longer fallow duration is vital for rejuvenating heavily cultivated soil. As the fallow duration increased from 6 to 12 months, total soil organic carbon, nitrogen, potassium, bulk density and earthworm numbers increased significantly ($P<0.05$). Furthermore, application of lime over time can significantly improve soil pH and Ca levels. Taveuni soils have high acid extractable aluminium levels (2% or more) and low bulk density (less than 0.9 g/cm^3). Application of lime, mucuna fallow and longer fallow duration

can sustainably overcome these problems. Application of rock phosphate had no significant (P>0.05) effect on taro yield and soil phosphorus levels during the research period. Rock phosphate should be finely ground and incorporated into the soil. The rock phosphate used in this experiment was coarse and was broadcast on the soil surface, thus solubility was low.

Key words: Taro, *Colocasia esculenta*, *Mucuna pruriens*, soil fertility, Taveuni

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SHORT NOTE

In Vitro virus elimination from taro (*Colocasia esculenta* (L.) Schott) for conservation and safe international exchange

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SUMMARY

Taro (*Colocasia esculenta* (L.) Schott) is a very important Pacific Island crop for food and nutritional security, being ranked in the top five of food crops. It is also very important culturally and for a few countries, makes a significant contribution to its economic growth. However pests and diseases as well as the increasing challenge of climate change are affecting taro production. Failure to address these challenges could lead to serious consequences on food security and trade.

Crop improvement either through selection or breeding offers a solution to these challenges, but availability of and access to taro diversity is essential for any worthwhile and effective selection and breeding programme to be implemented. The Centre for Pacific Crops and Trees (CePaCT) of the Secretariat of the Pacific Community (SPC) has a unique repository of taro diversity and is mandated to facilitate the conservation and safe exchange of this diversity.

CePaCT, SPC is able to achieve this exchange through *in vitro* cultures but the challenge of virus infection in taro cultures has prevented the exchange of some of its valuable diversity. The aim of this research was to investigate methods for the elimination of different viruses in taro. Using *Dasheen mosaic virus* (DsMV) as a model virus, the research evaluates different elimination methodologies (meristem extraction, chemotherapy, electrotherapy and thermotherapy), and proposes possible techniques for the routine elimination of viruses from taro. All methods evaluated were successful in the elimination of DsMV from taro. However, with electrotherapy, the highest regeneration was obtained (*avg.* 91.66%), as well as effective elimination of DsMV (*avg.* 76.57%) compared to the other three methods. Importantly with electrotherapy plantlets recovered faster than the other therapies (at least 1½ month faster than the other therapies). Of the four techniques evaluated, electrotherapy and thermotherapy had the highest therapy efficiency rates, 71.66% and 43.3%, respectively. Either of these methods can be used routinely to eliminate DsMV and optimized for the elimination of other viruses infecting taro.

A prerequisite for virus diagnostics is the availability of reliable detection methodologies. Both serology and molecular based diagnostics are available for the detection of DsMV. For germplasm exchange it is necessary to ensure that the most reliable and sensitive of the methods is used for the purpose of virus testing. Commercially available DAS-ELISA kits (Agida® Inc, France) and RT-PCR developed by Maino (2003) were compared to see which test was more effective in detecting DsMV from naturally infected samples. Comparisons between the two methods found that RT-PCR was 10 times more sensitive than the DAS-ELISA. RT-PCR was able to detect DsMV from 10^{-3} diluted samples while the DAS-ELISA had a detection limit of 10^{-2}. ELISA however, is much cheaper per sample than RT-PCR (15 times cheaper), requires less technical expertise, and does not require purpose build infrastructure. ELISA can be incorporated into national surveys and testing schemes so that production can be maintained at optimum level by reducing DsMV

infections in the field with annual testing and rouging. RT-PCR should be used at gene bank level as testing at the highest level of sensitivity and accuracy is required.

Availability of reliable testing method such as RT-PCR and the means (electrotherapy and thermotherapy) to eliminate DsMV will allow the dissemination of valuable taro diversity conserved at CePaCT, SPC. This research also provides foundation for future work on the elimination of other viruses from taro.

Key words: Taro, *Colocasia esculenta*, virus elimination, electrotherapy, meristem, chemotherapy, thermotherapy, ribavirin, adefovir, regeneration, *in vitro*, RT-PCR, *Dasheen mosaic virus* (DsMV), CTAB, ELISA

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SHORT NOTE

Trends in production and trade of major crop products in Fiji

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SUMMARY

Agriculture and its allied activities sustain bulk of rural population in developing countries such as Fiji. Development of agricultural sector not only helps in alleviation of rural poverty but also supports sustained economic growth in the country through its forward and backward linkages with other sectors of the economy. But, the growth of agricultural sector in Fiji has been very sluggish.

For designing effective development strategies a thorough understanding of the country's agricultural situation, especially about the strengths and weaknesses of the farm production and trading systems is very essential. Keeping this research gap in view and the importance of evidence-based agricultural development planning, the present study was undertaken to analyse trends in production and export of major crop products of Fiji and to identify the constraints faced by farmers in moving forward. Knowledge of root causes of the tardy growth in production and trade of agricultural commodities helps in finding solutions for acceleration of agricultural development in the country.

The study analysed time-series data for the period 1991 to 2010 for sugarcane, coconut, taro, papaya and ginger crops. Linear trend equations and growth rates were estimated for area, yield, production and export of each of the crops under study. National level data about the crops were obtained from the government sources. Data about the constraints faced in production and trading of crop products were obtained by a sample survey of farmers and exporters.

The study revealed that during 1991-2010 in Fiji, the area, yield and production of sugarcane crop were decreasing continuously at significant rates. Consequently, the quantity of sugar exported from the country was also declining over time.

This decreasing trend in sugarcane production was due to decline in area as well as yield rate of this crop. As most of the area under sugarcane crop was under lease from Mataqali (the Fijian clans), due to expiry of old land leases from 1997 onward there has been exodus of a large number of sugarcane tenant farmers and their families into informal settlements in the periphery of urban centres in the country or abroad. Yield per hectare was declining because in sugarcane farming, an intensive mono-cropping system was practised on the same piece of land continuously for the past 3-4 generations without crop rotation.

This resulted in soil fertility decline on the sugarcane farming lands. Also, frequent breakdown of sugarcane crushing mills leads to harvested cane deteriorating on stand. The trend analysis showed that if things remain as they are the area and production of sugarcane (and hence sugar exports) would further decline in Fiji.

As regards coconut crop, its area, production and export also had negative trends overtime. The decline in coconut production was mainly due to the decrease in the area of this crop. Coconut is a long term (about 40 years) income generating crop. It has about 5 year gestation period for the farmer to start benefiting from investment in this crop. Continuous fall in copra prices have changed mind-set of the coconut farmers forcing them to neglect replanting of coconut trees and opting

for short duration profitable crops. Furthermore, as most of the coconut farms are located in the Maritime Provinces, cost of transportation was high as farmers have to pay a hefty sum to boat owners for transporting their products to markets. Yield rate of coconut crop was also declining as most of the trees are quite old.

In the case of Taro crop, during 1991-2010, there were rapid and significant increases in its area, yield and production. Growth rate of taro export was also positive and significant.

The analysis revealed that in the growth of taro production, the contribution of yield-effect was stronger than the effect of area. This positive outcome was due to major emphasis placed by government on increasing production of taro to meet the growing demand for taro in the external markets. The trend analysis indicated that production and export of taro will further increase in Fiji.

As regards papaya crop, its area, yield, production and export increased at significant rates during the period 1991-2010.The major contribution to the overall rapid growth of papaya production in Fiji was by the 'interaction-effect' of area and yield of the crop. However, there were high fluctuations in papaya production from year to year as this crop is very susceptible to natural disasters, especially to flooding and cyclones. Poor drainage affects the crop causing rot. As majority of the papaya area was under native lease, the tenant farmers were reluctant to make long-term investments in improving drainage system on their leased-in farms.

The other major factor that hindered expansion of papaya area was low prices received by the farmers. Papaya fruit being highly perishable farmers cannot hold their produce longer. Hence, they are price takers and the marketing middleman (buyer) determines the price.

The situation of ginger crop was a little different. Its area, yield, production and the quantity exported was decreasing significantly. Main cause for decline in ginger production and export was high cost of production. Ginger crop production requires higher level of skills starting from sowing till harvesting. Continuous increases in the prices of agro-inputs (e.g., fertilizer, chemicals, and planting material) and high transportation costs decreased farmers' profit margin forcing them to shift to other, low input crops. To boost production of this spice crop in Fiji, it is essential to provide farmers with proper incentives and to develop agricultural marketing infrastructure in the rural areas of the country.

The study concludes that despite negative growth rates in sugarcane area and production and exports of sugar, this crop will remain lifeline of the Fiji's rural economy. Therefore, it is essential to give due attention to the problems of this crop. Similarly, coconut crop is a strong source of income for the people in the outer islands, its importance in rural household income and food security should not be undermined in the agricultural development planning of the country.

Taro and papaya are the cash crops produced for export and domestic markets. Area and production of these crops have been increasing steadily which should be further strengthened. Ginger is also a high value crop and the agro-climatic conditions of Fiji are quite suitable for its production. Government should support farmers in expansion of ginger area and production.

As a long term strategy to raise production and exports of farm products, it is suggested that farming areas lying unused after expiry of the land leases should be fully utilised. Secondly, to augment yield rates of crops, new sustainable farm technologies should be evolved by enhancing research and extension efforts in the country so that higher outputs could be obtained from the available land resources.

Key words: Taro, papaya, ginger, coconut, sugarcane, Fiji

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SHORT NOTE

Examining the chemical fertility of soils in Taveuni, Fiji: The problem of soil health and food security

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SUMMARY

Studies have shown that the soil health in Taveuni, Fiji is deteriorating over time due to continuous plantation and indiscriminate and imbalanced fertiliser use. The declining trend in soil fertility on the island of Taveuni, Fiji has threatened taro producers. There are visible impacts of deteriorating soil health such as stagnating/plateauing crop yields and slow agricultural growth. This situation has resulted in high rates of deforestation on the island as farmers are forced to search for new fertile soil.

Despite the crucial role of agriculture in Fiji's economy and the increasingly serious issue of soil degradation in Taveuni, Fiji, a perusal of literature reveals that no chemical analysis of the soils in the taro growing areas of Taveuni has been carried out. This project was therefore undertaken to study the problem of soil health affecting food security by examining the chemical fertility of soils in Taveuni, Fiji.

Four farms were selected as the study sites. Soil samples were collected four times during the cultivation period of taro: before planting of mucuna beans, before planting of taro, three months after planting of taro and at the time of harvest. The soil samples were analyzed for macronutrients (Ca, Mg, K, P and NO_3^--N), micronutrients (Cu, Fe, Mn and Zn), soil organic matter (SOM) and soil pH. Structured questionnaire survey was also conducted on 50 farmers from areas near the sampling sites to get a feedback on the trend of their crop production over the years, fertiliser usage and some of the constraints the farmers faced in following proper soil fertility management practices.

The adequacy of applied methodology for soil nutrient analysis was confirmed by measures of accuracy, reproducibility and recovery. Calibration was performed by the method of standard additions and quality control. Inter-laboratory comparison of results was carried out to confirm the accuracy of the method used. The detection limit for the essential nutrients in the soil matrix was also determined as a quality control measure. Measurements of each sample were carried out in three replicates. Mean, standard deviation and relative standard deviation were calculated for interpretation and comparison of data.

At the time of harvest, Matei site showed low levels of SOM, NO_3^--N, available P, exchangeable Ca and extractable Zn. The site however, had ideal levels of exchangeable Mg and K, as well as extractable soil Cu, Fe and Mn. During the same period of time, Mua site showed low levels of SOM, NO_3^--N, available P and extractable Zn. Extractable soil Cu, Fe and Mn were at ideal levels while exchangeable Ca, Mg and K were at critical levels. For Vione site, SOM and extractable Cu, Fe and Mn were at sufficient levels, while NO_3^--N, available P and extractable Zn were at low levels. The site also showed Ca, Mg and K deficiency. Similarly, Delaivuna site had low levels of exchangeable Ca, Mg and K as well as SOM, NO_3^--N and extractable Mn and Zn. There was however sufficient levels of available P and extractable Cu and Fe.

Statistical analysis of the soil test data confirmed the declining trend of the soil fertility on the island of Taveuni, Fiji. Crop output obtained through questionnaire survey also revealed the declining trend of taro production over the years. There was significant reduction ($\rho < 0.05$) in the soil macronutrients, micronutrients and SOM in all the four study sites and showed below critical levels, critical to medium levels of these nutrients in the soil at the end of the cultivation period of taro.

Key words: Soil health, Soil fertility, Nutrients, Soil management practices, Taro cultivation, Nutrient depletion

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