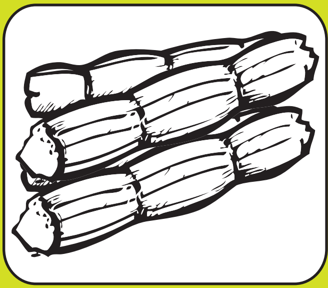

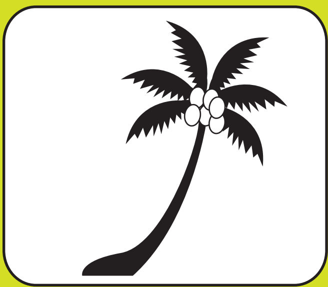

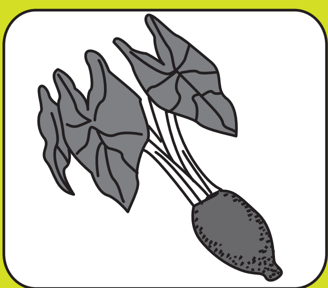
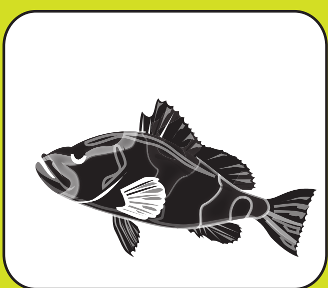


ISSN 0015-0886

Ministry of Agriculture

FIJI AGRICULTURAL JOURNAL

Volume 53
Issue No. 1
December 2013

Fiji Agricultural Journal

ISSN 0015-0886

Fiji Agricultural Journal

Vol. 53, No. 1, 2013

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From the Desk of the Permanent Secretary for Agriculture

The Fiji Agricultural Journal published its first volume in 1928 and so far has published 52 volumes altogether. For a number of years the journal has been out of publication although a lot have been mentioned about its revival.

We are so grateful to the few people who have worked hard to see the journal finds its way back to light and I believe a lot more people will be delighted to hear about this. The initiative will surely enhance and promote better access to knowledge and sharing, help promote the advances in the economic sector as well as encourage research and scholarly writing.

This Journal was considered as one of the highly reputable international journal for agriculture, fisheries and forestry research in the South Pacific region and the revitalization of this journal marks a new era in the documentation of findings within Fiji and the Pacific region.

As of the past, the journal will continue to publish scientific investigations in agriculture, fisheries and forestry that have applications in the region. It will also publish review articles, short notes, book reviews, conference reports, calendar of forth coming events, invited commentary/insight papers and research articles, on pure and applied laboratory research, field research, land-use surveys, development methods, critical observations on farming practices, extension methods and policy and planning.

I would like to extend an invitation to researchers, policy makers and academics in agriculture, fisheries and forestry sectors in Fiji and the Pacific neighbors to publish their findings in the Fiji Agriculture Journal which is hoped to produce two publications every year.

Again a big Vinaka Vakalevu to the Chief Editor and the Editorial Board members for their efforts and commitment in reviving this journal and I want to wish you all a continued success in this endeavor.

Vinaka

....

Mr Ropate S. Ligairi
Permanent Secretary for Agriculture

RESEARCH PAPER

Nutrient status and their availability in relation to properties of soils of Koronivia, Fiji

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ABSTRACT

Study of soil properties in relation to availability of important plant nutrients is vital to enhance crop productivity in Fiji. In the present study, soil samples were collected from various locations of Koronivia to determine their basic physico-chemical properties *viz*., pH, EC, OC, exchangeable cations, total nitrogen, available phosphorus and available potassium. Availability of important plant nutrients in relation to basic soil properties was studied. Soils were acidic in nature with an average pH value of 5.8; organic carbon (1.9%) and total nitrogen (0.15%) content were found to be very low in all the analyzed samples. The available phosphorus (16 kg ha^{-1}) and potassium (133 kg ha^{-1}) content were found in range of deficient to marginal in most samples. Further, pH showed a positive correlation with P and Ca and negative correlation with N. Organic carbon showed a positive correlation with N, P and Mg. Cation exchange capacity showed positive correlations with pH, P, Ca and Mg. This study suggests the necessity to apply organic manure and liming material, with appropriate nitrogenous and phosphatic fertilizer doses for enhancing farm productivity in the fields of Koronivia.

Keywords: soil properties, land use, available nutrients, Koronivia.

1.0 INTRODUCTION

Soil fertility is one of the important factors that controls yield of agricultural crops. It is the nutrient pool that plant utilizes for their growth and development. It determines the sustainable productivity of agro-ecosystems. The sustainable productivity of soil mainly depends upon its ability to supply essential plant nutrients to the growing plants.

Deficiency of nutrients has become major constraint to productivity, stability and sustainability of soils (Bell and Dell 2008). The concept of soil health and soil quality has consistently evolved with an increase in understanding of soils and soil quality attributes. The quality of soil is controlled by physical, chemical and biological components of a soil and their interaction (Pependick and Parr 1992).

Soil properties cannot be measured directly, but soil properties that are sensitive to changes in the management can be used as indicators (Andrew *et al.* 2004). Attraction for growing high yielding varieties without considering fertility of soils could result in depletion of soil organic matter reserves and reduce quality of soils.

Addition of appropriate doses of organic matter and lime helps in maintaining better and favourable physical conditions of soils for sustainable farm productivity. Determination of physico-chemical properties and available nutrients status of the soil of an area is vital for improving sustainable productivity.

Soil pH is a good indicator balance of plant available nutrients in the soil (Kinyangi 2007). The present study provides information on availability of plant nutrients in relation to physico-chemical properties of soils of Koronivia, Fiji.

2.0 MATERIAL AND METHODS

2.1 *Location*

The study was conducted at the College of Agriculture, Fisheries and Forestry (CAFF) crop farm, livestock farm, pasture land, Koronivia Research Station (KRS) research farms and farmer fields of Koronivia village. The geographical reference of the study area are 18°2’ 30”-18°3’ 36” S, 178°31’ 17”-178°33’ 10” E and elevation ranges from 6 to 23 m above mean sea level. The climate is tropical and the temperature is moderate (21°C – 26°C) with annual average rainfall of about 3,000 mm (Fiji Met. 2013). Soils are acidic in nature and pH varies from 5.1 - 6.6 with low to medium organic carbon and low electrical conductivity (0.01 - 0.08dSm-1) (Bell 1988).

2.2 *Soil sampling and analysis*

Twenty four representative surface (0-15cm) and sub-surface (15-30 cm) soil samples from twelve sites were collected (Fig. 1) considering the heterogeneity of soils by keeping in view the variation in soil type, slope and land use to determine physico-chemical properties and nutrient status. Collected samples were prepared as per standard methods and stored in properly labeled plastic bags for analysis. Standard analytical methods as described by Richards (1954) and Jackson (1973) were followed for measuring various soils attributes like pH, electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC) and important plant nutrients (total nitrogen, available phosphorus and available potassium) at Fiji Agricultural Chemistry Laboratory, Koronivia Research station (KRS).

2.3 *Statistical analysis*

The relationship between different soil physico-chemical properties and available nutrients content were determined using SPSS – 17.0, 2009. Where “r” is correlation coefficient,

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\sqrt{n(\sum y^2) - (\sum y)^2}}$$

where n is the number of pairs of data (x.y). Simple correlation coefficient (r) between different soils properties and availability of nutrients were determined.

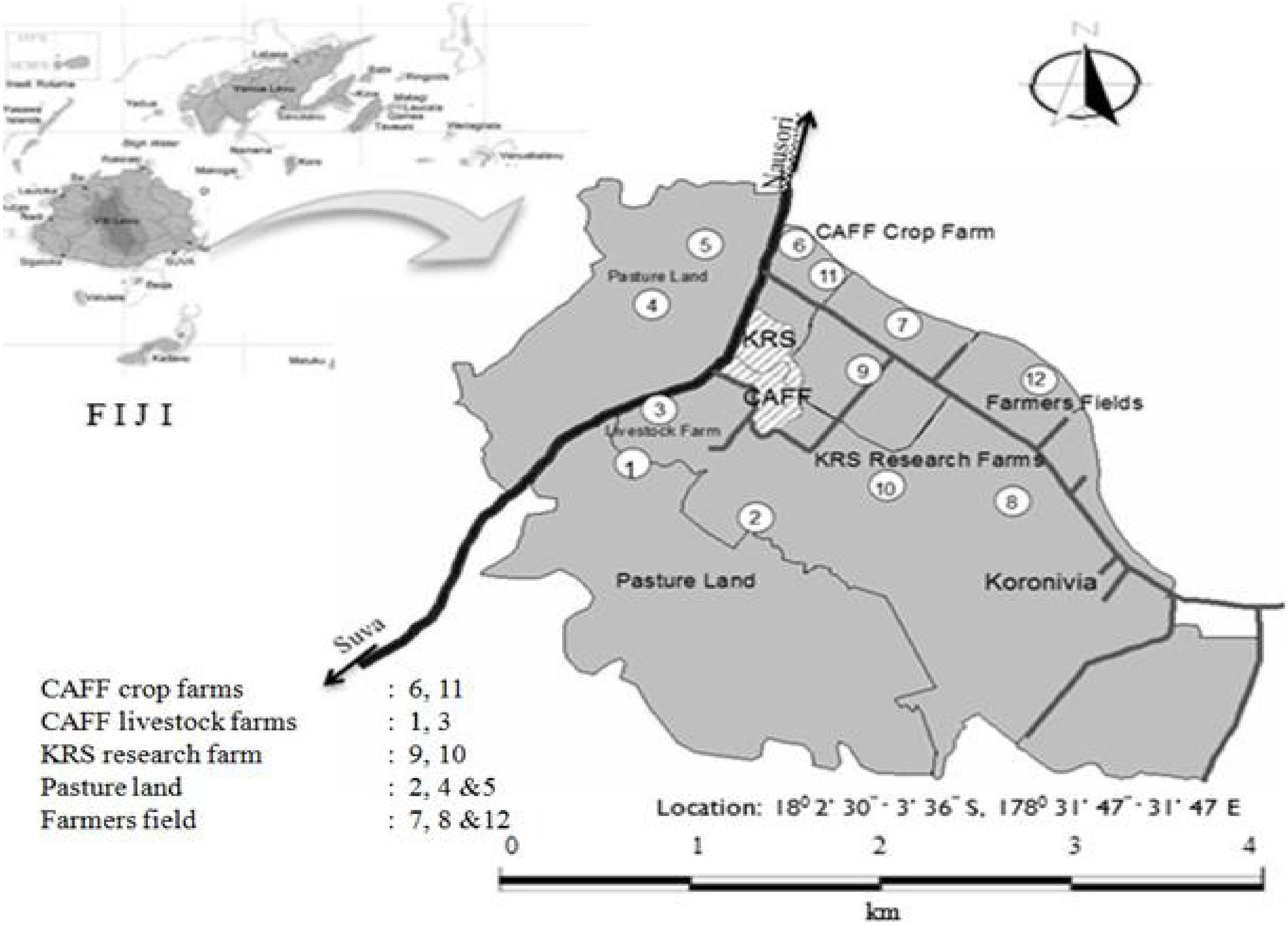


Figure 1. Map of Fiji showing the location of the 12 study sites at Koronivia.

3.0 RESULTS AND DISCUSSION

The soils of the study area are acidic in nature with the mean pH of 5.8 (Table 1). According to classification of soil reaction suggested by Brady (1985), 37.5% samples were acidic (< 5.6) and 62.5% samples were slightly acidic (pH 5.6-6.6) (Fig. 2A). Relative low values of pH are due to acidic parent material of these soils (Miyauchi *et al*. 1985). A positive correlation coefficient of pH with exchangeable bases like calcium and magnesium existed in the studied soils (Table 2). Further regression line between pH and P and Ca indicated a positive trend of increase in their content with increase in pH (Fig. 3).

The electrical conductivity values of the soils varied from 0.01-0.08 dSm-1with a mean value of 0.04 dSm-1. EC values showed a significant positive correlation with P and Ca (Table 2). The linear regression showed a positive trend (R^2 = 0.27) of EC with available phosphorus (Fig.3c). On the basis of limits suggested by Muhr *et al*. (1965) for judging soil salt problems, all samples were found normal (EC <1.0 dSm-1). The normal electrical conductivity may be ascribed as lower base concentration and leaching of salts from the soils.

The organic carbon (OC) content of soils varied from 0.8 - 2.9% with a mean value of 1.9% (Table 2). Data indicated that organic carbon content was below the range (4-10%) and found deficient for all analyzed samples. The low organic carbon content of these soils may be attributed to under hyperthermic temperature regime which leads to extremely high oxidizing conditions (Kameriya 1995).

A significant positive correlation was obtained between organic carbon and total nitrogen content(r = 0.78) (Table 2). Since most soil nitrogen is available in organic form such as decomposed plant parts, litter, crop and animal residues that released gradually for growth of plants by mineralization process and therefore this relationship was observed. However, OC content showed a decreasing trend with increase in soil pH (Fig. 3d). Similar results were reported by Verma *et al*. (1980).

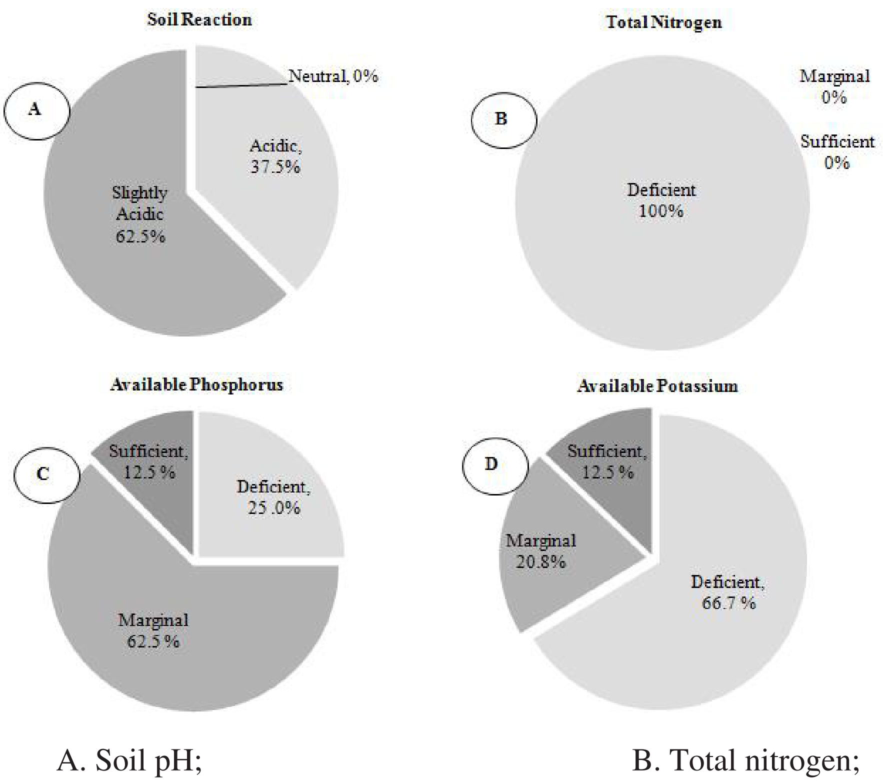
Table 1. The range of physico-chemical properties showing minimum, maximum and mean values of studied parameters.

Soil property	Minimum	Maximum	Mean	Standard error of mean
Physico-chemical properties				
pH (1:5)	5.10	6.60	5.79	0.08
EC (dSm-1)	0.01	0.08	0.04	0.01
Total Carbon (%)	0.80	2.90	1.92	0.13
CEC (cmol kg^{-1})	3.91	19.91	13.23	0.97
Texture [a]	scl	cl	-	-
Available plant nutrients				
Total Nitrogen (%)	0.10	0.20	0.15	0.01
Available Phosphorus (mg kg^{-1})	0.22	54.65	16.29	2.79
Available Potassium (mg kg^{-1})	43.80	332.82	132.47	18.18
Calcium (ppm)	220.00	2680.00	1365.80	130.70
Magnesium (ppm)	109.80	927.20	608.98	237.90

a: Textural class as per Soil Taxonomy (1975)

scl: sandy clay loam ; cl: clay loam

The cation exchange capacities of these soils were found low with average value of 13.23 cmol kg^{-1}. The soils of the study area are strongly weathered acidic with appreciable amount of clay mineral assemblage consisting of hydrous oxides (gibbsite / goethite) and kaolinite clay mineral (Curtin *et al*. 1991) that possesses CEC in range of 3-15 c mol kg^{-1}. Such soils can be better utilized by maintaining optimum pH with addition of ameliorant like calcite or dolomitic lime for better yield of crops which includes tomato, French bean, cabbage, spinach, eggplant, celery, spinach, radish, lettuce, cassava, turnip, corn, cucumber, leafy vegetables, peppers etc. Furthermore, the present research data indicated that increase in CEC had increased significantly the values of pH and available phosphorus (Table 2 and Fig.3).



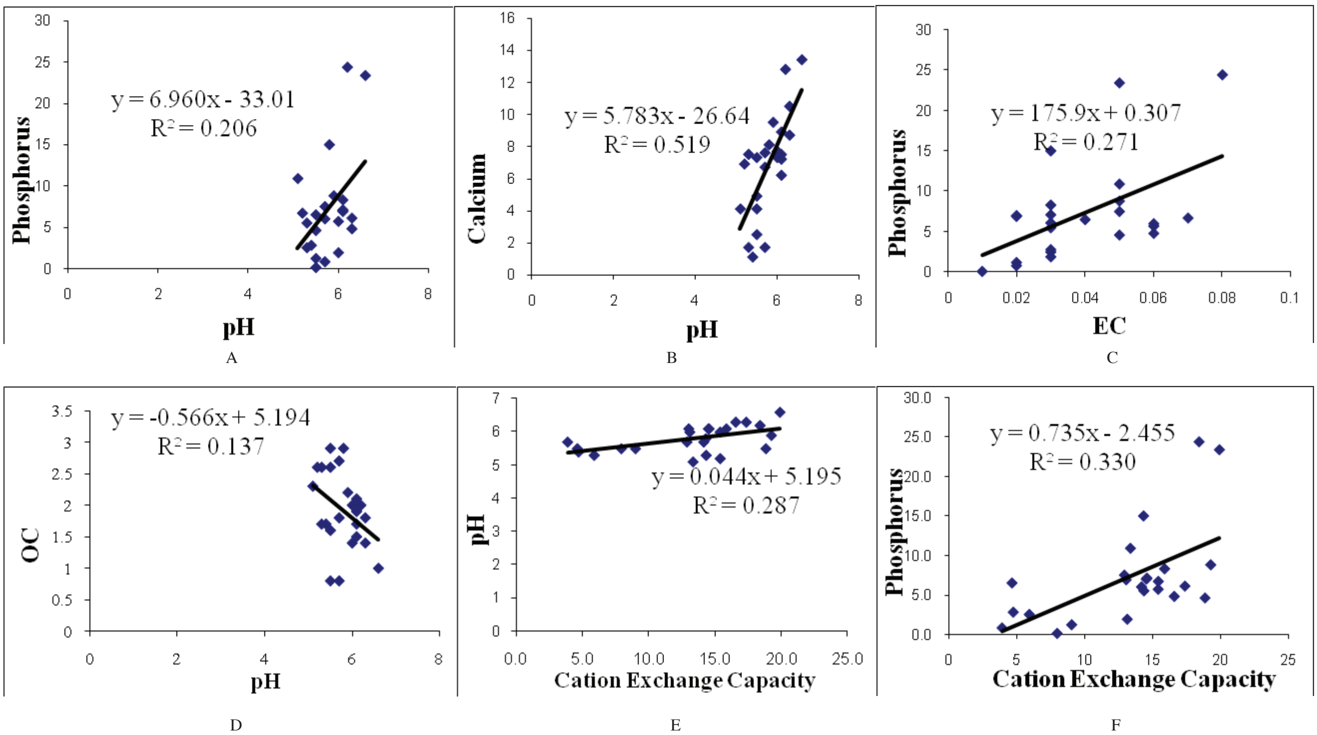
A. Soil pH; B. Total nitrogen;
C. Available phosphorus; and D. Available potassium.

Figure 2. Pie diagram showing soil reaction and nutrients status of soils based on critical range.

The total nitrogen content of the studied soils varied from 0.1 to 0.2% with an average value of 0.15%. Considering the critical range (0.3-0.6%) for total nitrogen, all samples were found to be deficient in total nitrogen content (Fig. 2B). The available phosphorus content of samples varied from 0.2 – 54.7 kg ha^{-1} with the mean value of 16.3 kg ha^{-1} (Table 2). The range is considerably large which might be due to variation in soil properties *viz* pH, organic matter content, texture, land use, various agronomic and management practices. On the basis of limits suggested by Muhr (10-25ppm), 25% (Fig. 2C) samples were found deficient and 62.5% samples marginal. This might be due to less Ca^{2+} and more Al^{3+} and Fe^{3+} in solution that results in precipitation of phosphate ions as insoluble aluminum and iron phosphates. Again, these phosphorus compounds have very low solubility, resulting in a low concentration of phosphate ions in solution (Foth 1990). The availability of phosphorus showed a positive correlation with pH (r = 0.46), OC (r = 0.12) and CEC (r = 0.58) (Table 2). This indicates that the presence of organic carbon increases the availability of phosphorus in soil. Tisdale *et al*. (1997) reported that about 50% of soil phosphorus found in organic form and decomposition of organic matter produces humus that works as chelating agent which forms complex with Al^{3+} and Fe^{3+} and protects the P fixation.

Table 2. Correlation coefficient values of important soil parameters.

	EC	OC	CEC	N	P	K	Ca	Mg
pH	0.084	-0.370	0.536**	-0.158	0.455*	0.259	0.721**	0.597**
EC		0.297	0.528**	0.215	0.521**	0.185	0.462*	0.321
OC			0.046	0.783**	0.114	-0.069	-0.036	0.119
CEC				0.151	0.575**	0.273	0.911**	0.817**
N					0.241	0.045	0.089	0.259
P						0.475*	0.702**	0.300
K							0.350	-0.003
Ca								0.771**



*$P < 0.05$, **$P < 0.01$

Figure 3. Regression analysis among important soil properties:
A. Soil pH & phosphorus,
B. Soil pH & calcium,
C. Soil EC & phosphorus,
D. Soil pH & organic carbon,
E. Cation Exchange Capacity (cmol kg^{-1}) & soil pH
F. Cation Exchange Capacity & phosphorus.

The available potassium content of samples varied between 44-333 kg ha^{-1} with the mean value of 133 kg ha^{-1} (Table 1). Considering the suggested critical range (108 -280 kg ha^{-1}), 67% samples were found deficient and 21% marginal (Fig. 2D). Data on extractable calcium and magnesium indicated that all samples have higher values than the critical range (60-300 ppm) and found sufficient. Calcium deficiencies are found only on very acidic soils and can be corrected by liming. Application of lime and ameliorant can be used to manage adverse effects of soil acidity or use of crops that are tolerance to high level of exchangeable Al (Biswas and Mukherjee 1994).

4.0 CONCLUSION

The study revealed that soils of Koronivia are acidic in nature having low values of EC and organic carbon content. Most soil samples showed low values for primary major nutrients. The total nitrogen content was low in all samples, whereas 88% samples were below the sufficient level for phosphorus and potassium. However, the studied soils contain adequate amounts of calcium, magnesium and sodium. This study suggests that such type of soils can be better utilized by maintaining optimum soil pH by addition of ameliorants and planting improved crop varieties that can grow well in the specific pH range. The results indicated that the soil properties viz; pH, EC, organic carbon and CEC are the main characteristics playing major role in controlling the availability of these nutrients.

ACKNOWLEDGEMENTS

Authors are thankful to the Fiji National University for providing the necessary facilities. Thanks to the Director Research, Koronivia Research Station for providing the laboratory facilities to analyse the soil samples.

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RESEARCH PAPER

Survival of various ages and lengths of *Sphagneticola trilobata* stem sections

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ABSTRACT

Sphagneticola trilobata (L.) Pruski an exotic weed species has invaded and colonised many ecosystems in Fiji including the agriculture production areas. Though it is commonly known to disperse vegetatively, but its capability to re-shoot from fragmented nodal stem sections is relatively unknown. The experiment was arranged in a randomized split plot design with the age of stem sections (young, middle age and mature) as the main plots, and number of nodes (one, two, three or four) as the sub-plots. The stem sections were buried under ca 3.0 cm potting mix in trays for 60 days in the glasshouse. The survival rate of young stem sections was 5% and 18% greater than that of middle age and mature stem sections, respectively. The young stem sections re-shoot at nine days after planting which is two days earlier than both middle age and mature stem sections. The average survival rate of stem sections with one, two, three and four nodes were 90%, 88%, 92% and 90%, respectively and all were not significantly different. This study has enhanced our understanding on the potential of *S. trilobata* to re-shoot and establish itself in the field situation and has also provided relevant information to improve weed management of *S. trilobata.*

Keywords: *Sphagneticola trilobata,* stem sections, survival, Fiji.

1.0 INTRODUCTION

Spagneticola trilobata (L.) Pruski) belonging to the family Asteraceae is native to Mexico, Central America, and the Caribbean (US Forest Service 2012). It is a perennial creeper and has established in 17 island states in the Pacific Island Countries and Territories (US Forest Service 2012). It has been listed as one of the top 100 world's worst invasive species in the world (GISD 2012). *S. trilobata* forms dense mat-forming thickets to displace other plant species and confine their propagules in the soil seed bank (Macanawai 2013). This species is capable to produce shoots and roots at its nodes (Wagner *et al.* 1999) in the same way as *Mikania micrantha* Kunth, a related species (Macanawai *et al.* 2010). In addition, it has the ability to produce viable seeds contributing to a relatively large soil seed bank (Macanawai 2013). According to Thaman (2009), *S. trilobata* was introduced into Fiji in mid-1970s as an ornamental plant in a residential property in Suva. However, forty years later, it has invaded and colonized around river banks, drains, pasture fields, road sides and vacant lots on many islands in Fiji (Thaman 2009; Macanawai 2013). *S. trilobata* was also found infesting taro (*Colocasia esculenta* L. Schott) cultivation in eastern Viti Levu (Macanawai *et al.* 2010) and in Taveuni (Macanawai, in press), and pasture areas in Tailevu Province (Macanawai 2013). Thus, *S. trilobata* can quickly adapt to wide range of environmental and ecological conditions including diverse soil types (US Forest Service 2012). Based on its current rate of rapid spread and colonization patterns, *S. trilobata* would potentially become a major weed of agriculture production areas in the near future.

Several weed management practices to control *S. trilobata* have been reported in the Asia Pacific region. Physically hand removing the plants and dig-up runners is labour-intensive and may be costly (Englberger 2009). These methods are recommended in Australia. In addition, burning of plant waste or placing them into a black plastic bag and leaving it in the sun for a few days before placing them in the refuse bins have been recommended in Australia (DAFF 2013). In China, *Cuscuta australis* R. Brown a holoparasitic rootless annual plant has been recommended for the biological control of *S. trilobata* (Yu *et al.* 2010). Cuscuta species have been observed on *S. trilobata* in Viti Levu, but its potential to regulate *S. trilobata* in Fiji is yet to be investigated. In Australia, metsulfuron methyl (600g/kg) has been registered for spraying this weed (DAFF 2013). In Fiji, metsulfuron methyl was first trialed and found effective against *Vitex trifolia* L. and later registered in 1994 for the control of *V. trifolia* on pasture areas (Nagatalevu 1994, unpublished report). In 2006, metsulfuron methyl was evaluated and found to be effective, and thus recommended for the control of *S. trilobata* in Fiji (Macanawai 2007).

S. trilobata is widely distributed in Fiji. It is a threat to many ecosystems because of its ability to rapidly colonise new areas and get established. Its capacity to invade new areas is facilitated by its ability to reproduce by seeds (Macanawai 2013) and also vegetatively (Batianoff and Franks 1997; DAFF 2013). However, the survival rates of the various ages and sizes (length) of its stem section is relatively unknown. Therefore, the aims of this study were to determine the survival rate and re-shooting capacity of leaf-less and root-less stems from young, middle age and mature stem sections of S. trilobata with one, two, three and four nodes.

Such information would provide insight into the vegetative propagation potentials of *S. trilobata* in the field situation in Fiji, and may lead to a better understanding of its invasive pathways and strategies, which may facilitate towards the development of a better long-term management practices.

2.0 MATERIALS AND METHODS

2.1 *Stem section preparation*

Healthy *S. trilobata* stem sections taken from the canopy region of *S. trilobata* mat-forming thicket, referred to as young or from the middle region of the thicket, referred to as middle age (middle) or from bottom region of the thicket, referred to as mature were harvested from an area of ca 1,900 m^2 infested with ca 45 cm dense mat-forming *S. trilobata* at Sawani, Naitasiri Province, Fiji. Eighty stem sections were cut to various lengths from each of the canopy region, middle region and bottom regions of the *S. trilobata* thicket. Leaves and roots were removed from the stem sections. The stem sections were placed in plastic bags and taken to the glasshouse at Koronivia Research Station for planting. In the glasshouse, stem sections were buried under ca 3.0 cm of

Yates Thrive Premium potting mix (Auckland, New Zealand) in trays (l x w x h; 52 cm x 36 cm x 10 cm).

2.2 *Maintenance and assessment*
The trays were inspected daily and watered as needed. The experiment was terminated after 60 days, which allowed sufficient time for the stem sections to sprout. Each tray was exhumed to retrieve the buried stem sections. The stem sections were examined and recorded based on the following parameters: sprouted and emerged, sprouted but not emerged or dead by decay and/ or desiccation. Survival was determined if a stem had sprouted irrespective of whether or not it had emerged.

2.3 *Experimental design and data analysis*
The experiment was arranged in a randomized split plot design, with the age of stem (mature, middle or young) was considered as the main plot and with five young or five middle or five mature stem sections of *S. trilobata,* each having one (4 cm long), two (10 cm), three (18 cm) or four (28 cm) nodes, respectively as the sub-plots. Therefore, this study had a 3 (age of stem: young, middle or mature) x 4 (number of nodes: one, two, three or four) design with four replications.

To test the effects of the number of nodes and age of stems on survival rate, a two-way combination analysis using a split plot design was conducted. Data on the percentage of surviving stem sections were arcsine transformed to satisfy the analysis of variance requirements. The data were analysed using STATISCA10.0-2010. The mean values were separated by using the Fisher's Least Significant Difference test at $P < 0.05$.

3.0 RESULTS

3.1 *Effect of age of stem on stem section survival*
There was a significant difference in survival between mature, middle age and young stems irrespective of length of the stem sections ($F_{2,36} = 10.52$, $P < 0.001$), the young stem sections having a significantly greater survival rate than mature stem sections (Fig. 1). However, there was no significant difference between the survival rate of young and middle stem sections (Fig. 1).

The survival rate of young stem sections was 5% and 18 % more than that of middle and mature stem sections, respectively. In addition, there was a significant difference between the age of stem sections on the emergence of the first shoot ($F_{2,45} = 4.81$, $P < 0.05$) (Fig. 2). The young stem section sprouted two days earlier than middle and mature stems (Fig. 2). The number of days taken for the first shoot to emerge was 9.25, 11.75 and 11.50 days for young, middle age and mature stem sections, respectively (Fig. 2).

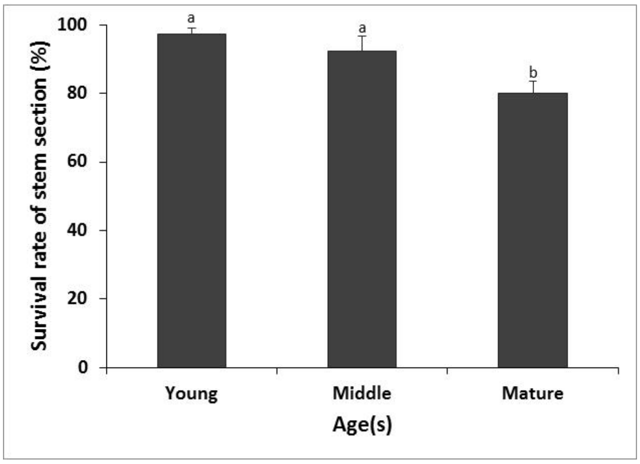

Figure 1. The effect of the age of the stem section on the survival rate of *S. trilobata* stem sections. Interval bars with the same letters are not significantly different at $P< 0.001$ and error bars show one standard error around the mean.

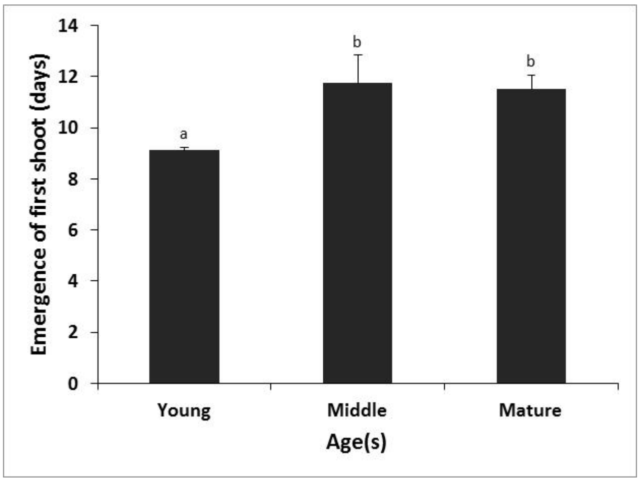

Figure 2. Number of days taken for the first shoot to emerge from young, middle age and mature stem sections of *S. trilobata* buried under ca 3.0 cm of Yates Thrive Premium potting mix in trays in the glasshouse. Interval bars with the same letters are not significantly different at $P< 0.05$ and error bars show one standard error around the mean.

3.2 *Effect of number of nodes on stem section survival*
There was no significant difference in survival between the number of nodes (stem section length) irrespective of age ($F_{3,36} = 0.02$, $P = 0.9$) (Fig. 3). The average survival rate of stem sections with one, two, three and four nodes were 90%, 88%, 92% and 90%, respectively (Fig. 3).

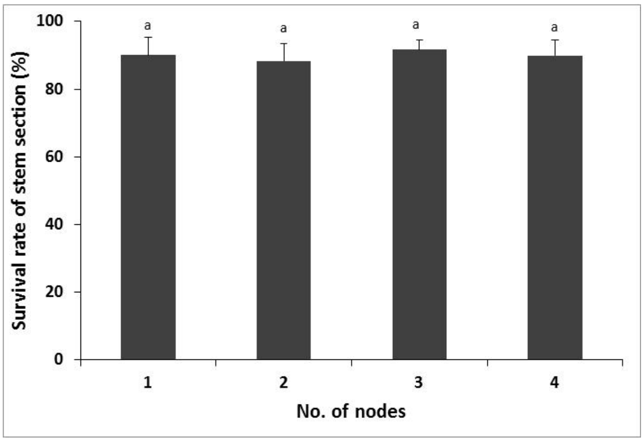

Figure 3. The effect of the number of nodes (stem length) on stem section survival rate of *S. trilobata.* Interval bars with the same letters are not significantly different at $P < 0.05$ and error bars show one standard error around the mean.

4.0 DISCUSSION

Young *S. trilobata* stem sections at the canopy region have a greater chance of survival than mature stem sections at the bottom region of ca 45 cm of mat-forming thickets. Even the stem sections at the middle region of the thickets had a greater chance of survival than the mature stem sections. This could have been attributed to the fact that the stem sections at the canopy region have been exposed more to direct sunlight hence increase its photosynthetic capacity and vitality than the mature stem sections which are deprived of light at the bottom region of *S. trilobata* dense mat-forming thickets. In addition, the young stems sections have active growing cells known as shoot apical meristem which may have contributed to their survival (Carles and Fletcher 2003; Dodsworth 2009). Furthermore, there were scarce foliages at the base as compared to the abundance at the canopy region (personal observation). Other studies have proven that shade decreased photosynthetic capacity and light saturation point (Zhao *et al*. 2012) and dry matter production (Patterson 1979).

The variation in sunlight intensity being captured at the various regions of the *S. trilobata* thickets may reflect the variation in the amount of stored resources in the stem sections of the three studied regions. Stem internode is responsible for storing proteins and carbohydrates that are translocated to other parts of the plant for re-growth (Baur-Hoch *et al.* 1990; Corre *et al.* 1996; Volenec *et al.* 1996; Stuefer and Huber 1999). This could have also contributed to the significant variation not only in the survival rate but also in the rate of shoot emergence. Although it takes a minimum of nine days for re-shooting to take place, the very high survival rate of root-less and leaf-less stem sections of *S. trilobata* suggests that they contain sufficient resources to allow them to form roots and shoots during favorable conditions.

The survival rate of a single nodal stem of *S. trilobata* is as good as stem sections with two, three or four nodes. The very high survival rate (between 88 – 92%) of freshly cut root-less and leaf-less stem sections of *S. trilobata* at different stem lengths buried at ca 3 cm deep in trays may indicate that there is a very high chance of their survival when they are cut into smaller fragments and buried at shallow depths in the field. The ability to re-shoot from the smallest stem section, i.e. a single nodal stem, may play a significant role in the re-establishment, spread and colonization of the weed in diverse ecosystems around Fiji (Thaman 2009; Macanawai 2013). However, the revelation of the presence of a large soil seed bank of *S. trilobata* in eastern Viti Levu (Macanawai 2013), clearly demonstrated that seeds also play a definitive role in the spread and colonization of *S. trilobata* in Fiji.

5.0 CONCLUSION

Our study has provided important findings to improve weed management of *S. trilobata.* Farmers practicing manual control may need to implement additional techniques. The usual practice of cutting all sections into one-node lengths and leaving them on the surface or burying them shallowly would not be feasible. Likewise, moving soil to other locations especially in *S. trilobata* non-infested areas should be monitored to reduce spread of the weed. In addition, identifying and implementing effective strategies to reduce or eliminate the spread of *S. trilobata* along main roads during road maintenance work should be considered. Apart from herbicide treatment, there are few options that could be considered like burying the *S. trilobata* plants deeper or slash stem sections into piles and burn, although their effectiveness, as well as economics and social acceptability needs to be evaluated.

ACKNOWLEDGEMENTS
We sincerely thank the financial support from the Government of the Republic of Fiji Public Sector

Investment Program 2012 (Management of Pest project), as well as Meleki Motu and Pravin Kumar for their assistance in the fieldwork. We also thank Dr. R.C. Joshi for reviewing the manuscript.

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RESEARCH PAPER

Interaction of nitrogen application and plant spacing on the yield and quality of head cabbage (*Brassica oleracea* L. var. *capitata*)

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ABSTRACT

A field experiment to determine the interaction of nitrogen and plant spacing on the yield and quality of head cabbage was undertaken at Maejo University, Thailand in 2010 in a soil containing 0.4 % N, 783 ppm available P and 121 ppm of extractable K. Four nitrogen application levels (0, 80, 100 and 120 kg ha^{-1}) were mainplots and three different plant spacing (50 x 30, 50 x 40 and 50 x 50 cm) were subplots. Split plots in RCBD were arranged with 3 replications. The results revealed that all nitrogen application levels gave significantly higher yields than no nitrogen application at $P< 0.01$. Nitrogen application level of 120 kg produced the highest yield (62.8 t ha^{-1}), while control (N = 0) produced the lowest yield (42.4 t ha^{-1}). However, plant spacing of 50 x 30 cm produced the highest yield of 63.6 t ha^{-1} when compared to wider plant spacing of 50 x 50 cm, but head size of cabbages were smaller. Significant differences were observed in the dry matter (DM) content among the different nitrogen applications. Higher nitrogen levels recorded low DM, while control plot recorded the highest (8.3%) DM. Highly significant differences were also observed in the nitrate content among different nitrogen levels and also among different plant spacing. Increasing nitrogen levels and plant spacing also increased the nitrate content. No interaction was observed in the measured parameters.

Keywords: head cabbage, nitrogen application level, plant spacing, head size, nitrate.

1.0 INTRODUCTION

Head Cabbage (*Brassica oleracea* L. var. *capitata*) is one of the important vegetable crops cultivated for human consumption around the world. It consists of water (92.8%), protein (1.4 mg), calcium (55.0 mg) and iron (0.8 mg). Its leaves are either eaten raw in salads or cooked (Adeniji *et al.* 2010). Potential yield of cabbage is determined by good husbandry practices and the surrounding environment provided to the crop. Amongst the factors that affect yield and quality, population or plant density is one of the most important elements (Moniruzzaman 2006). Cabbage yield usually varies with different plant densities. Suitable plant spacing can lead to optimum yield whereas too wide or too close plant spacing could result in relatively low yield and quality (Kobryn 1987).

Nitrogen is one of the most important elements required to increase yield of leafy vegetables (Aliyu *et al.* 2008). Nitrate is a naturally occurring form of nitrogen and is an integral part of the nitrogen cycle in the environment (Santamaria 2008). Due to the increased use of nitrogen based fertilizers to produce vegetables and pastures, there may be an increased concentration of nitrate in the crops and the drinking water. The presence of nitrate in vegetables, as in water and generally in other foods, is a serious threat to man's health (Santamaria 2008). Nitrates in the soil are a primary source of nitrogen which is essential for plant growth. Nitrate itself is relatively non-toxic but its metabolites (nitrite), is associated with methaemoglobinaemia; a blood disorder in which an abnormal amount of methemoglobin (a form of haemoglobin) is produced. Hemoglobin is the molecule in red blood cells that distributes oxygen to the body and methemoglobin cannot release oxygen. Nitrite might also react with amines to form carcinogenic nitrosamines in the stomach (EFSA 2008). Nitrate predominately enters the human body exogenously from vegetables, water, and other foods, but it is also formed to a limited extent endogenously (Lundberg *et al.* 2004 and 2008).

Head Cabbage is one of the major vegetables consumed in Fiji. Farmers over the years have complained of reduced head size and lower yields from their harvest. This study was therefore undertaken to determine the effects of plant spacing and nitrogen in order to increase yield and quality of head cabbage while maintaining an acceptable level of nitrate content.

2.0 MATERIALS AND METHODS

A field experiment was conducted in the experimental farm of Maejo University, Thailand in 2010 to test the interaction of nitrogen and plant spacing on the yield and quality of head cabbage under a randomized complete block design in split plot arrangement in a soil containing 0.4 % N, 783 ppm available P and 121 ppm of extractable K. Land was ploughed to fine tilth and 15 to 20 cm high raised beds were made. Poultry manure at the rate of 5 t ha^{-1} was applied in the main plots 2 weeks before transplanting.

NPK at the rate of 200 kg ha^{-1} were applied as basal application in the main plots prior to transplanting. From the total N [N1; 80 kg ha^{-1} (40 kg urea (46-0-0)ha^{-1}), N2; 100 kg ha^{-1} (50 kg urea (46-0-0)ha^{-1}) and N3; 120 kg ha^{-1} (60 kg urea (46-0-0) ha^{-1}]; 50% was applied as basal in main plots and mixed with soil according to the treatment specifications and the beds were covered with plastic mulch to conserve moisture and prevent weed growth. Four weeks old cabbage seedlings (variety FS cross, maturing in 68 days after transplanting) were transplanted in three different plant spacings (50 cm between rows and 30, 40 and 50 cm within rows) in subplots thereafter. The remaining 50% nitrogen was applied as side dress at 20 days after transplanting. Water was applied to plants when required. The growth of plants was monitored and fortnightly data was collected.

Measurement of the number of frame leaves and wrapper leaves per plant. Frame leaves were recorded at harvest by counting all loose leaves in a plant that did not form head while wrapper leaves were recorded by removing all the leaves in a head, starting from outermost and finishing at the innermost core of head consisting of only miniature leaf primordium.

2.1 *Measurement of head width, head height and head area*

Three heads from each plot were randomly selected and each head was diagonally sliced from the middle. The width and height was measured using Mitutoyo digital vernier calliper. The width was measured at mid-point of the head by keeping the head in a horizontal position, while the head height was measured from the base of head to the tip by keeping the head in a vertical position.

2.2 *Determination of marketable yield*

The stage of harvest of cabbage was determined by hardness of the heads when tip of the head was pressed with fingers. Plants were harvested by cutting stems from the base below the last frame leaves. Marketable weight (head weight) of cabbage on fresh weight basis were determined by removing all outer frame and loose leaves on the head, and only weight of intact head with firm wrapper leaves were recorded as marketable yield in a portable Camry platform weighing scale.

2.3 *Determination of dry matter content and total soluble solid*

Three heads of cabbage were randomly selected, chopped and mixed together at harvest to determine the dry matter content (% DM) and the total soluble solid (TSS) content (% Brix). A sample of 100 grams was accurately measured from each treatment and the samples were dried in hot air oven (Memmert) at 70ºC for 72 hours thereafter weighing the samples to determine its dry matter content.

For determination of TSS, three heads were randomly selected from each treatment and sliced into fine pieces and a sample of 200 grams from each treatment was ground and juice extracted by squeezing it in muslin cloth. The LCD Digital Hand Refractometer (Atago, PAL-1, Japan) was used in the determination of TSS.

2.4 *Determination of nitrate content in cabbage head*

Three cabbage heads were randomly selected from each plot, finely chopped and thoroughly mixed together. A sample of 200 grams for each treatment was analyzed for nitrate concentration using the In-house AOAC Official Method 976.14.

3.0 RESULTS

3.1 *Number of Frame and Wrapper Leaves*

There were no significant difference in the number of frame and wrapper leaves among different levels of nitrogen applied. However, significant differences were found in number of frame leaves between the different plant spacings at *P*<0.05. Highest number of frame leaves was found in the widest spacing of 50 x 50 cm while close spacing of 50 x 30 cm had the lowest number (Table 1).

Table 1. Effect of different rates of nitrogen and plant spacing on mean number of frame and wrapper leaves of cabbage

Rate of Nitrogen (kg ha^{-1}) (A)	Number of frame leaves	Number of wrapper leaves
0	15.4	34.9
80	15.2	37.3
100	15.2	36.8
120	15.6	37.4
F test	ns	ns
LSD at 0.05 level probability	0.89	4.10
CV (%)	6.2	5.8
Plant Spacing (B)		
50 x 30 cm	14.8 b	36.1
50 x 40 cm	15.3 ab	36.7
50 x 50 cm	15.9 a	36.9
F test	*	ns
LSD at 0.05 level probability	0.77	3.55
CV (%)	5.8	8.1
A x B	ns	ns

Data which represent same letters are not significantly different at P < 0.05.

Table 2. Effect of different rates of nitrogen and plant spacing on the head width & head height.

Rate of Nitrogen (kg ha^{-1}) (A)	Head height (cm)	Head width (cm)
0	10.5 c	13.7 c
80	11.9 b	14.8 b
100	12.4 ba	15.4 ba
120	13.1 a	16.3 a
F test	**	**
LSD at 0.05 level probability	0.69	0.94
CV (%)	3.2	12.1
Plant Spacing (B)		
50 x 30 cm	11.1 z	13.7 y
50 x 40 cm	11.8 y	15.3 x
50 x 50 cm	13.0 x	15.9 x
F test	**	**
LSD at 0.05 level probability	0.59	0.81
CV (%)	5.78	6.27
A x B	ns	ns

Data which represent same letters are not significantly different at P < 0.05.

3.2 *Yield and Weight per Head*

Highly significant difference at *P*<0.01 was observed in yield and weight per head among different rates of nitrogen and different plant spacings. Mean highest yield of 62.8 t ha^{-1} was recorded in the plot applied with highest rate of nitrogen (Table 3). Similarly, highest weight per head was also recorded in the same plot. Control plot had the lowest yield (42.4 t ha^{-1}) and lowest weight per head. There were, however, no significant differences in yield among different rates of nitrogen applied. Significant differences were observed for weight per head among different rates of nitrogen. Different plant spacings also had positive effect on yield and weight per head. Highest yield was recorded in the plot with closest spacing while highest weight per head (1.2 kg) was recorded in the plot with widest spacing (50 x 50 cm).

Table 3. Effect of different rates of nitrogen and plant spacing on the marketable yield of cabbage

Rate of Nitrogen (kg ha^{-1}) (A)	Yield (kg m^{-2})	Weight/head (kg)	Yield (t ha^{-1})
0	4.2 b	0.8 c	42.4 b
80	5.4 a	1.0 b	53.7 a
100	5.5 a	0.9 b	54.8 a
120	6.3 a	1.1 a	62.8 a
F test	**	**	**
LSD at 0.05 level probability	0.95	0.11	9.56
CV (%)	24.8	23.5	24.8
Plant Spacing (B)			
50 x 30 cm	6.4 x	0.8 z	63.6 x
50 x 40 cm	5.0 y	0.9 y	50.4 y
50 x 50 cm	4.6 y	1.2 x	46.2 y
F test	**	**	**
LSD at 0.05 level probability	0.82	0.09	8.28
CV (%)	7.9	11.7	17.9
A x B	ns	ns	ns

Figures in the same factor associated with a common letter are not significantly different from each other by the Least Significant Difference (LSD) at 0.05.

3.3 *Dry Matter, TSS and Nitrate content*

The dry matter contents among different nitrogen rates were significantly different at *P* < 0.05. Highest dry matter (8.3%) was recorded in the control plot. Dry matter content among different plant spacings were not significantly different at *P* < 0.05. Total soluble solids (TSS) recorded were not significantly different among rates of nitrogen and the different plant spacings (Table 4). Nitrate contents observed in cabbage were highly significant at *P* < 0.01 among different rates of nitrogen and also among the different plant spacings. Lowest nitrate content (171.0 mg kg^{-1}) was observed in control plot while the highest (964.9 mg kg^{-1}) was observed in plot with the highest rate of nitrogen (120 kg ha^{-1}). Nitrate content also significantly increased with increase in plant spacing. Closest spacing (50 x 30 cm) recorded the lowest nitrate content while the widest spacing (50 x 50 cm) recorded highest nitrate content.

Table 4. Effect of different rates of nitrogen and plant spacing on the dry matter content, total soluble solid (TSS) and nitrate content of cabbage

Rate of Nitrogen (kg ha^{-1}) (A)	Yield (kg m^{-2})	Weight/head (kg)	Yield (t ha^{-1})
0	8.3 a	3.7	171.0 d
80	8.1 a	3.9	476.3 c
100	8.0 ab	3.9	687.9 b
120	7.6 b	4.2	964.9 a
F test	*	ns	**
LSD at 0.05 level probability	0.55	0.56	39.45
CV (%)	6.6	17.5	8.1
Plant Spacing (B)			
50 x 30 cm	8.2	3.9	523.3 z
50 x 40 cm	7.9	3.9	566.3 y
50 x 50 cm	7.9	3.9	635.5 x
F test	ns	ns	**
LSD at 0.05 level probability	0.48	0.48	34.14
CV (%)	6.9	10.4	6.7
A x B	ns	ns	**

Figures in the same factor associated with a common letter are not significantly different from each other by the Least Significant Difference (LSD) at 0.05.

4.0 DISCUSSION

More frame leaves were observed in wider spaced plants, this may be due to having more space for development, and therefore, they produced more leaves to support their growth. Similar results were also obtained by Pervez *et al.* (2004) and Aliyu *et al.* (2008). Head width, height and area were directly proportional to the rate of nitrogen applied. Studies conducted by Westerveld *et* *al*. (2003) also indicated that head size of cabbage increased with increase in the rate of nitrogen applied. Larger head size can also be obtained through adopting wider plant spacing as indicated by the results of this experiment.

The study revealed that weight per head of cabbage can be increased with an increase in plant spacing. However, total yield will reduce with an increase in spacing. This is due to wider spacing having lower plant density per m^2. Similar findings were also reported by Khatiwada (2001).

Nitrate content observed in the cabbage was directly related to the rate of nitrogen applied and the increase in plant spacing. Wider plant spacing had higher level of nitrate due to increase in the amount of nitrogen applied per plant having lower plant density compared to the closer spacing having higher plant density. Palada and Crossman (1998) and Abu-Rayyan *et al.* (2004) also reported similar findings.

5.0 CONCLUSION

Nitrogen and plant spacing played an important role in determining the yield, quality and nitrate content in cabbages. The data strongly suggested that increasing nitrogen rates, increases yield and head size while increasing plant spacing, reduced yield and increased head size. Increase in both nitrogen rate and plant spacing also increases nitrate content in head cabbages. Fijians prefer bigger sized head cabbages, therefore the results from this experiment will be beneficial to the growers in producing crops as per market requirements.

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RESEARCH PAPER

Distribution of coconut stick insect, *Graeffea crouanii* and its parasitoids in selected islands of Fiji

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ABSTRACT

The Coconut stick insect, *Graeffea crouanii* (Le Guillou) (Orthoptera: Phasmidae), known as "mimimata" in Fiji, is a widespread economic pest of coconut palms in Fiji and in many Pacific Island countries. The nymphs and adults stages of pest are polyphagous, but prefer coconut palms.This paper reveals findings from the surveys conducted between 2009 and 2012 during the field work in selected islands of Fiji, and discusses needed research to enhance natural-mortality control mechanisms. Preliminary studies of *G. crouanii* in selected islands of Fiji (Viti Levu, Vanua Levu and Taveuni) showed that the pest was localised and abundant in areas with low temperature, which was also statistically proven.The pest was found to be feeding on leaves with damage starting from tip and ends up leaving only the midribs. The older fronds had more damage than new frond due to longest pest exposure. The two elasmid egg parasitoids in Fiji, *Paranastatus verticalis* and *Paranastatus nigriscutellatus* of order Hymenoptera have potential as a biological control agent. This study on the *G. crouanii* in Fiji provides significant recommendations for further management of *G. crouanii* in coconut farms.

Keywords: coconut stick insect, *Graeffea crouanii*, egg parasitoids, biological control, coconut pest distribution, Fiji.

1.0 INTRODUCTION

The Coconut stick insect (*Graeffea crouanii*) order Phasmatodea, was first described by Le Guillou in 1841, based on the specimen from Samoa (Paine 1968). The *G. crouanii* is native to South West Pacific, has long slender bodies with long, thin legs. They are broad green or pinkish-brown species, with bold pink, shortened wings thus allowing them to blend in with trees, leaves and twigs. This is their primary defence and camouflage against predators. Their eggs survive seawater, in which they float (Swaine 1969), and so have high capacity for natural dispersal. Canoes on beaches where eggs could fall into them from the palms could have transported this pest to many islands and coconut leaves infested with coconut stick insects may well have been transported from place to place. In many islands of the South Pacific, *G. crouanii* has for long been known to defoliate coconut palms *Cocos nucifera* (L.), a member of the family Arecaceae (palm family) (Taffin 1998). A significant decrease in *G. crouanii* infestation levels in coconut palms is thus mandatory for the survival and boost of the coconut industry.

Coconut palms are one of the most important crops often referred to as "Tree of Life", reflecting its dietary value and the uses for other products from the tree and nut (Watson 1997). The coconut industry remains the most important agricultural commodity for many smaller islands within Fiji and throughout the Pacific Islands where it is extensively grown and plays important roles in the livelihoods of people in terms of food and nutrition security, social, cultural and the economic aspects. Pest and disease tend to affect the quality and quantity of produce and if not controlled effectively, they can cause huge damage to crops thus affect the economic status of the country as a whole. In order to improve Fiji's economy, the Fijian government is investing heavily in agriculture by assisting farmers and stakeholders to produce better quality produce for export market.The insect eats pieces out of the edges of the oldest fronds, as these have been longest exposed to attack, and the worst damage is usually seen on old trees at least 25 m high (Swaine 1969). At times if the damage is very severe, it could defoliate the whole plant which could lead to death of the plant. For example, in 1958-1959, a severe outbreak in the island of Taveuni, Fiji affected over 200 ha whereby at least 50% of the palms were defoliated and nearly 400 killed (Paine 1968). By the end of 1961 the outbreak had extended over 500 acres in which the older fronds were at least 50 per cent defoliated and nearly 400 palms had been killed (Paine 1968). While coconut is the main host of *G. crouanii,* other plants of commercial importance attacked were sago, *Metroxylon sagu* Rottb. and panadanus, *Pandanus tectorius* Parkinson (Bedford 1978).

Earlier attempts to control this pest had been unsuccessful, because there were no practical means of applying insecticides to foliage of very tall palms. Adhesive bands round the trunks of the palms caught large numbers of nymphs, but a proportion of the eggs dropped by the stick insect lodged in the crowns of palms. Nymphs which hatch from these avoid the sticky bands. Chemical control is practicable on young palms, in which the crown is accessible (Swaine 1971), but the treatment if the crowns of tall palms with contact or stomach poison from ground is out of the question. Mist blowers are able to reach heights of about 12m, whereas many of the crowns are 25m above the ground (Anon. 1966). Aerial spraying was shown to be effective (O'Connor 1959), but is considered too costly for general use (Swaine 1969). Trunk injection with monocrotophos (Stelzer 1970) was reported to be highly effective, and left no significant residues in the milk or meat of the nut. The technique appears to have been routinely used in Fiji (Anon. 1970). This systemic chemical had no phytotoxic effect, but the adverse effects on arthropods' parasitoids introduced for the control of coconut pests is poorly known. However, the disadvantage of injecting chemicals is that fungal pathogens may invade the holes bored in the trunk and kill the palm (Dharmaraju 1977). The misuse and abuse of pesticides by farmers also led to negative impacts on environment.

Consequently, there have been several attempts at establishing other different aspects of biological control for this pest. Various management options for the pest have been documented in the Annual Research Reports of Department of Agriculture in Fiji (Singh *et al*. 1974-75; 1977; Kamath *et al*. 1979, 1981). One of them was to use the two egg parasitoids native to Fiji. Eady (1956) described two wasp parasitoids reared by O'Connor *et al*. (1954) from the eggs of *G. crouanii* in Fiji.These two elasmid egg parasitoids, *Paranastatus verticalis* Eady and *Paranastatus nigriscutellatus* Eady of Order Hymenoptera had potential as biological control agent. These wasps can be mass reared in laboratory. However, recent research data is not available to assess the effectiveness of these parasitoids for the control of the pest.

Therefore, in order to address the continuous damage caused by this pest to coconut farms, Fiji's Ministry of Agriculture, the Koronivia Research Station (KRS), initiated preliminary studies on distribution of pest and its parasitoids in some selected islands of Fiji. This paper reveals the findings from the field work conducted between 2009 and 2012 in selected islands of Fiji, and discusses research needed to enhance natural-mortality control mechanisms.

2.0 MATERIALS AND METHODS

2.1 *Survey sites*

For this study only three bigger islands namely, Viti Levu, Vanua Levu and Taveuni were chosen (Fig. 1). The *G. crouanii* surveys were conducted on main coconut growing areas with reference to three climatic conditions (temperature, rainfall and humidity).

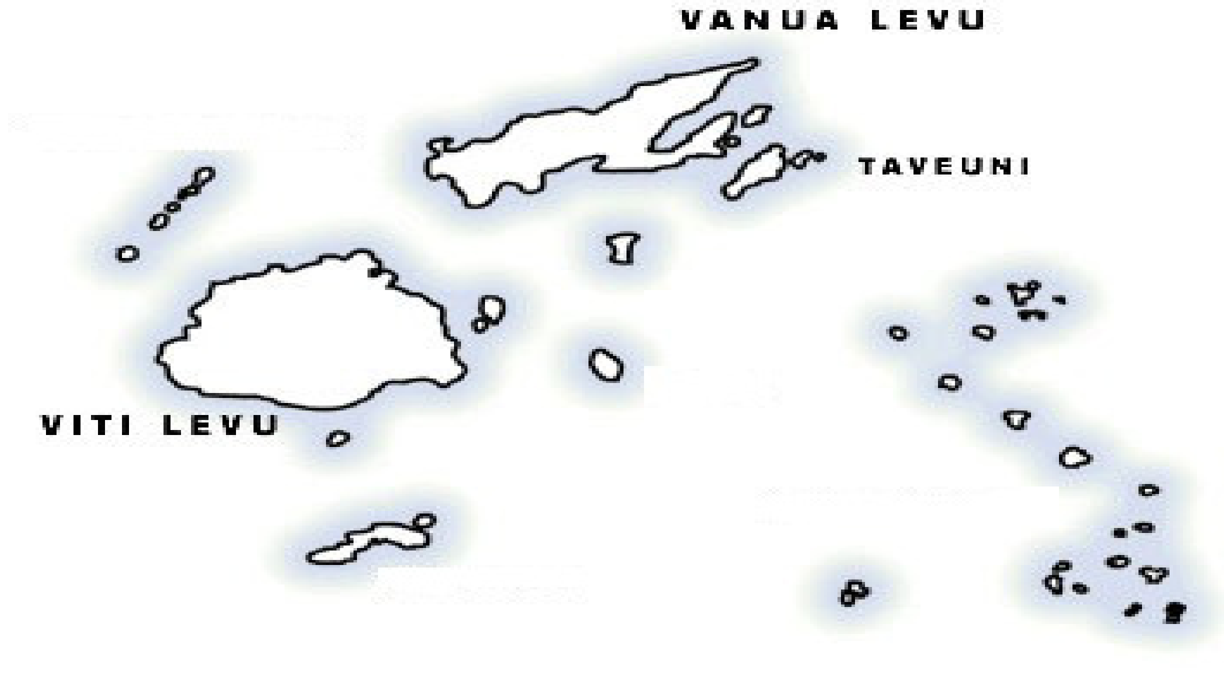

Figure 1. The survey sites for *Graeffea crouanii* in Fiji.

2.2 *Mapping-out pest distribution and damage in coconut growing areas*

Fields were selected at random depending on the pest distribution, road accessibility and area to be sampled. Between 2009 and 2012, a total of 40 farms (15 in Vanua Levu, 15 in Viti Levu and 10 in Taveuni, respectively), were visited and surveyed. At each farm during the survey, a visual assessment of *G. crouanii* occurrence was made on plants foliage of all ages using the damage scale index (Fig. 2). The distribution of the *G. crouanii* was determined by sampling coconut plantations of different growth stages in farmers' fields in each of these three islands. Some of the sites marked as "hot spots" were repeatedly visited between these four years field work.

< 30 % 30-50% 50-80% ≥ 80%

Figure 2. The damage scale index used for survey of *Graeffea crouanii* in Fiji.

2.3 Study of *egg parasitoids* of *G.crouanii*

In this study, the effectiveness of the biological control agents in controlling *G.crouanii* was studied. The wasps, *P.verticalis* and *P. nigriscutellatus,* used for biological control of *G.crouanii* was retrieved from the fields by placing white sheets around the base of pest infested palms to obtain eggs of *G.crouanii.* The eggs were collected after three days from the sheets expecting parasitism by the parasitoids. These eggs were kept under observation in laboratory and checked for emergence of egg parasitoids.The parasitoids reared from these collected eggs were used for rearing of more parasitoids by exposing the fresh *G.crouanii* for field release in infested sites.

2.4 *Statistical analysis*

The MINITAB statistical software was used to analyse data of this study using a logistic regression since it is useful to study the effect of different climatic conditions (i.e. temperature, rainfall and humidity) on the level of pest infestation. The logistic regression model for the expected number of infestation in a particular location is given by:

$$E(y) = \frac{n}{1 + e^{-[\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3]}},$$

where, n = number of farms trialled in the location, y = number of infested farm, x_1 = temperature, x_2 = rainfall, x_3 = relative humidity and $\beta_i; (i = 1, 2, 3)$ are the regression coefficients.

3.0 RESULTS AND DISCUSSION

There are ca 300 islands in Fiji and the entire islands have coconut palms which is widely used for the livelihood of the people. Presence of pest has hugely affected the development of the coconut palms and the presence of coconut stick insect in Fiji has been reported by researchers since early 1950. Results from this study further confirm that the pest distribution is not only all over Fiji, but at different levels as well.

3.1 *Pest distribution*

The highly infested coconut plantations were mostly in the leeward sides of the three larger islands surveyed (Fig. 3 and Table 1). Because of low temperature and wet nature of these environments, the survival and development of coconut stick insect is ensured in the overgrown weeds beneath the palms. The eggs laid by adults from the crown of palms normally undergo development at the base of palms. The moisture present protects the eggs and assists in early development stage of the pest nymphal stages. Moisture was vital for early development and since its absence in dry climatic zones induced death and controlled the pest population.

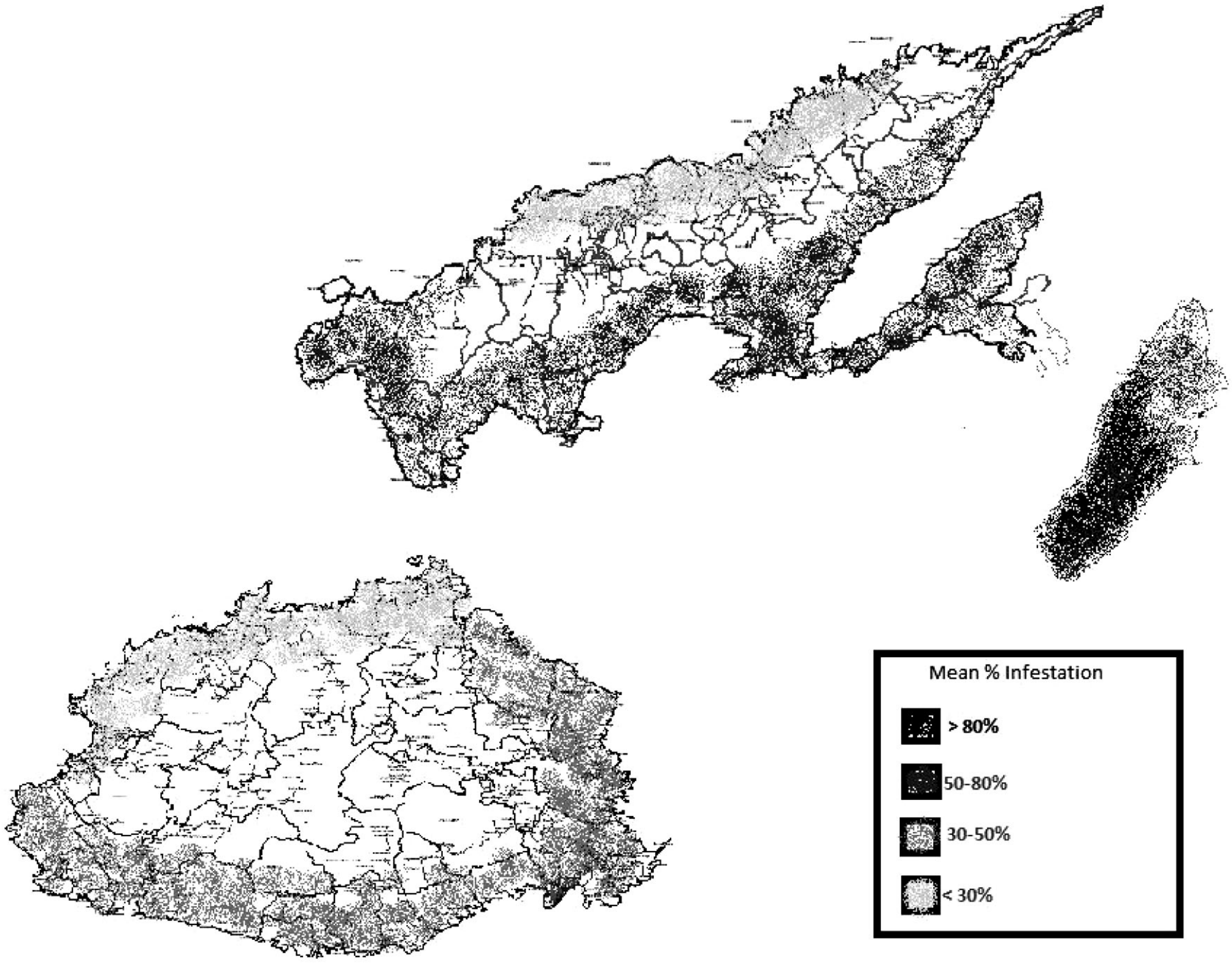

Figure 3. Distribution and infestation of *Graeffea crouanii* in three selected islands of Fiji between 2009 and 2012.

Table 1. Relative damage by *Graeffea crouanii* and parasitism in three selected islands of Fiji between 2009 and 2012.

Location (Island)	Coconut fields visited			Climatic conditions 2009-2012 (Average)*		
	Total No.	No. of farms infested with pest	% infestation	Temperature (°C)	Rainfall (mm)	Relative Humidity (%)
Central Viti Levu	5	2	40	29.22	261.83	80.81
Western Viti Levu	5	1	20	29.95	218.00	76.35
Eastern Viti Levu	5	2	40	29.22	261.83	80.81
Northern Vanua Levu	5	1	20	31.07	213.80	76.08
Western Vanua Levu	5	4	80	28.97	261.91	78.82
Southern Vanua Levu	5	4	80	29.16	191.15	78.98
Northern Taveuni	5	4	80	29.12	225.16	79.23
Southern Taveuni	5	5	100	29.12	225.16	79.23

* Source: Fiji Meteorological Services.

3.1.1 *General trends*

The statistical analysis of results show that the only coefficient = -2.24326 is significant (*P*-value = 0.042), indicating that the temperature has a significant effect on the level of infestation in farm surveyed. However, the effect of rainfall and the humidity on the infestation is not statistically significant. The odds ratio for temperature is 0.11, which explains that every one degree increase in temperature reduces the odds of infestation by 0.11. Where as, from the odd ratios of rainfall and humidity, every one centimetre increase of rainfall and one percent increase of humidity reduce the infestation by 0.94 and 0.42, respectively. However it is statistically not significant.

3.1.2 *Viti Levu*

A total of fifteen coconut plantations were visited of which five of the plantations were located in Central part, five in Western part and five in Eastern part of the island. In Central and Eastern parts most of the coconut is cultivated along the coastal areas, while for Western part the coconut is cultivated along coastal and inland. *G. crouanii* infestation was high (30-50%) in Central and Eastern areas where temperature was less compared to the Western part which had higher temperature and lower pest infestation (< 30%). This correlation of temperature and pest infestation was statistically proven and implies that rise in temperature will lead to reduction in pest infestation.

3.1.3 *Vanua Levu*

Fifteen coconut plantations were visited of which five plantations were located in northern part, five in western part and five in southern part of the island. In northern part the temperature was more and level of pest infestation was lower (<30%) compared to western and southern parts which had lower temperature and high level of pest infestation (50-80%).

3.1.4 *Taveuni*

A total of ten coconut plantations were visited, of which five plantations were located in northern part while another five in southern part of the island. Coconut is grown throughout this island and the level of pest infestation was found to be very high due to favourable weather conditions in Southern part of the island which was also observed by previous researchers. It should be noted that the average temperature provided by Fiji Meteorological Services was only taken at one site in Taveuni which represents whole of Taveuni, however the climatic conditions differs for southern and northern parts of the island. In southern part of the island the pest infestation was more (≥80%) compared to northern parts which had slightly lower pest infestation (50-80%).

3.2 *Biological control: Egg parasitoids of G.crouanii*

In Fiji, the biological control agents, the wasp (egg parasitoids) *P.verticalis* and *P. nigriscutellatus,* were present and used as control measure in conjunction with field sanitisation against *G. crouanii.* Successful rearing of the two species of biocontrol agents, *Paranastatus* was done in the laboratory and it was observed that it parasitized up to 65% of exposed fresh egg of *G. crouanii*. Previous field studies have found parasitism from less than 10% up to as high as 52% of the eggs (Paine 1968). In the outbreak area on Taveuni in 1963, Paine (1968) obtained less than 10% parasitism by *Paranastatus* spp. Singh *et al.* (1974-75; 1977) observed highly variable levels of parasitism by *P. verticalis* and *P. nigriscutellatus*, whereby they found that thick weed cover led to lower parasitism by both species. A range of 2.7-35.9% and 24.5-52.4% parasitism was observed in two studies by Kamath *et al.* (1979, 1981). In all these studies, *P. verticalis* was found to be the most active of the two egg parasitoids. In addition, about 6-17 adult egg parasitoids emerged after approximately 18-111 days of incubation period upon parasitism.

4.0 CONCLUSION

Graeffea crouanii is widely spread on the three island surveyed and found to cause significant damage to coconut palms. The best prospects available for biological control are the establishment which should be combined with clearing around the bases of affected trees and if facilities are available, the occasional mass rearing and release of egg parasitoids in hotspots. Clearing around palm bases to expose eggs to sun and predators, and also interplanting with non-host would help to reduce pest status. Cultural practices should help to reduce the damage to coconuts by reducing weed cover and exposing eggs, nymphs, and adults to natural mortality. In addition, the continuing nation-wide farmers' education and awareness training programmes in the outbreak areas will assist them to learn about the life cycle of *G. crouanii,* how to recognize its damage, and understand why cultural and biological control methods are preferred to the 'shot-gun approach' to pesticides which is not ecologically sustainable. Detailed ecological studies evaluating the critical mortality factors and mechanisms affecting the eggs of *G. crouanii* need to be carried out to improve the biological control for *G. crouanii*.

ACKNOWLEDGEMENTS

We acknowledge the Ministry of Agriculture, Fiji for funding support and staff of Plant Protection Section, Entomology Unit (Joni Wede, Akisi Cavuilati, Mohammed Janif and late Surendra Rohit) for their assistance in laboratory and field work. Thanks are also due to the Director of Fiji Meteorological Services, Nadi, Fiji for providing the climatic data. We also thank Dr R.C. Joshi for reviewing the manuscript.

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RESEARCH PAPER

Biology of mucuna (*Mucuna pruriens* (L.) DC.) in eastern Viti Levu, Fiji

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ABSTRACT

Mucuna pruriens (L) DC. is an annual cover crop belongs to the family Fabaceae. It has a rapid growth rate and found to suppress weeds, improve soil fertility and crop yields however, studies on the biology and ecology of *M. pruriens* in the Pacific Island region is relatively unknown. The species was re-introduced into Fiji from the Kingdom of Tonga in 2010. Five seeds were planted at Koronivia Research Station, Fiji and preliminary results demonstrated that first harvesting of pods occurred at five months after planting. The number of pods in a bunch ranges from 4 to 27, with a mean of 9.12 ± 0.68 SE out of 60 bunches randomly sampled. The average length of mature pod from the 200 pods measured was 11.08 cm ± 0.12 SE with a range of 5.7 to 15.3 cm. From 1,000 randomly sampled mature pods, the average number of seed per pod was 4.57 ± 0.04 SE with a range of 1 to 7 seeds per pod. Germination rate of seed stored at 4°C in the refrigerator and at room temperature was ca 100% at 10 months of storage. The average fresh weight of 50 lots of 10 mature seeds was 13.37 g ± 0.13 SE with a range of 10.88 to 15.64 gram. At 14 months after planting, the five *M. pruriens* plants have produced a total of 5,275 pods. This baseline data has not only enhance our understanding of the biology of the species, valuable for those who wishes to cultivate *M. pruriens* for seed but also provide vital knowledge on the potential of the species to become a serious invasive species if they are not effectively managed.

Keywords: *Mucuna pruriens,* seed, Fiji

1.0 INTRODUCTION

Mucuna (*Mucuna pruriens* (Lour.) A. Chev.) is an annual cover crop belongs to the family Fabaceae (Sidibe-Anago 2009; Shave *et al.* 2012). It has a rapid growth rate after establishment and found to improve soil fertility and crop yields (Shave *et al.* 2012). *M. pruriens* has the potential to suppress weeds up to c. 50% in maize intercropping (Shave *et al.* 2012) and improves earthworm population in the soil (Mike Smith, DAFF Queensland *pers. comm.* 10/09/12).

M. pruriens has been introduced to several countries in the world for cover crop and to improve soil fertility (Sidibe-Anago 2009; Shave *et al*. 2012). Attributed to its high content of crude protein, feeding *M. pruriens* has resulted in improvement in the growth rate of calves and increased milk yields in dairy cows (Sidibe-Anago *et al.* 2006 cited in Sidibe-Anago 2009). *M. pruriens* is known to fix nitrogen, mobilise fixed phosphorus and increase level of potassium in the soil (Sidibe-Anago 2009; Mike Smith, *pers. comm.* DAFF Queensland, 10/09/12). It has the potential to mine phosphorus and potassium and make it available to shallow rooted plants (Siosiua Halavatau Secretariat of the Pacific Community, *pers.comm.* 10/09/12).

In Fiji, out of the five Mucuna species recorded, *M. pruriens* (L.) DC., and *M. novo-guineens is* Scheffer were introduced, *M. gigantea* (Willd.) DC, *M. platyphylla* A. Gray and *M. stanleyi* C.T. White were native species (Smith 1985). The benefits of *M. pruriens* in soil health improvement had resulted in the introduction of *M. pruriens* seed from Tonga into Fiji in 2010 (Steve Hazelman Secretariat of the Pacific Community, *pers. comm.* May 2013), where the plant species was used as a fundamental component of the ACIAR-funded Soil Health Project trial on taro *(Colocasia esculenta* L. Schott*)* on Taveuni Island (Halavatau *et al.* 2013).

Studies on the biology and ecology of *M. pruriens* in the Pacific Island region is relatively unknown. This could be due to the fact that the species has just recently been introduced into most countries and lack of literature on research conducted on the species in the region. The Kingdom of Tonga's Ministry of Agriculture has worked with *M. pruriens* since 1990s (Secretariat of the Pacific Community, 2009) however, literature on mucuna research is relatively unknown. Research on *M. pruriens* is relatively new to Fiji since its introduction in 2010 and basic knowledge of the plant species is relatively unknown in the country. Therefore, the aim of this study is to determine the biology of *M. pruriens* in field situation. Knowledge gained from this study would provide baseline data for *M. pruriens* production and research in Fiji.

2.0 MATERIALS AND METHODS

2.1 *Study site*

Five *M. pruriens* seeds were raised in Yates potting mix in plastic pots in the glasshouse at Plant Protection Section, Koronivia Research Station in March 2012. At two leaf stage, the seedlings were transplanted 1.5 m apart onto soil mixed with two handful of Yates potting mix per plant, underneath a 11.8 m x 5.9 m x 2.2 m (l x w x h) structure made of treated pine log as posts, 10 x 5 cm timber as top plate and wire mesh as roof to support the vine, ca 5 m away from the glasshouse. Each of the five plants was later trellised when they were ca 50 cm tall using a twine tied on to the wire mesh roof directly above each plant. The plants were maintained during the growing period. At four months after planting, the vines has covered about 40% of the roof and started flowering. Harvesting of mature pods commenced at five months after planting for five months. Pods were harvested when they were mature, i.e. turn blackish grey and make a sound upon shaking. Mature pods were stored in card boxes in the laboratory until used for the study.

2.2 *Number of pods per bunch*

The bunches were hanging underneath the mesh wire and were easy to count. A total of 60 bunches were sampled when they were still green. The number of pods in each bunch was counted and recorded.

2.3 *Length of mature pod*

Immediately after harvest, 200 mature pods were randomly sampled from the lot and length of each pod was measured using one end of a string placed at the distal end of the pod along the middle to the other end of the pod where a mark was placed on the string then the string was transferred to a 30 cm ruler to determine the length of each pod. The length of each pod was recorded in centimeters.

2.4 *Number of seed per pod*

For this study, a total of 1,000 mature pods were sampled. A pen knife was used to open up the pod and to extract the seeds. The seeds in each pod were counted and recorded.

2.5 *Weight of mature seed*

Seeds were extracted from the pods and then 50 lots of 10 seeds were randomly sampled from the heap, weighed in grams to 2 d.p and recorded.

2.6 *Total number of pods produced*

The number of pods harvested during the harvesting season were counted and tallied at the end of the season.

2.7 *Seed viability*

Five hundred seeds were extracted from pods, separated in half and one lot of 250 seeds was placed in a plastics bag and stored in a refrigerator and the other was kept in a paper bag and stored in the laboratory at a temperature range of 19 to 25 °C. Forty seeds were randomly sampled from each treatment every month to determine their viability. In each germination test and in each treatment, ten seeds were randomly picked and placed in each of the 90 mm diameter Petri dishes each lined with Whatman filter papers, moistened with ca 5 mL of water. Each treatment was replicated four times at each germination test. Seed was positioned evenly onto the filter paper surfaces at least 1 cm apart to minimise any possible autotoxic effects (Navie 2002). Seeds were irrigated when needed. Seeds were considered to have germinated when white, healthy radicles >1 mm long were observed to be protruding through the fruit walls. To test the effects of storage method on germination (%) of *M. pruriens* seed, a one way ANOVA was conducted. Data were analysed using STATISCA10.0-2010.

3.0 RESULTS AND DISCUSSION

3.1 *Number of pods per bunch*

The largest number of *M. pruriens* bunches have 6-10 pods (57%; 48), followed by bunches with ≤ 5 pods (23%; 14), 11-15 pods (12%; 7), 26-30 pods (5%; 3) and the least with 16-20 pods (3%; 2) (Fig 1). The average number of pods in a bunch was about nine.

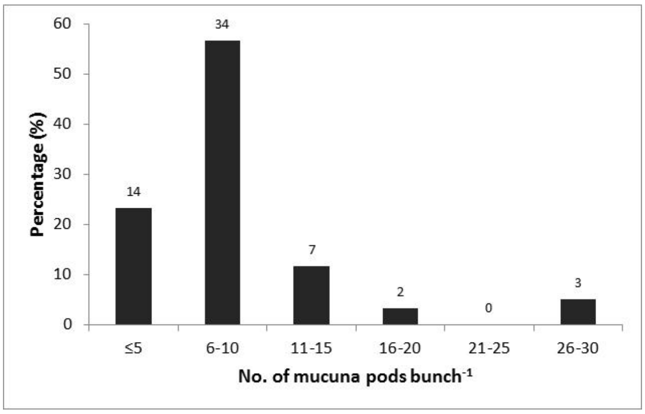

Figure 1. Range of the number of *M. pruriens* pods bunch^{-1} sampled from the 60 bunches on the five *M. pruriens* plants raised at Koronivia Research Station, Fiji.

3.2 *Length of mature pod*

From the 200 mature *M. pruriens* pods sampled, the pods with the length range of 10.1-12.0 cm were the most dominant with 43% (86), followed by 12.1-14.0 cm (30%; 59), 8.1-10.0 cm (22%; 44), 6.1-8.0 (4%; 8), 14.1-16.0 (1%; 2) and shortest was 4.0-6.0 with only one pod fell within this length range (Fig 2). The average length of a mature *M. pruriens* pod was 11.1 cm.

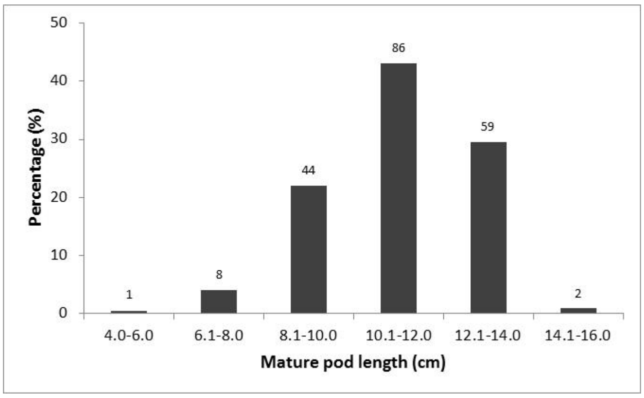

Figure 2. Length range of mature *M. pruriens* pods (cm) against the percentage of the 200 pods randomly sampled from the pods harvested from five *M. pruriens* plants raised at Koronivia Research Station, Fiji.

3.3 *Weight of mature pod*

From the 200 mature *M. pruriens* pods sampled, the pods with the weight range of 9.51-12.50 g were the most dominant with 40% (80), followed by 12.51-15.50 g (29%; 58), 6.51-9.50 g (22.5%; 43), 3.51-6.50 (6.5%; 13), 15.51-18.50 (2.5%; 5) and the heaviest pod was 19.48 g as the only pod fell within 18.51-21.50 g range (Fig 3). The average weight of a mature *M. pruriens* pod was 11.02 g.

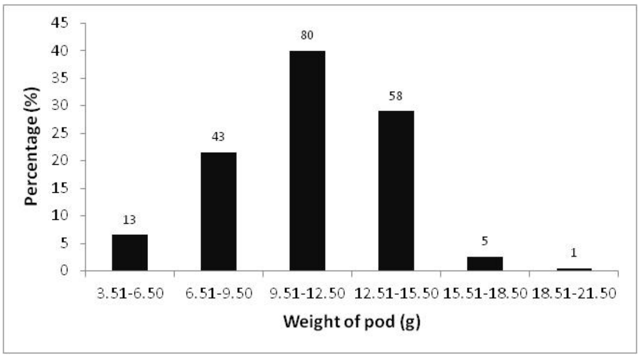

Figure 3. Weight range of mature *M. pruriens* pods (g) against the percentage of the 200 pods randomly sampled from the pods harvested from five *M. pruriens* plants raised at Koronivia Research Station, Fiji.

3.4 *Number of seed per pod*

The maximum and minimum number of seeds extracted from the 1,000 pods sampled were seven and one, respectively (Fig 4). The largest proportion of pods (35%; 345) have five seeds, followed by four (24%; 241), six (23%; 233), three (12%; 116), two (6%; 62), one (0.2%; 2) and the least was seven (0.1%) found in only one pod (Fig 4). About 82% (819) pods have seeds in the range of four to six seeds (Fig 4).

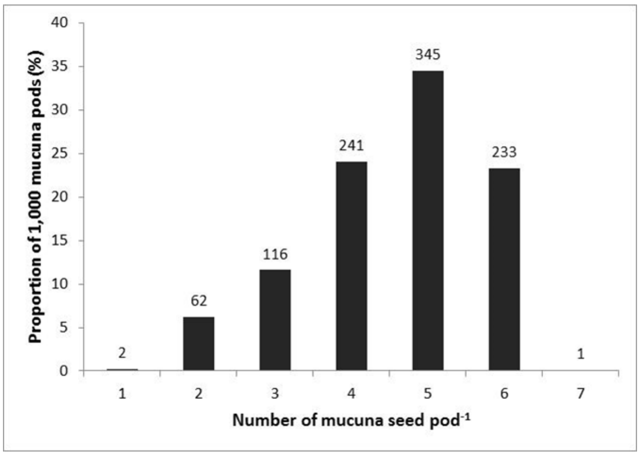

Figure 4. The number of *M. pruriens* seed pod^{-1} and the total number of pods carrying the respective number of seeds from the 1,000 pods as sampled from pods harvested from five *M. pruriens* plants planted at Koronivia Research Station, Fiji.

3.5 *Weight of mature seed*

There was a variation in the weight of mature seed. From the weight of 50 lots of 10 seeds examined, the largest proportion of seeds have weights in the range of 13.01-14.00g (54%; 27) followed by 12.01-13.0g (22%; 11), 14.01-15.00g (12%; 6), 11.01-12g (6%; 3), 15.01-16.00 (4%; 2) and the least proportion of seeds examined have weight ranged from 10.0-11.01g (2%; 1) (Fig 5). The average fresh weight of 10 *M. pruriens* seed was 13.37g or 1.3g seed^{-1}.

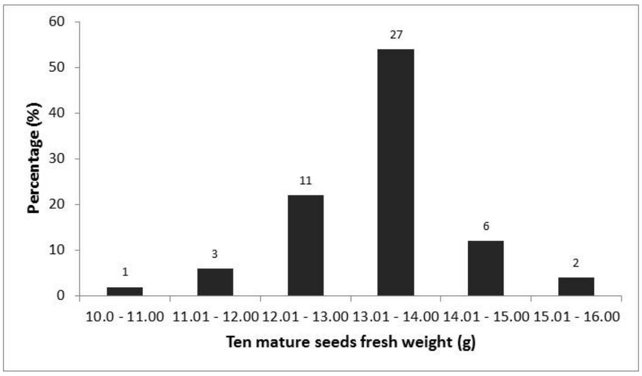

Figure 5. Fresh weight range of 50 lots of 10 mature *M. pruriens* seeds sampled from the seeds extracted from the pods harvested from the five *M. pruriens* plants raised at Koronivia Research Station, Fiji.

At end of first fruiting season (August 2012 to January 2013), the five *M. pruriens* plants have produced 5,275 pods. However, the second flowering season commenced in February 2013 and the total number of pods produced were 1,026. Unfortunately, the five plants died in May 2013, 14 months after planting.

3.6 *Seed viability*

There was no significant difference ($F_{1,62} = 2.07$; $P = 0.156$) between the two storage treatments in the germination of *M. pruriens* seeds during the eight months period (Table 1). The germination (%) of *M. pruriens* seed stored in the refrigerator (4°C) was 100% every month in the first nine months while seeds stored at room temperature recorded the same germination (%) in eight of the 11 months but 98% germination each in three other months (Table 1).

A similar *M. pruriens* seed viability study reported a seed germination rate of 90 to 95% occurred within 5-7 days (Bachmann, n.d). This suggests that Mucuna can maintain its high seed viability status for 11 months after harvesting even if its stored under room temperature provided the seeds are kept dry.

Table 1. Comparison of the germination (%) of *M. pruriens* seeds stored in a refrigerator (4°C) and at temperature (19-25°C) in the laboratory. Data are the average of four reps of 10 seeds per rep. The average time (days) taken for the viable seed to germinate is in parenthesis.

Month	Refrigerated seed (4°C) (% Germination)	Room temp. seed (19-25°C) (% Germination)
October 2012	100 (5d*)	100 (5d)
November 2012	100 (4d)	100 (5d)
December 2012	100 (5d)	100 (7d)
January 2013	100 (5d)	100 (6d)
February 2013	100 (6d)	98 (7d)
March 2013	100 (7d)	100 (6d)
April 2013	100 (6d)	100 (6d)
May 2013	100 (7d)	98 (6d)
June 2013	100 (6d)	100 (6d)
July 2013	98 (6d)	100 (7d)
August 2013	100 (7d)	98 (8d)

**5d represent 5 days to attain the respective seed germination %.*

4.0 CONCLUSION

The results of this study has filled the gaps in knowledge on the reproductive biology potential of *M. pruriens* in Fiji. Further studies on seed persistence in the soil, growth rate of the species in the field and its effect on weed growth in crop production in Fiji would provide vital information on soil seed bank potential, extent of spread and on the role of *M. pruriens* in reducing herbicide application in crop production system in Fiji.

ACKNOWLEDGEMENTS
We sincerely thank Mr Fereti Atu and Dr Siosiua Halavatau of the Secretariat of the Pacific Community for approving our involvement in the ACIAR-funded project 'Improving Soil Health in Support of Sustainable Development in the Pacific PC/2009/003' which actually introduced the principal author to the *Mucuna pruriens* cultivation in Taveuni resulted in the initiation of current study on Mucuna at Koronivia Research Station. The support from Plant Protection Section staff is duly acknowledged and sincerely appreciated. We also thank Dr R.C Joshi for reviewing the manuscript.

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RESEARCH PAPER

Properties and potential uses of *Xylopia pacifica* (Dulewa)

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ABSTRACT

Research and development on Lesser Known Species (LKS) is essential to determine the best use of the tree species which would not only be used as an alternative to commonly demanded tree species meaning reduced pressure in their harvest but could also be used to generate income in areas where they are found. The Timber Utilisation Division, under the Ministry of Fisheries and Forests in Fiji has embarked on a new project, 'Research and Development of Wood and Non-wood Species' in which it aims to provide accurate and technical quality information on both wood and non-wood properties. In 2012, a LKS identified was *Xylopia pacifica* (A.C.Sm) species, commonly known locally as Dulewa. The results indicated that *X. pacifica* is suitable for light construction, i.e. for furniture and parts of building structure.

Keywords: Lesser Known Species (LKS), *Xylopia pacifica*, utilisation, Fiji.

1.0 INTRODUCTION

Tropical forests hold a multitude of Lesser Known Species (LKS) and a great number of these are potentially valuable timber species. Lesser Known Species are simply those species that are not being put to best advantage (CPET 2011). The Timber Utilization Division (TUD), under the Fiji Ministry of Fisheries and Forests continues to focus on improving its outcome for research development on wood and non-wood forest species and its products. The 2007 National Forest Inventory (NFI) was analyzed and five LKS species were identified. Out of the five LKS identified, two were recommended for further research to enable their technical properties and potential uses to be known. In 2012, the LKS selected was the *Xylopia pacifica,* locally known as 'dulewa', 'wako ni sacau' or 'kavukavu' (Smith 1981). *Xylopia pacifica* in its natural form has a slender trunk formation up to 40 cm in diameter with branches roughly horizontal to its trunk. It is endemic to Fiji and found on Viti Levu, Vanua Levu, Taveuni, Ovalau and Kadavu (Smith 1981). The distinctive feature of *X. pacifica* is that its greyish brown bark emits a ginger-like smell when cut and are sometimes covered with black lenticels (Keppel and Ghazanfar 2011). The aim of this study was to evaluate the physical and technical features of *X. pacifica* to determine its potential use.

2.0 MATERIALS AND METHODS

2.1 *Source and Extraction of X. pacifica*

Six *X. pacifica* trees were selected and marked before felling at Landing 5, Vunisea, and Dreketi in Vanua Levu. The Diameter at Breast Height (DBH) and length of each tree was measured (Table 1). Discs for density determination were removed from the tree at 3 m interval for trees with shorter lengths and 6 m interval for those with longer lengths. The discs were labelled and properly wrapped with glad wrap to prevent moisture from being absorbed or released from the discs. The discs were then taken to Nasinu Laboratory for density determination.

Table 1. Extracted Logs with their measurements.

Log No.	Diameter at Breast Height (DBH) (cm)	Length (m)	Volume (m^3)
1	40	15	1.889
2	32.5	14	1.164
3	43.5	11.6	1.1728
4	37.5	9.3	1.030
5	40	8.9	1.121
6	40.7	11.1	1.448
Total			8.380

2.2 *Density measurements*

The discs were cut diagonally from the pith to the outer layer and numbered accordingly for basic density and moisture content assessments. The green weight of each piece was measured and recorded in grams (g) and were then subjected to saturation process. The basic density (1), air dry density (2), green density (3) (Timber Utilisation Research Division, 1978) and moisture content (MC) (4) (Timber Utilisation Division, 1989) were measured.

$$\text{basic density (kg/m}^3) = \frac{\text{oven dry weight (kg)}}{\text{green volume (m}^3)} \quad \text{①}$$

$$\text{air dry density} = \frac{\text{Weight at 12 \% MC}}{\text{Volume at 12\% MC}} \quad \text{②}$$

$$\text{Green Density} = \frac{\text{green weight}}{\text{green volume}} \quad \text{③}$$

$$\text{Moisture Content (MC)} = \frac{\text{initial weight} - \text{oven dry weight}}{\text{oven dry weight}} \times 100 \quad \text{④}$$

2.3 *Sawmill Conversion*

The diameter, length and the input volume of the logs (5 & 6) (Timber Industry Training Center, 2012) were measured and recorded. The logs were then graded and defects were counted and recorded.

$$\text{Log volume} = \frac{(\pi) r^2 x\ Length}{10{,}000} \quad \text{⑤}$$

$$\text{Sawn timber volume} = \frac{Length\ x\ Width\ x\ Thickness}{1{,}000{,}000} \quad \text{⑥}$$

The bark was removed and logs squared and sawn length wise. The sawing pattern used depends on the size of the log diameter. The 'round sawing' method was used for big diameter logs while the 'through and through' method was used for logs with small diameter. The timber sizes ranged from 50 x 25 mm to 200 x 50 mm with lengths ranging from 0.6 m to 4.5 m. The sawn pieces were numbered correlating to the log number. The characteristics of each sawn piece were recorded, from which the output recovery was calculated (7).

$$\text{Recovery} = \frac{Output\ (sawn\ timber)}{Input\ (logs)} \quad (7)$$

2.4 *Grading*

The logs were graded according to the National Grading Rules for Fijian Timbers (Metric Version). These rules were designed to cover sizes, shapes and quality of timber required for light building construction and general purposes, including joinery and dressing (Yabaki 1986). The timbers were graded according to the 'Finishing Grade' which is the Fiji F-Select, Fiji F-Standard and Common Grade. All timber pieces below one meter in length were graded as shorts. The proportion of different types of defects for each grade was also determined.

2.5 *Dipping*

Sixty (60) timber pieces with lengths of 1.0 m and dimensions of 100 x 25 mm were selected for the dipping process. The chemicals used in this process were Antiblusapstain and Vascol (Gremm Chemicals Fiji Limited). There were five (5) different concentration percentages of each of Antiblusapstain and Vascol used to determine the most effective concentration to reduce mould, stain and decay (Table 2).

Table 2. Concentration of Antiblusapstain and Vacsol tested.

A	B	C	D	E
Antiblu-0.5% Vacsol-0.4%	Antiblu-1.0% Vacsol-0.4%	Antiblu-1.5% Vacsol-0.4% (Recommended)	Antiblu-2.0% Vacsol-0.4%	Antiblu-2.5% Vacsol-0.4%

2.6 *Air Drying and Further Kiln Drying of Green Sawn Timber*

A total volume of 2.08 m³ was air dried at the TUD drying shed at Nasinu. After 3 weeks of drying, the average moisture content attained was 26% and presence of fungi and mould were observed on the top surface of the stacked timber pieces. The drying defects were assessed once the average moisture content reached 25% or less. The timber pieces after having reached 25% MC from air seasoning were further dried in the kiln to 14% MC and the drying defects were re-assessed. A total volume of 1.35 m³ was kiln dried.

2.7 *Treatment*

Treatment of timber refers to the impregnation of chemicals such as Tanalith NCA into the timber to prolong the life of timber which usually increases durability and resistance from being destroyed by insects or fungus. (Timber Industry Training Center 2012). Green Treatment however refers to treatment of timber straight after the sawmill conversion process, while dry treatment are those timber pieces that are treated after air dried to 25% moisture content.

2.8 *Green Treatment*

Ten green sawn timber pieces with dimensions of 150 x 25 mm each were selected for green treatment analysis using 3.0% Tanalith NCA (H3); while another 10 pieces with dimensions ranging from 50 x 50 mm to 150 x 50 mm were treated using 1.5% Tanalith NCA (H2). The weight of each timber before and after treatment was recorded to determine the weight gained.

2.9 *Dry Treatment*

The same procedure for the Green Treatment was done for the Dry Treatment, except that it was being treated after air drying to 25% MC.

3.0 *Natural heartwood durability assessments*

Natural durability of a timber is determined by using graveyard trial. In this trial, 20 *X. pacifica* wood stakes, 50 mm x 45 mm in section, 30 cm in length were inserted to the ground so that half of the length of the stake is buried. The average time taken for this stakes to fail is used to assign a natural durability rating. The graveyard trial was assessed after three months.

3.1 *Wood Working Properties*

The screwing, nailing, turning and varnishing properties of the species were also tested (Fig. 1).

3.0 RESULTS AND DISCUSSION

The average density of *X. pacifica* was 713 kg m^{-3} at 12% MC, which is in the range of 580-800 kg m^{-3} density at 12% MC, and is classified as medium hardwood species which is in the same class as Damanu (*Calophylum vitiense* (Turril) A.C. Sm), Mavota (*Gonystylus punctatus* A.C. Sm) and Rosawa (*Gmelina vitiensis* (Seem.) A.C. Sm).

Figure 1. *X. pacifica* work piece under turning and moulding process into a coffee table leg in the lathe machine.

Table 3. Density and Moisture Content.

Moisture Content	57 %
Average Basic density	637 kg m^{-3}
Average Relative Density	773 kg m^{-3}
Average Green density	976 kg m^{-3}
Average Density @12%	713 kg m^{-3}

3.1 *Sawmill – Percentage Recovery*

Log Input: 4.745 m^3; Output: 2.361 m^3; Total Recovery: 50%

3.2 *Grading*

The total grade recovery for the 18 logs processed indicated that 24% were F.Select, 32% F. Standard, 28% Common and 15% Shorts (Table 4).

Table 4. Total Grade Recovery for the 18 Logs.

Grade	Total Vol (m^3)	Total Recovery (%)
F.Select	0.603	24
F.Standard	0.798	32
Common	0.685	28
Shorts	0.379	15

Timber is graded on the better or the clearer surface (Timber Industry Training Center, 2012). There were nine different types of defects identified while grading (Table 5) and they affect the quality of sawn timber. The defects of the timber then determine which grade the timber will be classified under, according to the National Grading Rules for Fijian Timbers (Yabaki 1986)

Table 5. The percentage of a particular defect on the total output of sawn timber and the percentage of each defect in each grade.

Defect	Total Sawn Timber (%)	Grade
Wane	22.7	16% F.Select
		16% F.Select
		57% F.Standard
Knots	7.5	27% Common
		26% F.Standard
		58% Common
Stain	12.8	14% F.Select
		37% F.Standard
		49% Common
Rot	47.2	1% F.select
		29% F.Standard
		69% Common
Pith	5	100% Common
Cross grain	7.3	100% Common
B/Pocket	30.1	46% F.Standard
		54% Common
Shake	11.3	34% F. Standard
		66% Common
Pin hole	2.26	100% Common

Mould and stain were visible in the 'control' samples a month after the trial establishment as they were not dipped in the Antiblusaptain and Vacsol solutions (Table 6). Samples 'C' which was the recommended chemical concentration had similar percentage of stained timber as sample 'A' but the values became constant after the fourth assessment (Table 6).

Table 6. Proportion (%) of treated timber surface area infected with mould and stain or decay estimated after every 25 days (average).

Dipping Assessment Date	A Antiblu- 0.5% Vacsol- 0.4%			B Antiblu- 1.0% Vacsol- 0.4%			C Antiblu- 1.5% Vacsol- 0.4% (Recommended)			D Antiblu- 2.0% Vacsol- 0.4%			E Antiblu- 2.5% Vacsol- 0.4%			Control		
	M (%)	S (%)	D (%)	M (%)	S (%)	D (%)	M (%)	S (%)	D (%)	M (%)	S (%)	D (%)	M (%)	S (%)	D (%)	M (%)	S (%)	D (%)
03/07	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	10	15	-
25/07	-	10	-	-	5	-	-	10	-	-	5	-	20	-	-	30	-	-
13/08	10	15	-	-	10	-	-	15	-	-	10	-	20	-	-	35	25	-
12/09	20	20	-	-	15	-	-	18	-	-	15	-	20	5	-	35	25	-
03/10	22	22	-	20	20	-	-	20	-	3	17	-	20	7	-	37	25	-
01/11	23	25	-	20	20	-	-	20	-	3	17	-	22	7	-	37	28	-
27/11	23	25	-	20	25	-	1	20	-	3	17	-	22	7	-	37	28	-

(M = Mould, S = Stain, D = Decay)

The proportion (%) of grade recovery after Kiln drying at 15% MC (Table 7) decreased for F.Select and F.Standard, but increased for Common and Shorts as compared to the before kiln drying (Table 4). This has resulted from the further drying of the timber as bound water is removed from the cell walls thus affecting the cell structure of the timber, leading to poor quality timber.

Table 7. Overall percentage of grade recovery after Kiln Drying at 15% MC.

Grade	Total Volume (m^3)	Percentage (%)
F. Select	0.2046	15
F.Standard	0.3051	23
Common	0.5396	40
Shorts	0.2974	22

The results of the treated green timber indicated that 39% and 59% of the total logs tested passed H3 and H2, respectively (Table 8). Full preservative penetration was not attained in the cross section of most timber tested and this was due to high moisture content in the samples.

Table 8. Green Treatment. The percentage copper (% Cu) and percentage Arsenic (%As_2O_5) indicates the amount of each chemical that was penetrated through the samples. The required loading for Hazard Levels 2 and 3 (H2, H3) is 0.09 to which some of the samples failed to attain.

Sample No.	Species	Size (mm)	Spot Test	% Cu	%As_2O_5	Remarks (H3)	Remarks (H2)
1	Dulewa	150x25	Doubtful	0.08	0.04	Fail	Fail
2	Dulewa	150x25	Doubtful	0.08	0.04	Fail	Fail
3	Dulewa	150x25	Pass	0.10	0.06	Pass	Pass
4	Dulewa	150x25	Doubtful	0.08	0.04	Fail	Fail
5	Dulewa	150x25	Pass	0.09	0.06	Pass	Pass
6	Dulewa	150x25	Doubtful	0.07	0.06	Fail	Pass
7	Dulewa	150x25	Pass	0.09	0.06	Pass	Pass
8	Dulewa	150x25	Doubtful	0.08	0.04	Fail	Fail
9	Dulewa	150x25	Doubtful	0.08	0.04	Fail	Fail
10	Dulewa	150x25	Doubtful	0.08	0.04	Fail	Fail
11	Dulewa	150x50	Pass	0.09	0.06	Pass	Pass
12	Dulewa	100x50	Pass	0.09	0.06	Pass	Pass
13	Dulewa	150x50	Doubtful	0.08	0.07	Fail	Pass
14	Dulewa	100x50	Doubtful	0.08	0.04	Fail	Fail
15	Dulewa	100x50	Doubtful	0.06	0.08	Fail	Pass
16	Dulewa	150x50	Pass	0.10	0.07	Pass	Pass
17	Dulewa	100x50	Pass	0.09	0.06	Pass	Pass
18	Dulewa	100x50	Doubtful	0.08	0.04	Fail	Fail

3.3 *Dry Treatment*
Laboratory evaluation of *X. pacifica* samples that were pressure treated after air drying to 25% MC met the preservative and copper loading requirements for H2 and H3 treatment.

3.4 *Graveyard Trial*
Assessment results after nine months illustrated the absence of both decay and insect attack. However the assessment for the natural durability of *X. pacifica* is an ongoing research activity which will be assessed every three months, up until the samples have failed due to severe decay and insect attack; from which we will conclude our findings on the natural durability trial of *X. pacifica.*

3.5 *Potential Use*
Xylopia pacifica which is classified under medium hardwood species, is suitable for light construction, interior construction and other uses where light work is required (Fig. 2)

Figure 2. Potetial use of *Xylopia pacifica.* A coffee table, a flower vase and a bowl made from *X. pacifica* and constructed by the Timber Utilization Division of the Department of Forestry at Nasinu, Fiji.

Timber can be easily worked with to manufacture wooden products. It can also be used for interior and exterior lining and weatherboard provided it is treated dry to Hazard levels 2 & 3 with Chromated Copper Arsenate (CCA) or Boron preservatives. *Xylopia pacifica* is comparable with other medium hardwood species like *Endospermum macrophyllum* locally known as 'Kauvula'

ACKNOWLEDGEMENTS
This research project would not have been possible without the assistance and support from staff of the Timber Utilization Division.

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RESEARCH PAPER

Carbon content of non-native invasive tree species on *mataqali* owned native tropical forest: Study from Sote, Fiji

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ABSTRACT

Eighty five percent of the total land area in Fiji is owned by *mataqali-i-taukei,* a term representing the Fijian clan or land owing unit. Trees and pastures cover more than eighty percent of these areas. Disturbances like clearing forests for growing agricultural crops and logging creates gaps. Non-native invasive species filled up these gaps in forests all over the world. The present study was conducted with an attempt to understand the quantity of carbon stored by non-native invasive forest tree species that quickly fills the vacant gaps in *mataqali*-owned patch of native forest. Results revealed that two non-native invasive trees, *Spathodea campanulata* P. Beauv. (Pasiu) and *Swietenia macrophylla* King. (mahogany) stores 14.11 t and 7.23 t of carbon, respectively. The study provides scope to recognize the importance of utilizing invasive for managing carbon stocks in tropical forests.

Keywords: carbon stock, biomass, islands, rainforest, forest gaps.

1.0 INTRODUCTION

Rapid forest conversions, degradations, and fragmentation threatens tropical forests all over the world (Lanly 1982; Brown and Lugo 1990; Sala *et al.* 2000). Potential of invasive species to inflict enormous environmental damage in oceanic islands (Mack *et al.* 2000) and biodiversity loss (Millennium Ecosystem Assessment 2005) are widely considered. The ability of plant invaders to alter nutrient cycling, hydrology, energy budgets, fire regime and threatening the abundance of native species is also reported (Mack *et al.* 2000). There are only few options available to manage invasive species in the tropical forest (Chapman and Chapman 1996).

Exotic plants have been widely introduced in the tropics for industrial timber, for land reclamation and forage crops, and as ornamentals (Denslow and DeWalt 2008). Rejmuinek (1996) observed forty two exotic plant species invades tropical rainforests, about half of those were known to invade forests only on islands and eight were reported only from tree fall gaps. While exotic species are rare in undisturbed tropical forests, they readily invade disturbed tropical forests, often dominating and even irreparably changing the ecosystem (Fine 2002). Exposure of fragmented forest to propagule pressure from exotic species in nearby disturbed or managed ecosystems is greater, due to availability of light and space (Sala *et al.* 2000).

Emissions of greenhouse gases increased to 9 billion tons of carbon per year entering the atmosphere at twice the rate at which vegetation and oceans can naturally sequester carbon (IPCC 2006). Forest trees are considered as an important factor in mitigating climate change because of their role in carbon sequestration - the process of removing carbon dioxide from the atmosphere and storing it in plants that use sunlight to turn carbon dioxide into biomass and oxygen (IPCC 2001; Tagupa *et al.* 2010). Plantations of exotic tree species in *mataqali* owned land in Fiji is not new and is more than half a century old practice. Large scale exotic tree plantations started getting preference in the country on the fragmented forest patches, impacting silently the native forest trees. The FAO (2010) reveals that there is a constant decrease in native forest in the country both on closed and open types and there is an increase in area under plantations. Edge effect renders native tropical forest susceptible to droughts, invasive species and physical disturbances (Gonzalez and Marques 2008). The aim of this study was to estimate in a simple way the carbon content of non-native invasive trees in fragments of native tropical forests surrounded by exotic plantations. It will help to value the importance of utilization of non-native invasive species growing in native forest fragments for managing carbon stocks in the tropics.

2.0 MATERIALS AND METHODS

2.1 *Study site*

The study sites were located at S18º 4' 19" to E178º 22' 23", 100 masl in the native land tropical forest owned by Vunidomudua mataqali in Sote, Tailevu Province, Fiji (Fig. 1). The forest patches were surrounded by *Swietenia macrophylla* King plantations owned by the Fiji Hardwood Coop-eration. It receives an average annual rainfall of 2,800 mm and the annual temperature ranges be-tween 18ºC and 25ºC (Fiji Met 2013).

2.2 *Sampling procedure*

After meeting the *mataqali* households and performing *sevusevu,* a tradition to seek permission and participation of Vunidomodua *mataqali,* representatives were consulted to identify four quadrats each of size 20 m x 10 m on the basis of their accessibility from the road and the river Waidalice. The topography, soil texture, litter height, soil moisture content, species and stand density characterizing the quadrats were recorded. Five soil hydraulic properties namely wilting point, field capacity, saturation, saturated hydraulic conductivity and available water were estimated following Saxton *et al.* (1986). All trees above 35 cm diameter falling within each quadrat were identified and their diameter measured using a diameter tape. Above ground biomass (kg tree^{-1}) was calculated following Brown (1997) using the equation:

Above Ground Tree Biomass = exp (-2.134+2.53ln (DBH))

The calculated average tree biomass value was then multiplied by 0.45, the IPCC default value for estimating the tree carbon content (kg tree^{-1}).

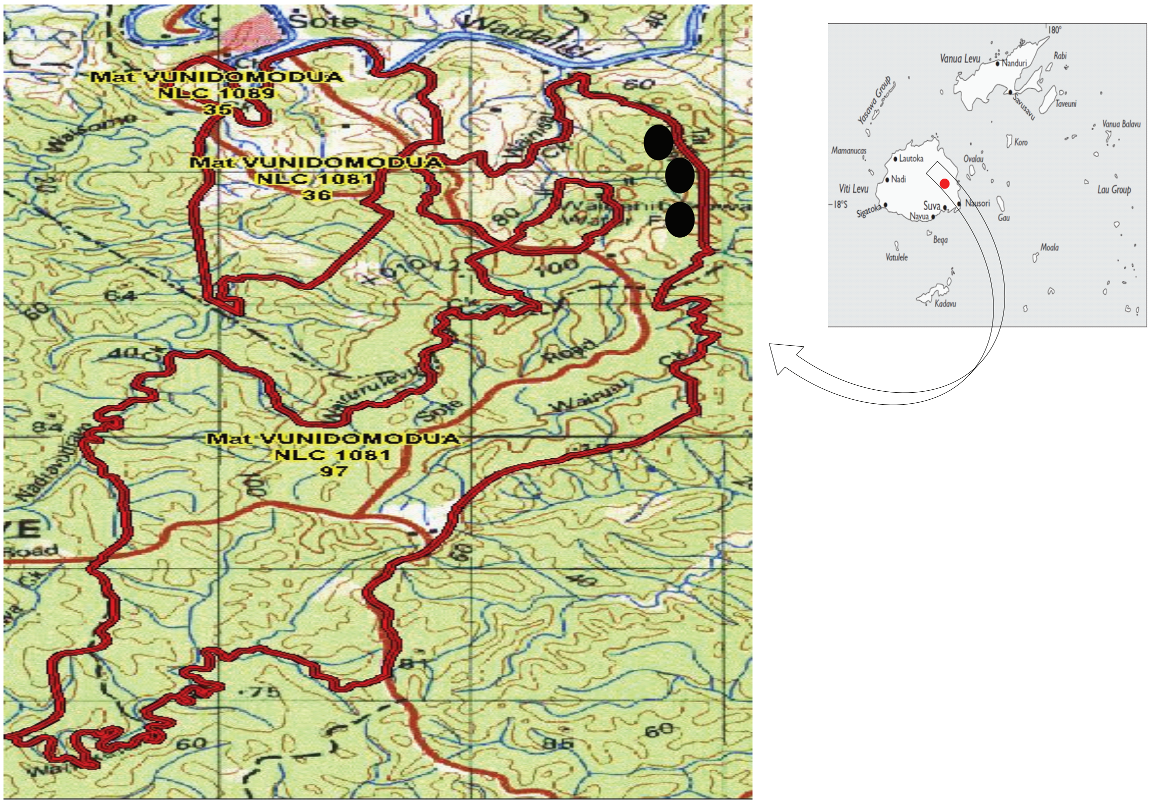

Figure 1. Map of Fiji showing the location of the study area at a native land tropical forest fragments owned by the Vunidomodua mataqali, Sote, Fiji.

2.3 *Statistical analysis*
A one way ANOVA was conducted using SPSS (version 22) to analyse the data and perform F-test at 5% significance level (Jayaraman 1999).

3.0 RESULTS AND DISCUSSION

3.1 *Quadrat characteristics*
Observations of quadrats characteristics revealed that the slope of the studied quadrats ranged from 4 to 5 degrees. Quadrats 1, 2, 3 and 4 faced east, north, west and south, respectively. The soil in all the studied quadrats was clayey loam and the soil bulk density was 1.32 gm cm^{-3}. The values of calculated soil hydraulic properties per cm^3 soil were: wilting point (0.178 cm^3 water), field capacity (0.322 cm^3 water), saturation (0.502 cm^3 water) and available water (0.144 cm^3 water). In addition, the saturated hydraulic conductivity was 0.347 cm hr^{-1}. Litter height was maximum (12.4 cm) in quadrat 2, followed by quadrat 3 (9.1 cm), quadrat 1 (6.3 cm) and the lowest (5.7 cm) was recorded in quadrat 4. Lower exposure of sunlight on quadrat 2 may have contributed to the low rate of litter decomposition within the quadrat. Soil pH was 5.4 in quadrat 2, 5.5 in quadrat 4 and 5.6 in quadrats 1 and 3. Soil moisture content was highest (32%) in quadrat 1, followed by quadrat 3 (27%), quadrat 4 (25%) and quadrat 2 (16%). The results demonstrated that higher litter height does not necessarily increase soil moisture content. This could have been due to the presence of fungal hyphae that binds litter together and covers the soil from rainfall (Tam *et al*. 1991).

Spathodea campanulata and *Swietenia macrophylla* exhibited higher stand density than the native species (Table 1). It may be due to the fact that gaps occurring in the natural forest fragments are quickly occupied by *S. campanulata* and *S. macrophylla* because of their ability to favourably disperse and place their propagules in vacant spaces. It is interesting to note that stand density of these two non-native invasive species are comparatively lower than those reported by other workers (Fu *et al.* 1996; Pratt *et al.* 2007; Lima *et al.* 2013). Perhaps in native forest, invasive species initially establishes with lesser robustness to build a strong base for their future generations to proliferate.

Table 1. Species with stand density of tree species above 35 cm in diameter in a native tropical forest fragment of Vunidomodua *mataqali* land, Sote, Fiji.

No.	Common Name	Botanical Name	Family	Stand density (trees ha^{-1})
1.	Tarawau	*Dracontomelon vitiense* Engl.	Anacardiaceae	100
2.	Kuluva	*Dillenia biflora* (A. Gray) Martelli ex Durr. & Jacks.	Dilleniaceae	200
3.	Dawa	*Pometia pinnata* J.R.Forst. & G. Forst.	Sapindaceae	300
4.	Sa	*Parinari insularum* A. Gray.	Chrysobalanaceae	50
5.	Makosoi	*Cananga odorata* (Lam.) Hook.f. & Thomson	Annonaceae	50
6.	Kauvula	*Endospermum macrophyllum* Benth.	Euphorbiaceae	250
7.	Bau	*Palaquium vitilevuensis* Gilly ex Royen	Sapotaceae	200
8.	Yasiyasi	*Cleistocalyx eugenioides* Merr.& L. M. Perry	Myrtaceae	200
9.	Kaudamu	*Myristica castaneifolia* A. Gray	Myristicaceae	300
10.	Pasiu	*Spathodea campanulata* P. Beauv.	Bignoniaceae	400
11.	Mahogany	*Swietenia macrophylla* King.	Meliaceae	350

3.2 *Basal area, biomass and carbon content*

The basal area ranges between 1.48 m^2 (*Myristica castaneifolia* and *Cleistocalyx eugenioides*) to 5.65 m^2 *(Dillenia biflora)* (Table 2). The result indicated that average above ground biomass of *S. campanulata* was the highest (34.03 t) and *Dillenia biflora,* a native species was the lowest (5.38 t) (Table 2).

Table 2. Average basal area (m^2), above ground biomass (t) and carbon content (t) of tree species above 35 cm in diameter in the native tropical forest fragments of Vunidomodua mataqali land, Sote, Fiji.

No.	Species	Average basal area (m^2)	Average above ground biomass (t)	Carbon content (t)
1.	*Dracontomelon vitiense*	2.23	13.82a	5.22a
2.	*Dillenia biflora*	5.65a	5.38	2.12
3.	*Pometia pinnata*	1.65	8.18	3.35
4.	*Parinari insularum*	1.76	8.97	4.14
5.	*Cananga odorata*	1.68	8.01	3.35
6.	*Endospermum macrophyllum*	2.26	18.18a	8.08a
7.	*Palaquium vitilevuensis*	1.68	8.01	3.70
8.	*Myristica castaneifolia*	1.48	6.11	2.85
9.	*Cleistocalyx eugenioides*	1.48	5.86	2.64
10.	*Spathodea campanulata*	3.03 a	34.03a	14.11a
11.	*Swietenia macrophylla*	2.58 a	15.62a	7.23a

[a]denotes statistically significant values

The average carbon content values ranges from 2.12 t to 14.11 t in the 11 tree species studied (Table 2). The two non-native invasive tree species, *S. campanulata* and *S. macrophylla* recorded 14.11 t and 7.23 t carbon content, respectively. Field observations revealed that two native trees *Endospermum macrophyllum* and *Dracontomelon vitiense* are fast growing and accumulate biomass and carbon at par with the non-native invasive species (Table 2). This indicates the efficiency of carbon storage by tree species largely depend on biomass (Meunpong *et al.* 2010). Furthermore, the results demonstrated that significant quantity of carbon is stored as biomass by non-native invasive tree species that grows in native tropical forests. The current study provides a scope to urge utilization of this carbon in Fiji, an effort to adapt against the changing climate. Interestingly, no significant relationships were observed between basal area of trees above 35 cm diameter and the carbon content.

4.0 CONCLUSION

Invasive tree species fill gaps formed in tropical native forests. The study revealed that invasive trees mainly *S. campanulata* considered as a problematic exotic species in Fiji store considerable quantity of carbon. This species is very fast growing and has shorter rotation (6 to 8 years) (Francis 1990). If the trees are not utilized and left out to decay in the field, considerable quantity of stored carbon will return to the atmosphere as carbon dioxide due to microbial action. Therefore, the study urges utilization of invasive trees mainly *S. campanulata* in Fiji by manufacturing useful value added wood based products to reduce carbon dioxide emissions and also income generation.

ACKNOWLEDGEMENTS

Authors acknowledge College of Agriculture, Fisheries and Forestry, Fiji National University for providing all the necessary materials for conducting the research. Sincere thanks to Mr. Luke and his family of Sote village and Vunidomodua *mataqali* for assisting in field work. Field data collection and recording by Mr. Sevanaia, T. Ducivaki and Mr. Vanabasa K. Rokobiau is duly acknowledged. Comments from the Chief Editor and anonymous reviewers were very much helpful in improving this manuscript.

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SHORT NOTE

Performance of introduced wheat varieties (*Triticum aestivum* L.) at Legalega, Fiji

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ABSTRACT

Nine varieties of wheat from International Maize and Wheat Improvement Center (CIMMYT), Mexico were evaluated at Legalega Research Station, Fiji in 2012 in a RCBD trial with three replications. These varieties were SKAUZ*2, ELVIRA, THELIN, MILAN, MUNIA, PFAU, VEE, WEAVER and WAXWING*2. Variety WEAVER recorded the highest yield (0.44 tons ha^{-1}), highest seed weight (19.9g) and was statistically the tallest plant at maturity (65.3 cm) compared to other varieties while WAXWING was the earliest maturing variety (91 days). Variety MILAN recorded the lowest yield of 0.19 t ha^{-1} while SKAUZ*2 recorded the lowest seed weight of 15.1 grams, while variety VEE was the shortest plant at maturity (54.5 cm). Varieties MUNIA and SKAUZ*2 took 97 days and longest time to mature among all the varieties evaluated. All the varieties will be further evaluated in the intermediate zone to assess their full potentials.

Keywords: wheat, *Triticum aestivum*, varieties, Fiji.

1.0 INTRODUCTION

Wheat is one of the major grain crops that is cultivated in the world and is the staple food for millions of people. It is widely consumed due to its protein quality in flour which accelerates rheological properties of dough- related to baking (Svec and Hruskova 2010). Its grain is rich in mineral, essential amino acids (except lysine) and vitamins (Khan and Zeb 2007). About 65% of wheat grains are used as human food, 21% as animal feed, 8% as seed and remaining 6% for industrial applications in the world (Khan *et al*. 2009). The demand for wheat is expected to increase by 60% by 2050 due to the rapid increase in the world population. Fiji annually imports about 14,000 to 16,000t of wheat into the country. Wheat can be grown in different climatic conditions and has been successfully cultivated in many different parts of the world. Even though the local climatic conditions are suitable for wheat cultivation, Fiji has been importing all its requirements from abroad. Wheat cultivation is new to Fiji and no introductions have been made till 2008. Fifty varieties were introduced from CIMMYT, Mexico in 2008 to screen for their performance under local conditions. The present investigation was aimed to identify the most suitable variety for its performance and yield under Fiji's climatic conditions with the aim to reduce import of wheat in future.

2.0 MATERIALS AND METHODS

Fifty varieties were introduced from CIMMYT in 2008 and seed multiplication was done in 2009 to initiate the evaluation process. In 2010, monthly evaluations were carried out to assess the performance of varieties in individual months. Fifteen varieties were selected for further evaluation in 2011. Nine varieties were then selected in 2012 and planted in a RCBD experiment with three replications at Legalega Research Station; which is located in the dry zone of Fiji. It has average minimum temperature of 21°C and maximum of 31°C with the annual average rainfall of 1863 mm. The trial was planted on Nadi soil series which was described by Leslie, (2012) as Typic eutrustox clayey, mixed with isohyperthermic. Each variety was sown with 5 rows. Each row was 5 m long and 50 cm apart from the other next adjacent row. The net plot was 6 m^2. Fertilizer levels and all other cultural practices were similar in all the plots. The traits measured from each genotype were days to emergence (when 80% of the emergence was observed in the individual plots). Days to heading and plant height were recorded (when 50% of the spikes were extruded from the flag leaf). Days to maturity of the spike, plant height at maturity, weight of 500 dry grains and dry grain yield were recorded at maturity stage.

Data were analyzed by analysis of variance method and the means were compared using the Duncan's Multiple Range Test (DMRT) using a SAS analytical package.

3.0 RESULTS

3.1 *Days to heading*

There were highly significant differences observed in the days to heading among the different varieties tested. Variety WAXWING, WEAVER and VEE were early to head; taking about 52.3, 52.7 and 52.7 days, respectively while variety SKAUZ*2 was late to head (64.7 days) (Table 1).

3.2 *Plant height at heading*

Highly significant differences were also observed in the height of the plants at 50% heading among the various varieties evaluated. The tallest plant (43.4 cm) was observed on variety SKAUZ*2 while the shortest plant (36.5 cm) was observed in variety PFAU and MILAN (Table 1).

3.3 *Days to maturity*

Significant differences were observed among the different varieties in the days to maturity. All varieties tested matured between 91-97 days, of which WAXWING matured in 91 days, and varieties MUNIA and SKAUZ*2 in 97 days (Table 1).

3.4 *Plant Height at Maturity*

Plant height at maturity was statistically significant among different varieties. While variety MILAN recorded the tallest plant (67.3 cm) at maturity, variety VEE was the shortest (54.5 cm) (Table 1).

3.5 *Seed Weight*

Weights of 500 dry seeds were significantly different among different varieties. Variety WEAVER recorded the highest weight of 19.9g grams while variety SKAUZ*2 recorded the lowest weight of 15.1 grams (Table 1).

Table 1. Mean performance of different varieties for yield and yield associated traits.

Varieties	Days to 50% heading	Plant Height at 50% heading (cm)	Days to maturity	Plant Height at maturity (cm)	500 seed weight (gms)	Yield (t ha^{-1})
SKAUZ*2	64.67a	43.40a	97a	56.53dc	15.12e	0.26bc
ELVIRA	62.67b	43.27a	94bc	64.53ba	15.34e	0.35ba
THELIN	57.67c	38.53cb	95bcd	64.93ba	17.60bdc	0.39ba
MILAN	57.33c	36.53c	93bcd	67.33a	17.63bdc	0.19c
MUNIA	57.33c	36.60c	97a	57.2bdc	16.05edc	0.35ba
PFAU	54.67d	36.53c	92cd	65.07a	18.03bac	0.38ba
VEE	52.67e	39.67b	94bc	54.52d	15.72ed	0.33bac
WEAVER	52.67e	42.67a	92cd	65.33a	19.88a	0.44a
WAXWING*2	52.33e	39.53b	91d	62.73bac	18.87ba	0.39ba
LSD at (0.05)	1.37	2.40	2.66	7.79	2.20	0.158

Means followed by same letters do not differ significantly ($P < 0.05$).

3.6 *Yield*

Weaver variety produced the highest yield of 0.44 t ha^{-1} while the lowest yield of 0.19 t ha^{-1} was obtained from variety MILAN. However, they were significantly different. There was no significant difference among the rest of the varieties (Table 1).

4.0 CONCLUSION

WEAVER recorded the highest yield, seed weight and was statistically the tallest plant when compared to the rest of the varieties evaluated. WAXWING was the earliest variety to mature. These varieties will be further evaluated under different climatic conditions to fully assess their genetic potentials and interactions with environments.

ACKNOWLEDGEMENT

We would like to thank the field staff of Legalega Research Station in assisting us to successfully carry out this experiment. In particular our appreciation goes to Mr. Satish Chand for his hard work in assisting us to maintain the trial block.

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SHORT NOTE

Evaluation of assorted varieties of tomatoes

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ABSTRACT

The crop variety evaluation is used to predict the future performance of a variety. With the increase in demand for vegetable production, good quality and high yielding crops need to be introduced. Evaluation trial is used as one of the methods to screen and analyze cultivars suitable for local climatic condition and high yielding to meet consumer demand. Many tomato varietal trials were conducted by the Research Division of the Ministry of Agriculture since 1980s. In the present study, Alafua large variety was used as the check variety as it was the most superior among the released varieties in the previous trials. A new variety, CLN 2413L produced 5.5 t ha^{-1} more than Alafua large. The number of fruits produced by Alafua large was not significantly different from CLN 2463D, CLN 2514A, CLN 2514B, CLN 1466EA, CLN 2418A and CLN 2413L, however, it was significantly different from variety CLN 2463C and CLN 2463E. The highest level of brix obtained in this study was 6.4% less than the best brix tomato. Field testing of the varieties for another season is necessary to validate these results.

Keyword: tomato, *Solanum lycopersicon, varieties,* Fiji

1.0 INTRODUCTION

Tomato (*Solanum lycopersicon* L.) belongs to the family Solanaceae, is an important crop for income generation for small and large scale farmers throughout Fiji. Many tomato varieties are unsuited to the wet zone and low land areas because of plant diseases such as bacterial wilt (*Ralstonia solanacearum* (Smith), Fusarium wilt (*Fusarium oxysporum f*.sp. *lycopersici* Snyder & Hansen) and environmental conditions prevailing in the warm and wet season (Iqbal *et al*. 1988). The vegetable research activities at Sigatoka Research Station and Koronivia Research Station continue to focus on screening and determining the adaptability of major varieties which have economic potential and suitability for growth under the environmental conditions of Fiji. In the process of selecting varieties, productivity, disease resistance and potential for fruits splitting are usually considered and forms the backbone of any plant-breeding program (Trinklein 2010). In Fiji, the major emphasis on varietal evaluation programmes in past years have been to develop the high yielding tomato varieties and their adaptability to grow in the wet zone, intermediate and dry zones of Viti Levu (Datt *et al.* 1999; Ucuboi *et al.* 2000). The objective of this experiment was to determine which of the introduced varieties differ in yield performance from the standard in the high rainfall region of Viti Levu, Fiji.

2.0 MATERIALS AND METHODS

2.1 *Study site*

The field trial was established on a clay-loam soil at Koronivia Research Station farm (S18° 02. 89', E178° 32. 26'; 12 masl) which receives an annual rainfall c. 3, 000 mm.

2.2 *Tomato varieties*

The field trial was conducted from April to September 2010, during the main season of vegetable production in Fiji. Seeds of nine new varieties were imported from Asian Vegetable Research and Development Centre (AVRDC), Taiwan and were tested against Alafua large the locally recommended variety. Ten varieties were selected for the field trial but due to poor germination of CLN2464B only nine varieties were tested. The identification number given to the new varieties were CLN 2463C, CLN 2463D, CLN 2463E, CLN 2514A, CLN 2514B, CLN 1466EA, CLN 2418A and CLN 2413L. The seedlings were raised in trays in the nursery for four weeks before transplanting. The seedlings were planted at a spacing of 1.0 m between rows x 0.5 m within rows. The field trial covered a total area of 388 m^2.

2.3 *Maintenance*

Poultry manure 12 tons ha^{-1} was broadcasted two weeks prior to transplanting and rotovated. Fertilizer NPK 13:13:21, (200 kg ha^{-1}) was broadcasted at the time of planting. Side dressing of urea 1.87 kg (100 kg ha^{-1}) and hilling were undertaken four weeks after transplanting. Garden hoe was used for hilling the plants. Insecticides Rogor (Dimethoate 400 g L^{-1}) and Bi-fenthrin (Bifenthrin 80g L^{-1}) at rate of 15 ml/15 Lof water each were applied alternatively every three weeks to prevent Tomato fruitworm (*Helicoverpa zea* Boddie) and semi looper (*Helicoverpa amigera* Hubner), damage on the fruit. Fruits were harvested at colour break. Tomato picking started about 70 days after transplanting and continued for six weeks.

2.4 *Data analysis*

A Randomized Complete Block Design of three replications was used. Each experimental plot had three rows and nine plants were assessed per plot. To test if there was any variation in yields and production of the tomato varieties tested, a one way ANOVA was undertaken. The data were analysed using STATISCA 10.0-2010. The mean values were separated by using the Fisher's Least Significant Difference test at $P< 0.05$.

3.0 RESULTS AND DISCUSSION

There was a significant difference in the yield between the nine tomato varieties (P = 0.019) (Fig. 1). Variety CLN 2413L gave the highest yield (18.5 t ha^{-1}) compared to the check variety Alafua large (13 t ha^{-1}) (Fig. 1). Both varieties produced large sized fruits compared to other varieties. Variety CLN 2413L had greater fruit yield and number of fruits than Alafua large. There was a large variation in the yields produced by Alafua large in the three replications due to fruitworm (*Helicoverpa zea* Boddie) and semi looper (*Helicoverpa amigera* Hubner), which damaged the fruit and thus affecting the yield.

Even though after insecticide treatment, both insects continue to feed on Alafua large fruits rather than the other varieties which were foreign to Fiji's wet zone conditions. Further research is required to substantiate this finding.

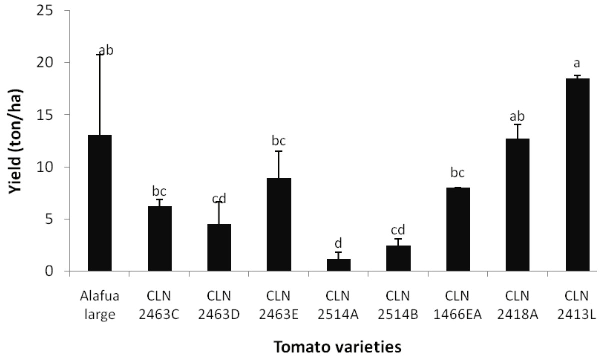

Figure 1. Mean yield (t ha^{-1}) of tomato cultivars tested. Data from nine plants per variety and replicated three times. Vertical bars with same letters are not significantly different at *P*< 0.05.

There was no significant difference between yield of Variety CLN 2418A (12.7 t ha^{-1}) and Alafua large (13 t ha^{-1}), however, CLN 2418A had more number of fruits than Alafua large, but there was no significant difference between the two (Fig. 2). Variety CLN 2463E gave the highest number of fruits but was not significantly different to Alafua large (*P* = 0.117) (Fig. 2). However, there was a significant difference between yield of variety CLN 2463E and Alafua large (*P* = 0.012) (Fig 1 & Fig 2).

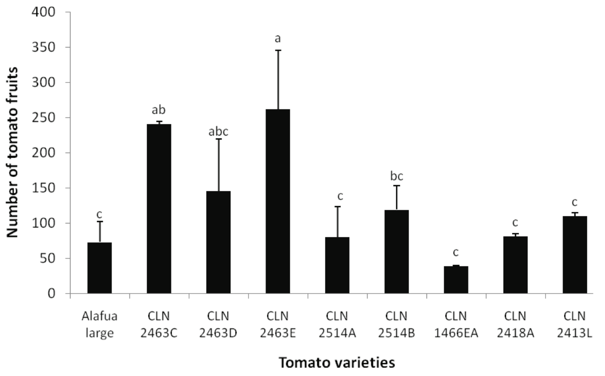

Figure 2. Mean number of tomato fruits produced by each variety tested. Data collected from nine plants per variety and replicated three times. Vertical bars with same letters are not significantly different at *P*< 0.05.

According to Jones (2010), high brix means high sugar, mineral and protein content. A lower freezing point, longer shelf life and better pest resistant should be criteria for selection. Variety CLN 2463C gave the highest brix but it has smaller fruit size (45-55 mm) and high moisture content (93%) which reduces its shelf-life as compared to Alafua large (fruit size > 85 mm and moisture content 78%).

4.0 CONCLUSION

This study has shown that Variety CLN 2413L gave the highest yield, number of fruits and has higher moisture content compared to Alafua large. However, its brix content is less compared to Alafua large. Further research is required on these tomato varieties to determine their adaptability, production and pest problems on various locations in Fiji.

ACKNOWLEDGEMENT

The author is grateful to the Horticulture Section staff Mr. Amena Banuve, Aseri Raikalevu and Chandra Deo for their assistance in the field work and, Dr Apaitia Macanawai for analyzing the research data.

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Layout & Design by: Information & Communication Section, Ministry of Agriculture Headquarters,
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