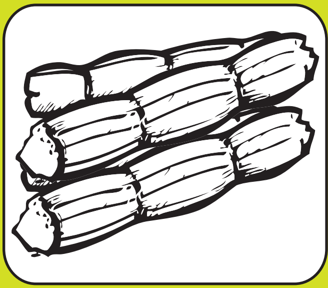

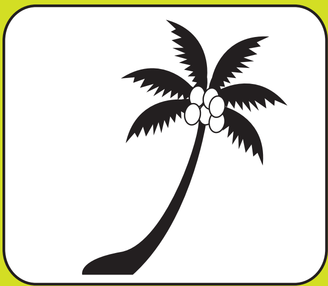

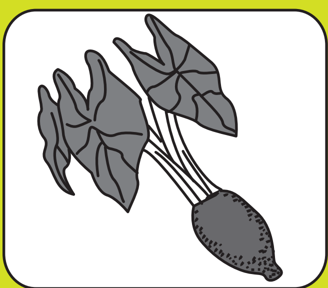
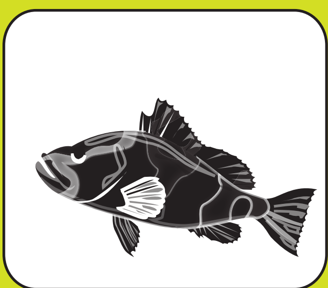


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REVIEW

Deployment and Importance of Genetic Resources in Food Security and Agriculture - Future Perspective to Climate Smart Agriculture in Pacific Island Countries

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ABSTRACT

The genetic resources play a crucial role in food and nutrition security, and livelihoods of the agriculture sector. In the current situation worldwide, rapidly changing climate poses new threats to the conservation of the existing genetic diversity. Loss of genetic diversity equals to loss of valuable gene pool with climate change as the major driver. Modern agriculture and genetic resources are critically interdependent because agricultural commodities are derived and improved from genetic resources around the world. The increasing agriculture production depends on continuing infusions of genetic resources for yield stability and growth. Any plant material can be utilized for developing improved crop varieties for high yield, superior quality and better adaptation to constant changes of environmental conditions. Crop Genetic Resources (CGR) are valuable for current and future crop improvement programmes. It is to be noted that the existing genetic diversity in plants or crops, that plants adapt and survive when their environments changed. Changing Climate poses new challenges to sustainable management of the genetic resources for food and agriculture, but it also underlines their importance in Pacific island countries and territories. Therefore, conservation of existing genetic resources is important to support food and nutrition security in a growing human population and for development of adaptation in changing climate, as well as for the genetic improvement programmes.

Keywords: Climate change, genetic resources, germplasm, crop improvement, breeding programme

INTRODUCTION

The genetic resources in food and agriculture are referred as the genetic materials which the world relies to improve the yield and quality not only in agriculture crops, but also in livestock, forestry and fisheries. The genetic resources play a crucial role in food and nutrition security, and it is also useful to maintain healthy populations of crop species. These genetic resources are the key components of sustainability, resilience and adaptability in the agricultural production schemes, and are able to contribute significantly to the scientific efforts to cope with climate change. The changing climate and its severity have now become a tremendous challenge for present and future generations to deal with environmental adaptation in crop species and to enhance food production. The knowledge gained about the impact of climate change on agriculture over the past 20 years are showing that climate change will fundamentally alter global food production patterns (FAO 2015). Like viruses, a small biological infectious agent which are found in almost every ecosystem on earth and causes threat to every living cells, the climate change is an utmost issue on earth which need to be focused for sustainable development of agriculture sector (Bansode et al. 2015; Elbehri et al. 2011). The speed of climate change exceeds our ability to identify, select and reproduce the resilient varieties in agriculture field, especially in the Pacific (*Elbehri et al.* 2015).

In general, lack of attention had been given to genetic resources in the climate change dome due to lack of awareness. Embark upon the climate change is vital factor in genetic uniformity and genetic erosion are important arguments that underline the need for achieving a sustainable future for the food security, for that the preservation of genetic resources must lie at the core (Hufler and Lefeber 2011). Growing interdependence and climate change as a serious factor globally, research states that there is a hike in agriculture crop production in some regions of the world, but cannot neglect the influence of climate change on global food security (Lipper and Cooper 2009). Although the agricultural sector has a clear understanding to maintain the genetic diversity and its sustainable management, there is an urgent need for greater awareness in Pacific island countries about the roles and values of genetic resources among those engaged in climate change discussions. It is required to enhance the regional and national knowledge base on the climate change issues, potentials, opportunities and constraints relating to crop diversification, covering existing crop and tree genetic resources and resistant/tolerant traits of crops and trees to be identified in Pacific island countries (FAO 2008).

The existing civilizations are totally dependent on plants for their livelihood, then genetic resources are valuable for present and future crop improvement programmes. Numbers of the world's ecosystems have been affected by climate change, where it affects plant biodiversity, pollination in plants, soil biodiversity, microbial biodiversity and other animal diversities. The above valuable gene pools are being lost day-by-day due to various threats and one among of these is climate change, which have a profound impact on losing the genetic resources. Unfortunately, few studies provide detailed analyses of the impacts of climate change on the loss of gene pools. The impacts of climate change and increased carbon dioxide concentrations on plant growth, productivity and the nutrient value of crops commonly grown in Vanuatu is not well understood (FAO 2008) while the other Pacific island countries should also be studied about those impacts in details. These findings could provide us guidelines and perhaps promote awareness in conservation of genetic resources; however, each area and country will have its unique circumstances. Climate affects almost all aspects of life in the Solomon Islands, and due to climate change, a severe damage to agriculture sector had been reported (IPCC 2011). The Ministry of Agriculture and local farmers have expressed significant interest in improving their understanding of the future climate change and its impacts on farming, as there is limited information currently available in the Solomon Islands (Australian Bureau of Meteorology and CSIRO 2011). Papua New Guinea has a strong effect due to changes in the climate and has undertaken projects for the collection of germplasm in traditional crops and established ex situ gene banks at research stations, even though due to several constraints, they are unable to protect the genetic resources (Ayalew and Kambuou 2008). The Pacific Community's (SPC) Centre for Pacific Crops and Trees uses in vitro technology to conserve germplasm collections of some of the region's important staple crops, and such as taro, yam, cassava, banana, vanilla and sweet potato comprising of germplasm from the Pacific and Southeast Asia (SPC 2013). Other than the above studies and collection, based on the massive and adorable vegetation, a systematic and scientific approach will be urgently needed to meet the challenges of climate change and then to protect our genetic resources in Pacific island countries. Funding and collaboration for multidisciplinary researches to be done in Pacific island countries could provide better insights and recommendations for the conservation of genetic resources and to meet the challenges of climate change.

CROP GENETIC RESOURCES

Biological resources include the genetic resources of those wild ancestors and closed relatives used to produce agricultural crops. Brockhaus and Oetmann (1996) defined the plant genetic resources (PGR) as the reproductive or vegetative propagating materials of any plant or agriculture varieties (crops) in current use. They also incorporated the newly developed varieties (by breeding), obsolete cultivars, primitive cultivars (landraces), wild and weed varieties, near relatives of cultivated varieties and special genetic stocks such as elite and current breeder's lines and mutants. In common, agricultural and biological resources includes both crop and livestock genetic resources. Crop genetic resources (CGR) are used by breeders to develop new and improved varieties for farmers, and thereby enhancing substantial economic benefits.

Many reasons could cause a loss of CGR. Industrialization and habitat degradation can destroy the homes of wild species if the resources are not being protected. Another concern would be the consumer preferences. Consumers nowadays would prefer certain varieties. With the addition of various types of resistances, seed companies have been developing improved varieties based on consumer preferences, or even based on their technological and developmental trends. Instead of planting the old landraces with lower production and quality, growers start to abandon the old practices and adopt the new high yield and consumer preferable lines. As a result, these important CGR can gradually disappear if the resources are not being protected. For breeding perspectives, wild species, ancestors, close relatives and special landraces represent as a hidden treasure box containing multi-facet tools in combat with production, pests, diseases and even climate challenges. Once CGR disappeared, the tools neither can be replaced nor be applied in developing new and improved varieties.

A strong CGR base is important for any developing country due to two important reasons, (i) lack of genetic diversity in local fields, and (ii) increase in risk of pest or disease epidemics. Many developing countries are used to consider production more than conservation. Most of the locally adopted species usually do not have a relevant breeding programme for sustainable development. CGR are always important requirement for the continuing process of crop improvement through breeding. CGR in agriculture sector have a prime importance not only in poverty reduction and global food security but also in environmental protection and sustainable development. The Cook Islands, Samoa and Kiribati have limited crop diversity and could be adapted for local needs. Samoa has demonstrated the importance of breeding, having now bred taro varieties, resistant to taro leaf blight (TLB), but still need more awareness on importance of plant genetic resources to public (FAO 2010). Food and Agriculture Organization of the United Nations (FAO) (2010) also reported that existing animal and plant genetic resources are threatened due to sea-level rise, seawater intrusion, drought, and competition for access to land due to population growth and urban drift. In the same report, it is also mentioned that more effort is required at the policy level, and very few countries have any policy, which relates to genetic resources conservation and use. A hypothetical scenario would be if a plant found in any Pacific island countries is known to have healing properties based on the existing traditional knowledge, a research company from overseas analyzes the plant compounds and uses certain compounds for a medicine production and marketing for sale. Then, the existing protocol may not ensure such lawful dividends from the sale of this medicine coming to the actual owners of this plant and its knowledge in Pacific island countries. Collection, preservation, promotion and utilization of existing traditional knowledge of those crop species which have a commercial, medicinal, social and cultural importance, and the potential to provide much enhanced values to be further developed (SPREP 2007). Therefore, the conservation of CGR is important in agricultural production.

LATENT IMPACT OF CLIMATE CHANGE ON CGR

The climate change and its impacts on crop production are already being felt worldwide. The researches have clearly shown that the negative impacts dominate over the positive ones for agriculture, and adaptation is urgently needed (IPCC 2014); especially in Pacific island countries. For revealing the consequences about the conservation and utilization of CGR, it is necessary to understand how climate change is affecting those resources, then in what ways the issues can be resolved and interpreted, and toward identification of a solution for the future. A summary by the Intergovernmental Panel on Climate Change (IPCC) has provided evidences of observed increase in temperature across the globe, and they found it is greater at higher northern latitudes (IPCC 2007b). Furthermore, it is expressed in the instrumental record that for the past three decades, Earth's surface had become even much warmer than all the previous decades' (IPCC 2013). In fact, according to National Aeronautics and Space Administration (NASA), global surface average temperature has increased 0.98°C in 2019 compared to 1951-1980 average temperature (NASA 2020). The introduction of modern hybrid and genetically modified crop varieties has led to the erosion of natural genetic diversity and almost 75% of the genetic diversity of agricultural crops has been lost (FAO 2015). Climate change is an additional threat to agricultural biodiversity, because it leads to the increase in genetic erosion of landraces and crop wild relatives (*Jarvis et al.* 2008). Current varieties will be lost as farmers replace them with other improved varieties that are healthier and able to adapt the new climate conditions. Weltzien et al. (2006) mentioned in a research study about the Guinea sorghum varieties southern Mali that the range of local varieties grown by families and villages is replaced with modern varieties due to shortened rainy season over the last 20 years as a part of climate change. Therefore, all countries across the globe that rely on crop genetic diversity has to provide potential consideration to environmental and climatic changes, to maintain agricultural production systems (FAO 2015). Climate change may also increase the importance of otherwise minor or underutilized crops and plant species. Landraces themselves contain the solution to many of the problems of climate change. They contain a wide range of traits for adaptation to abiotic and biotic stresses that may contribute to the adaptation of global agriculture to climate change. The major issues to be identified and solved such as: i) increased need for crop wild relatives, ii) novel and increased demands on germplasm in gene banks for adapting agriculture to climate change, iii) review of breeding strategies in each country for each crop to release improved varieties, and iv) review and strengthen policies for promoting seed and seed exchange between the farmers and its availability (FAO 2003). Folland *et al.* (2018) reconstructed a time series of monthly global mean surface temperature from 1891 till date. Based on their analyses, two historically strong warming periods (1911-1940 and 1976-1997) were found, and increasing greenhouse gases and anthropogenic aerosols were the two main reasons that can be attributed to the causes of most warming incidences found from 1891. The speed and complexity of the ongoing climate change worldwide, makes adaptation for agriculture crops more challenging when compare to earlier stages of climate change (*Ramirez-Villegas et al.* 2013). Some research studies have indicated that high-elevation CGR are more vulnerable than lower elevation crops to the effects of climate change (Mercer and Perales 2010). Three factors are majorly relevant for crops to fight against the changed climate and these are plasticity, evolution and gene flow. From this plasticity, it allows the plants to endure extreme climate conditions without considering changes in genotypic characters. Climate change can cause alterations in the physical form of plants and affects its survival ability. In plant breeding practices, artificial crossing is introducing a higher pace of gene flow and speeding up the natural process of evolution. Through careful selection, one would be able to reveal plasticity and identify traits and phenotypes of particular interests. Plant breeding can be an applicable tool to overcome the consequences brought by climate change and increase phenotypic plasticity (*Haussmann et al.* 2012). Climate change is not only expected to bring directional changes (e.g. higher average temperatures at a given location in the future), but also to increase the variability of the climate. Farmers usually address directional changes either by drawing on adapted material from among the genetic resources already present locally or by seeking material from neighboring areas. However, as the climate becomes more variable, and extreme events become more extreme, new strategies may be needed. Greater intra varietal diversity may be needed in order to cope with unpredictable extreme climate events. Traits that contribute to phenotypic plasticity (the capacity to cope with a wide range of environmental conditions) may become increasingly important. Climate change may increase the importance of plant species that have previously been underutilized or considered to be of minor importance (*Jarvis et al.* 2008).

Microevolution or short term changes may provide leverage for crops to survive climate change through selection. There might be correlations between the traits needed that serve as constraints to their simultaneous development (Jump and Penuelas 2005). Variation as well as evolution in traits according to change in climate constitutes can be an advantage for crops because that evolution in traits may help the crop to adapt to rapid influences brought by climate change. Higher the evolution, higher the proportion of crops that are adapted to the changed environment. Evolutionary adaptation actually has the potential to reduce future adverse consequences brought to the plants (*Jump et al.* 2008). The gene flow is taking place through pollen or seed movement, thereby new and potentially adaptive genetic variation can be delivered into a population. This is the natural way for spreading the adaptive capacity, but these may be affected due the climate change by increase in temperature. The pollen-mediated gene flow depends on overlapping flowering times, but due to increase in temperature, original pollen production or transfer patterns may be affected and resulted in altered gene flow patterns (Mercer and Perales 2010). Landraces, which often contain considerable phenotypic variability, still dominate agriculture in many areas especially against the effects of climate change, and possess all the above mentioned factors. The landraces tend to be more diverse than genetically improved varieties, but it is still not able to meet several climatic variations. Single landrace never fulfils farmer's utility criteria will usually be replaced by another, either it may be a new landrace or else it may be an improved variety.

As a result of climate change, the CGR require a greater need for conservation and maintenance. This may lead to sustain the crop genetic diversity as well as food security. Adaptation will depend not only on conservation, including further collecting and characterization efforts, but also on broad utilization and exchange of CGR. There are many underutilized species which are not only the great contributors to agricultural adaptation but also have high food security potential (*Sthapit et al.* 2009; Padulosi et al. 2011). According to the changes in climate conditions, some crops adapt to the particular area and its grains become an integral part of the food system (Lane and Jarvis 2007a; Lane and Jarvis 2007b). The extreme changes in temperature and weather patterns are affecting CGR and crop genetic diversity, where the scenario will continuously create new chapters and episodes (Turner and Meyer 2011). Therefore, it is necessary to ensure that human interventions such as ex situ and in situ conservation efforts will be taken to maintain crop genetic diversity, including potentially climate relevant traits, landraces and other locally adapted varieties. Climate drivers of significance over the industrial era include both those associated with anthropogenic activity and, to a lesser extent, those of natural origin. The only significant natural climate drivers in the industrial era are changes in solar irradiance, volcanic eruptions, and the El Niño–Southern Oscillation. Changes in solar irradiance directly impact the climate system because the irradiance is Earth's primary energy source. Most volcanic eruptions are minor events with the effects of emissions confined to the troposphere and only lasting for weeks to months. Cloud feedbacks also influence natural variability within the climate system and may amplify atmospheric circulation patterns and the El Niño–Southern Oscillation (*Fahey et al.* 2017). Another climate change parameter is changes in precipitation patterns and it affects and increase the frequency of drought events (IPCC 2007a). The IPCC issued a global climate assessment in 2013 clearly mentioned that major reason for climate change is accumulation of carbon dioxide in the atmosphere and that influence the existing food and agriculture systems (IPCC 2007a).

BRIDGING THE TECHNOLOGY GAP/ SUSTAINABLE MANAGEMENT STEPS TO PROTECT THE GENETIC RESOURCES

The PGR are the most valuable source of plant genetic diversity, and are considered as essential materials for the crop improvement programmes, for developing crops to mitigate the far run climate change challenges. The plants are unique of their individual genotypes which may not be useful currently, but they may become useful in the future due to climate change (Campbell et al. 2009). Due to the concealed responses of previous underutilized plants against climate change, they may be far better than the useful plants that we considered, and they may become essential for crop improvement in meeting climate challenges. If a particular genotype is lost, then it is difficult to rebuild the same genetic combinations. Subsequently, it should be the primary goal for any scientific community to collect and conserve this diversity in a systematic manner, and then undertake a sustainable management, which including procedures to protect the PGR. The scientific communities need to establish initiatives in order to support farmers in mitigating agricultural adversity in climate change epoch. One of the approaches can be the development of crop varieties with better traits. Such new genetic traits in crops need to be focused mainly on biotic and abiotic stresses that are expected to combat with the consequences brought by climate change. Traits to boost crop adaptation may be found in genetic resources such as landraces or wild relatives of domestic crops; therefore, there is an urgency to conserve these genetic resources before it is too late. In light of their likely social and economic benefits, such resources have probably been underused and required further investigation in the developing nations of Pacific island countries.

Local crop varieties should be genetically analyzed Historically, anthropogenic factor determines crop utilization in many areas. This is particularly true in Pacific island countries, which had undergone different colonization eras. Various types of exotic species had been brought in for production, where adaptation and variation could exist through years of cultivation. If the pedigree record of a crop is well kept, then breeding efforts can follow its trace in attempts to bring improvement. If the pedigree record of a crop is partial or even unknown, this would make breeding efforts very difficult. In order to solve the puzzle and provide better understanding, molecular tool sets may offer insights for breeding purposes.

Natural plant populations routinely and consistently show small-scale genetic differentiation (more than 100 species demonstrated) although important exceptions are known (Linhart and Grant 1996). Most molecular variation observed is presumed to be neutral or nearly neutral characters. Regardless of that, a minority of evolutionary biologists argues that genetic differentiation has been typically produced by natural selection in response to environmental heterogeneity. It has been shown that beneficial mutations are more common than assumed and methods have been developed to screen them (Schlotterer 2002). Neutral theory of molecular evolution predicts that the majority of evolutionary changes and variability within species are caused by random genetic drift of alleles, which are selectively neutral. Selection may operate but the intensity is weak when compared to neutral processes (Graur and Li 2000). Most molecular markers are presumed to be neutral and these can be used to analyze problems in evolution. Molecular markers possess many advantages, which make them superior to morphological markers. Molecular markers offer a great scope for improving the efficiency of conventional plant breeding by carrying out selection not directly on the trait of interest but on molecular markers linked to that trait (Buu and Lang 2003). Furthermore, these markers are used in mapping of specific genes, cultivar identification and biodiversity studies (Rana and Bhat 2004). Molecular markers are not environmentally influenced and are detected in all plant growth stages (Rungis et al. 2000). DNA based markers are considered as the most suitable markers for genetic distance estimates because of potentially large number of polymorphisms. There are various types of DNA markers presently available to evaluate polymorphism in sample genomes.

The genetic resources could be collected through geographic information systems for predicting adaptation based on spatial information, then evaluated and characterized by molecular marker analyses. It may be helpful to increase the efficiency in incorporating valuable genetic traits into commercial crop varieties, based on spatial specificities. In this development of modern molecular tools, the researchers may be able to reduce the time spent and cost in collection and analysis of genetic resources. Such development can also assist in conservation of PGR and thus increase their use for climate change adaptation.

Collection of wild species, ex situ conservation of germplasm

The goal of ex situ conservation as stated by Marshall and Brown (1975) is to conserve, “95% of existing genes” or gene pools in local. For the above, a first requirement is to classify and identify the prioritized species and regions already affected or will be affected by climate change. Many earlier studies suggested that wild species are mostly exposed to climate change, and in addition to the wild species of currently utilized crops, crop relatives or cultivated crops, biological control species and underutilized species such as tree species should be considered at a high priority. Collections of crop wild relatives and all taxonomic species of relevance will be needed for future crop improvement. In some cases, fairly distant wild relatives will be needed. Collections are also needed to cover the full geographic distribution of the species, and especially populations on the extremes of the distribution where novel traits of interests in combating climate change may be found.

The subsistence and salable agriculture on small islands would be adversely affected by climate change significantly. It should be seriously considered, and the precautionary steps should be taken to prevent the heavy lose and damage in the near future (*Smith et al.* 2003). With the increase of adverse effects in climate change, many studies also suggested the evidences of increased introductions and enhanced colonization of alien species in island ecosystems, therefore its impacts are also increasing simultaneously (Frenot et al. 2005). Climate change threatens the wild relatives of cultivated crops and potential landraces, while exotic and invasive species conquer their original habitats, thereby these strengthen the needs for conservation of diverse germplasms to bolster crop resistance and enhancement of abiotic and biotic stresses. These factors represent both a challenge for gene banks to ensure that important gene pools are adequately conserved and an opportunity for stimulating greater use of germplasm holdings. Efforts to conserve crop diversity by the scientific community can lead to the collection and conservation of seeds in ex situ gene banks, which all Pacific island countries can be benefitted from.

Gene bank collection, in situ conservation of germplasm

The climate change knowingly looms the diversity in crops as previously mentioned in their wild relatives. A significant portion of the crop diversity is already conserved in gene banks across several areas of the world, but more will be needed for future safety. When considering the in situ conservation strategies, the limitations of certain crop varieties for adaptation and acclimatization are quite unknown, due to the uncertainty in intensity of climate change. Improved monitoring will help Pacific island countries to pinpoint sites or species most in need of attention, then coordinated researches are required to make it clear about what levels of in situ conservation required in Pacific island countries.

The in situ conservation refers to the persistence of genetic resources in their natural habitats. It should start with farmers maintaining genetic diversity on daily basis in their farms. This can also be visible in regions where farmers maintain local crops, their landraces, or their high yielding modern varieties. In situ conservation programmes majorly designed to influence farmers in the direction of maintaining local crops. This type of conservation may come across with continual social, technological, and biological change. When preserving these evolved crop varieties, it should be based on genetic diversity, farmers’ knowledge and selection, and exchange of crop varieties. Therefore, in situ conservation practices and projects are concerned with the wide spectrum of genetic resources related to crops such as wild and weedy relatives of crops.

One reason for our focus on diversity within cultivated crops is that science of in situ conservation of cultivated resources is relatively less developed than the science of conserving wild resources such as wild and weedy crop relatives. Another reason is that in situ conservation of cultivated plants requires novel approaches, while in situ conservation of wild crop relatives can draw on theories and methods developed for conserving many different species in their natural habitats. Finally, focusing on variation within cultivated species is warranted by the fact that this type of diversity is arguably the most important one for the future viability of agricultural evolution, as it has been in the past.

Breeding strategies for crop improvement to adapt to climate change.

The climate change is considered as one among the major causative of abiotic stress for agricultural crops. The changes in temperature and rainfall patterns have a direct impact on the cultivation of agricultural crops. In future, it is very much important for Pacific island countries to carry out and invest major researches for developing crop varieties that are more resilient to climate change, and then the focus can be directed toward genome based breeding, i.e. genetic engineering and marker-assisted selection methods to assist conventional breeding. Genetics and genomic based researches may focus more on the understanding of genetic mechanisms and for strengthening stress tolerance in crops, especially against drought, salinity and temperature stress to agriculture crops.

The frequent changes in the climate over a long period may leads to several new problems such as development of new insect pests, new diseases, and new weeds. Life cycles of many wild plants and agriculture crops may be affected severely as in successful pollination and yield due to the increase in temperature, intensity of drought, and changes in rainfall pattern. Water scarcity and drought may affect severely to agriculture crops especially in seasonal crops. The genetic changes may occur in the agriculture crops due to change in the intensity of sunlight and total day length i.e. photoperiod. Thus, it is important to study the change in adaptation of crops in the areas of climate change, as well as making suitable adjustments in crop improvement and cropping pattern in the region. Although developing stress tolerance can have a high priority, to understand the interactions between plant and newly evolved stress elements can provide breeding guidelines for better crop improvement.

The germplasm collections are the important potential sources, which can be utilized for developing suitable crop cultivars for areas of climate change. By using appropriate genetics and genomic based breeding techniques, it is able to develop new resistant cultivar and solve the specific problems in the region. If the resistant traits are not able to borrow from existing germplasms or incompatibility exits, genetic engineering could assist in introduction of the resistant traits from suitable donors. Evidences from various commercial crop varieties have been shown to carry multiple traits of resistance against pests and herbicide application or with additive nutritional values in crop species. Another approach (mutation breeding) is to induce mutations for developing resistant cultivars suitable for climate change. Such approach mimics natural selection process but with a much higher speed in finding out the stress tolerant traits. Numerous early studies demonstrated successful usage of induced mutation technique for developing crop varieties resistant to diseases and insect pests.

While doing the breeding researches, Pacific island countries should give importance to develop crop cultivars with multiple-resistance in adversities, such as resistance to insects, diseases and drought. It is to be noted that plenty plants in nature and several agriculture crops are resistant to multiple diseases. In addition, some components of plant defense are relatively nonspecific, therefore with modern breeding technologies we can now produce multiple resistance crop varieties which may withstand the climate change effects. From a grower's perspective, growing one crop equipped with multiple weaponries would save the production costs and deliver the most benefits to them. On the other hand, farmer's participation in breeding development can be important as well since previous mentioned interactions between crops and stress agents are best known at the production sites. Trails and demonstration sites should also be developed along development timelines in a breeding programme. Research and education can work side-by-side to improve livelihoods which may suffer from the consequences in climate change. In this development, the capacity in research and resilience can be gradually built up in Pacific island countries.

CONCLUSION

Germplasm is considered as a basic tool to crop improvement or breeding programmes for sustainable agriculture. The trait-specific genetic or genomic modification or naturally diverse plants are considered as primary need of the plant breeding programme in a country. As an island country which have adverse effects from climate change, it is to be primarily focus its research on collections, conservation and identification of new elite germplasm in and around the islands, which can ultimately use in breeding programmes of country to produce locally adopted and genetically superior cultivars with a capability to survive against the climate change threats. The crop genetic conservation programmes should be based on the importance of climate change and its threats to food and nutrition. Land races and local varieties should be given a high priority for genetic conservation. Maintaining the existing genetic diversity by in situ and ex situ reserves should give much importance in developing crops with more adaptation to new changed environments. These reserves should be actively managed to increase the resistance of crops to biotic and abiotic stress. The threats to CGR due to climate change should be given the first priority and then take precautions for the maintenance and utilization of these resources. Germplasm or genetic resources to be kept as a prominent agenda of all Pacific island countries.

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REVIEW

Spices - Low Volume And High Value Crops - Perspectives And Prospectives For The Development of Agriculture In Fiji

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Introduction

The term 'SPICE" defined by different dictionaries, Merriam-Webster Dictionary as "any of various aromatic vegetable products (such as pepper or nutmeg) used to season or flavor foods", Cambridge dictionary as "a substance made from a plant, used to give a special flavour to food", Oxford Leaner's " one of the various types of powder or seed that come from plants and are used in cooking. Spices have a strong taste and smell". The Food and Agriculture Organization defines "SPICES are vegetable products such as leaves, flowers, seeds and roots that are rich in essential oils and aromatic principles. They are used mainly as condiments". The term "spice" is defined in the U.S. Code of Federal Regulations for specific labeling requirements. "Spice" is defined under 21 CFR Sec. 101.22(2) (2) The term spice means any aromatic vegetable substance in the whole, broken, or ground form, except for those substances which have been traditionally regarded as foods, such as onions, garlic and celery; whose significant function in food is seasoning rather than nutritional; that is true to name; and from which no portion of any volatile oil or other flavoring principle has been removed. ISO (International Organization for Standardization, ISO-676, 1995) has defined 'spices and condiments' as "such natural vegetable products, or mixture thereof, without any extraneous matter as are used for flavouring, seasoning and importing aroma to foods; the term applies to the product either in the whole form or in the ground form". Farrell (1999) has given acceptable definition for food industry is "the term spice be applied to any dried, fragrant, aromatic, or pungent vegetable or plant substance, in the whole, broken, or ground form, that contributes flavor, whose primary function in food is seasoning rather than nutrition, and that may contribute relish or piquancy to foods or beverages; that is true to name and from which no portion of any volatile oil or other legal flavoring principle has been purposely removed or to which no additive or spent spice has been added. Spices may be dried arilla, bark, buds, bulbs, flowers, fruits, leaves, rhiozmes, roots, seeds, stigmas and styles, or the entire plant tops". Ravindran (2017) finds defect in this comprehensive definition because it included only 'dried' plant materials, there are quite a few spices that are used fresh(such as chillies, capsicum, ginger, curry leaf, celery leaves, coriander leaves etc.). He coined a simple definition "Spices are products of plant origin, used primarily for adding taste, flavor, colour or all such qualities to foods and beverages during the process of their preparation or manufacture".

The spice is one of the earliest traded commodities in the world, the history of the cultivation and use of spices is perhaps the most romantic story of any vegetable product. From the earliest known eras of civilization spices were eagerly sought in all parts of the world. It must be noted that the greater part of the spices that have been valued by man are derived from the Asiatic tropics, while the other quarters of the globe have produced comparatively few. Spices played an important role in the evolution of human civilizations. The great navigations by Christopher Columbus, Vasco de Gama, Ferdinand Magellan are in search of spice producing lands, as a result 'Spice route' connecting Asia and Europe were established. Every household in the world irrespective of the ethnicity uses one or other spice every day. At present, there are 109 spices listed by ISO, whereas, Seidemann (2005) listed 1400 plants for similar uses and mentioned that some of them relevant to certain regions of the world.

Perspectives of Spices in Fiji

The spices have different origins, black pepper (King of Spices) and small cardamom (Queen of Spices) from Western Ghats of India; ginger and turmeric Indo-China region; Tree spices like clove, nutmeg, cassia are from Indonesia and nearby regions; true cinnamon from Sri Lanka and India; herbal spices from Europe regions; Seed spices from Mediterranean, Allspice and Chilies from America, onion and garlic from China; Basil from Australia, etc., (Duke 2003). European colonization helped to spread the spices across the globe. Many spices are naturalized and performs better in the newly introduced locations.

Spices are essential for every culture, Seemann (1862) has noted four different spices are cultivated in Fiji, he mentioned turmeric (Cago)(*Curcuma longa* Linn.), *Zingiber zerumbet* Roscoe, (Beta), Bird's eye pepper (*Capsicum frutescens* Linn.) and *Myristica castaneifolia* A.Gray (Male), he also made a mention about tamarind but he might have not considered it as spice at that time. Another aromatic plant he mentioned was 'Cevuga' (*Amomum* sp.). In his subsequent book : Flora of

Vitian Islands (Seemann 1869) he mentioned about Cinnamon (*Cinnamomum pedatinervium* Meisn). Many spices were introduced to Fiji, black pepper and vanilla during 1880's; ginger introduced before 1890, cardamom, nutmeg and clove during 1930's and some became naturalized. Few species of nutmeg and cinnamon are indigenous to Fiji. The monumental work of Albert C Smith on Flora Vitiensis Nova - A New Flora of Fiji (Smith 1979, 1981, 1985, 1988 and 1991)documented the full list of plants available at Fiji, from that following list of spices (Table 1) are identifed, few herbal spices are later introduction. Fiji is suitable for cultivation of important spices. As such there is no statistics on area and production of spices in the country except for ginger, but, a well-documented statistic is available on import and export of spices in Fiji. Vinning (1990) has given comprehensive account on spices development in Fiji and found out that black pepper and turmeric has bright prospectus in Pacific. Lim and Fleming (2000) documented the published information on spices in Fiji.

Export and import of spices in Fiji

The spices export and import trend is given in Fig. 1 & 2, which shows an increasing trend between 2013 and 2019. Fiji exports on an average 2730.5 tonnes of spices to the value of 16.6 million FJD, whereas, it imports 1305.7 tonnes to the value of 5.8 million FJD (Table 2). There is a strong domestic market exists in Fiji for spices. The spices imported are consumed internally both in households and hotels, part of the imported spices is converted into spice mixtures or valued added and reexported. The quantity and value of export of individual spices are lower than the imported items of the same, except for ginger, ginger preserved, mixtures of spices and turmeric (Table 2). It is noted that majority of the spices imported are converted into 'spice mixtures' and reexported (the average import of spice mixture is only 253.1 tonnes to the value of 1.25 million FJD, whereas, export is 559.0 tonnes to the value of 3.23 million FJD). The ginger is locally cultivated and majority of turmeric is harvested wildly (now few farmers are cultivating)

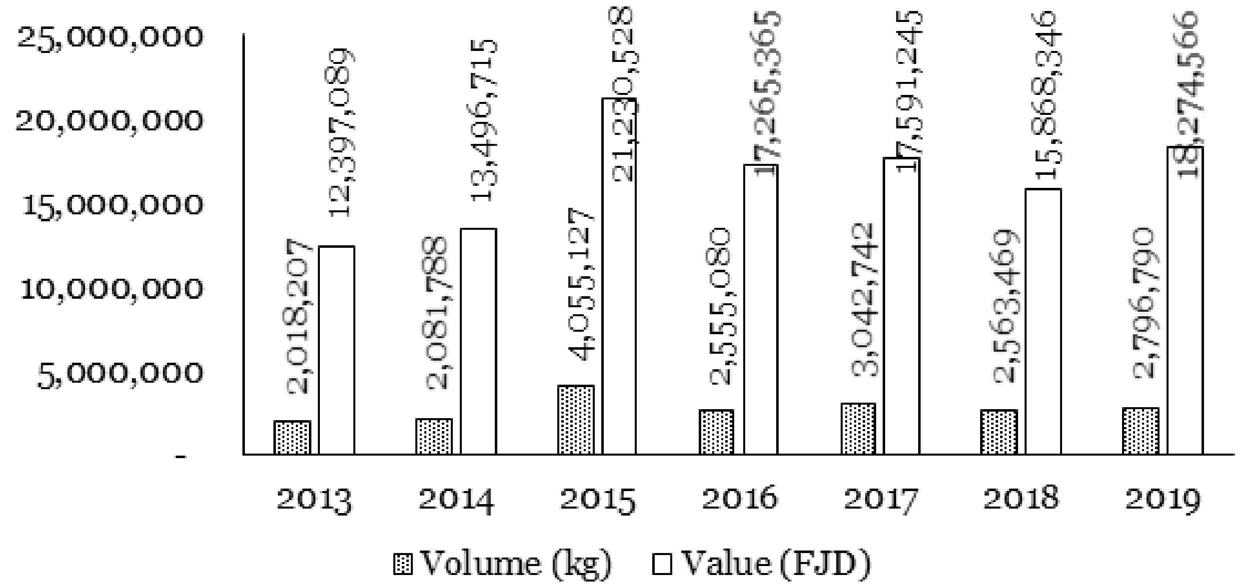
Table. 1. List of spices grown or possible to grow in Fiji

	Botanical name of the plant	Family	Common English name	Name of plant part used as spices
1.	*Allium ascalonicum*	Liliaceae	Shallot	Bulb
2.	*Allium cepa*	Liliaceae	Onion	Bulb
3.	*Alpinia galangal*	Zingiberaceae	Greater galangal	Rhizome
4.	*Apiumgraveolens*	Apiaceae(Umbelliferae)	Celery, garden celery	Fruit, root, leaf
5.	*Averrhoa bilimbi*	Averrhoaceae	Belimbing, bilimbi cucumber tree	Fruit
6.	*Averrhoa carambola*	Averrhoaceae	Carambola, caramba	Fruit
7.	*Brassica junceae*	Brassicaceae	Indian mustard	Seed
8.	*Capsicum annuum*	Solanaceae	Capsicum, chillies, paprika	Fruit
9.	*Capsicum frutescens*	Solanaceae	Chillies, bird's eye chilli	Fruit
10.	*Cinnamomumzeylanicum*	Lauraceae	Sri Lankan cinnamon, Indian cinnamon	Bark, leaf
11.	*Coriandrum sativum*	Apiaceae(Umbelliferae)	Coriander	Leaf, fruit
12.	*Curcuma longa*	Zingiberaceae	Turmeric	Rhizome, leaf
13.	*Cymbopogon citratus*	Poaceae	West Indian lemongrass	Leaf
14.	*Cymbopogon nardus*	Poaceae	Sri Lankan citronella	Leaf
15.	*Elettariacardamomum*	Zingiberaceae	Small cardamom	Fruit, seed
16.	*Elettariacardamomum*	Zingiberaceae	Sri Lankan cardamom	Fruit, seed
17.	*Foeniculum vulgare*	Apiaceae	Sweet fennel	Leaf, twig, fruit
18.	*Mangiferaindica*	Anacardiaceae	Mango	Immature fruit(rind)
19.	*Mentha x piperita*	Lamiaceae	Peppermint	Leaf, terminal shoot

20.	*Mentha spicata*	Lamiaceae	Spearmint, garden mint	Leaf, terminal shoot
21.	*Murrayakoenigii*	Rutaceae	Curry leaf	Leaf
22.	*Myristica fragrans*	Myristicaceae	Indonesian type nutmeg, Indonesian type mace, Siauw type mace	Kernel Aril
23.	*Ocimumbasilicum*	Lamiaceae	Sweet basil	Leaf, terminal shoot
24.	*Origanum vulgare*	Lamiaceae	Oregano, origan	Leaf, flower
25.	*Petroselinum crispum*	Apiceae	Parsley	Leaf, root
26.	*Pimentadioica*	Myrtaceae	Pimento, allspice, Jamaica pepper	Immature fruit, leaf
27.	*Pimentaracemosa*	Myrtaceae	West Indian bay	Fruit, leaf
28.	*Piper nigrum*	Piperaceae	Black pepper, white pepper, green pepper	Fruit
29.	*Punicagranatum*	Punicaceae	Pomegranate	Seed (dried with flesh)
30.	*Rosmarinus officinalis*	Lamiaceae	Rosemary	Terminal shoot, leaf
31.	*Salvia officinalis*	Lamiaceae	Garden sage	Terminal shoot, leaf
32.	*Schinusterebenthifolius*	Anacardiaceae	'Brazilian pepper'	Fruit
33.	*Sesamum indicum*	Pedaliaceae	Sesame, gingelly	Seed
34.	*Syzygiumaromaticum*	Myrtaceae	Clove	Flower bud
35.	*Tamarindusindica*	Cesalpiniaceae	Tamarind	Fruit
36.	*Thymus vulgaris*	Lamiaceae	Thyme, common thyme	Terminal shoot, leaf
37.	*Trachyspermumammi*	Apiaceae	Ajowan	Fruit
38.	*Trigonellafoenumgracecum*	Fabaceae	Fenugreek	Seed, leaf
39.	*Vanilla planifolia syn. Vanilla fragrans*	Orchidaceae	Vanilla	Fruit (pod)
40	*Zingiber officinale*	Zingiberaceae	Ginger	Rhizome

in Fiji, it is reflected in the spices export. Ginger and ginger preserved have shared around 60.0% in quantity and 65.0% in value of the total spice export from Fiji, followed by turmeric and spice mixtures. The maximum import share is by celery followed by spice mixtures. Spices grown in Fiji are exported to Australia, New Zealand, USA etc.,. Every grocery shop and super markets has separate spice section, many companies engaged in spices manufacturing. Few examples of spice dealers in Fiji are Ahmed & Co, D Kumar Singh Limited, Dayals Spices & Kava Ltd, *Ganga* (Fiji) Ltd, Hardip Narayan & Sons Ltd, Home Maid Pickles Ltd, Indiana Spices, Naveenbhai P. Patel & Co. Ltd., Punja & Sons (Spice) Ltd., Salends Best Quality Spice, Shiu Prasad & Sons Ltd. Etc.,

Fig 1. Export of spices from Fiji



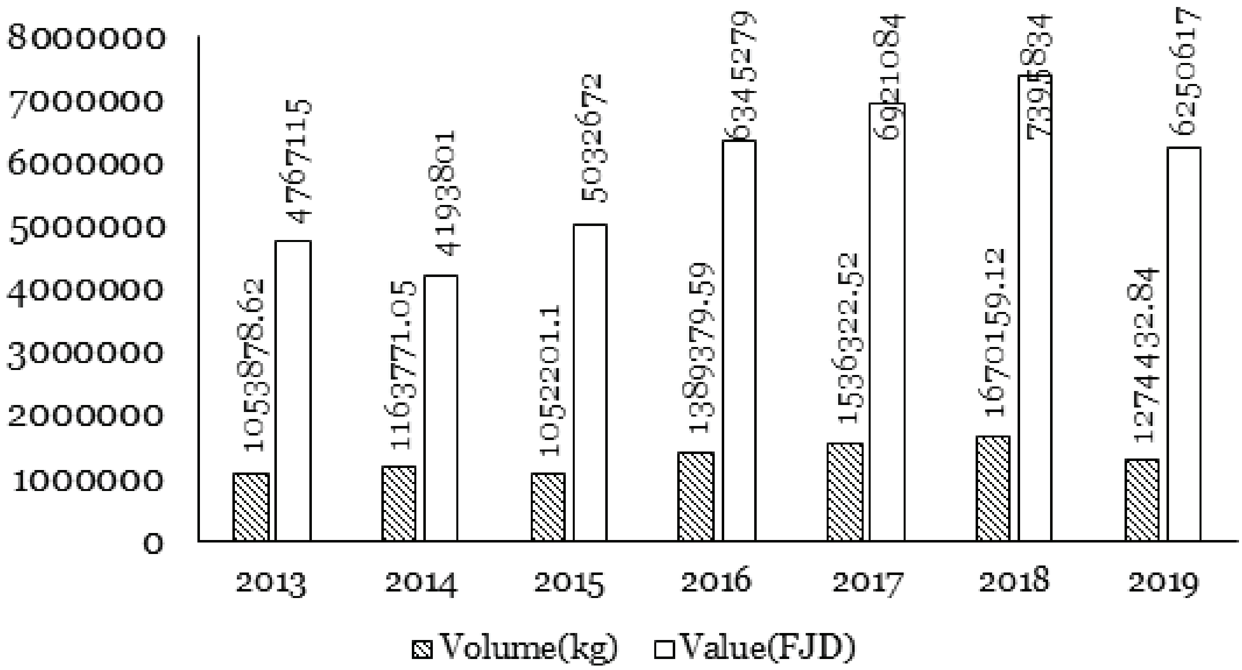


Fig 2. Import of spices into Fiji

Table 2. Mean Export and import of spices between 2013 and 2019

Commodities	Export		Import	
	Quantity ('000kg)	Value ('000FJD)	Quantity ('000kg)	Value ('000FJD)
Cardamoms	0.432	2.392	25.605	424.901
Celery other than celeriac	0.275	0.776	505.884	1324.944
Cinnamon	0.964	8.591	18.115	85.327
Cloves	0.313	0.752	21.454	245.502
Ginger	1275.514	8058.282	74.500	331.580
Ginger preserved by sugar	342.047	2595.414	2.710	19.488

Mace	0.040	0.110	0.475	4.458
Mixtures of Spices	559.061	3235.941	253.172	1251.279
Mustard Seeds	0.741	0.282	48.846	110.245
Nutmeg	0.160	0.262	15.014	155.375
Pepper	1.196	8.008	59.373	488.842
Poppy Seeds	4.862	27.308	18.772	61.804
Saffron	–	–	0.587	10.743
Seeds of anise, badian, caraway or fennel	2.949	21.559	50.959	254.958
Seeds of cumin	0.602	2.947	93.464	576.691
Tumeric	633.183	3043.625	133.850	511.004
Vanilla	1.483	40.133	2.145	60.269
Total	**2730.458**	**16589.122**	**1305.735**	**5843.772**

Spices consumption pattern in Fiji

A survey was conducted to study the spice consumption pattern of people of Fiji during March to April 2019. A structured survey proforma was circulated among 103 families. The data was tabulated and analysed. A summary statistics indicates (Table 3) that 49.0% of the sample population belongs to Fijian 38.0% Fiji-Indian, 5.0%, Chinese, 3.0% English and rest 5.0% belongs to others (which include Indian, Papua New Guinea, Rotuman, Togan) with average family size of 6, 5, 6, 5 and 6, respectively, the mean number spices used among the group is 9, 15, 9, 4 and 9, respectively. The result indicated that average number of spices used by Fiji-Indian is maximum (15) and minimum by English (4). The maximum quantity of spice used was onion around (3.0 kg per month) followed by garlic 1.6kg per month.

Further the survey indicated that mean usage per month was in the order of fresh ginger (461g), green chilli (322g), coriander leaf (259g), dry turmeric powder (229g), masala powder (214g), mustard seed (146g), tamarind (144g), cumin seed 138g), and fresh turmeric and fenugreek seed each 100g. The rest of the spices are used < 100g per month. In general, Fiji-Indian use more spices both in number and quantity and less by English, others use moderate level. Fresh ginger usage was maximum (498 g/month) by Fijian family followed by Fiji-Indian family (474 g/month).

Table 3. Average spices consumption in gram per month per family at Fiji.

Spice items	Fiji- Indian	Fijian	Chinese	English	Others	Overall
Average No of family members	5	6	6	5	6	6
Av. No of spices used	15	9	9	4	9	11
Fresh ginger	474	498	370	67	300	461
Dry ginger powder	46	42	0	0	0	39
Fresh turmeric	130	86	0	233	0	100
Dry turmeric powder	383	131	138	17	213	229
Green chilli	367	323	340	0	75	322
Dry chilli	101	43	40	167	0	67
Tamarind	221	109	40	0	50	144
Black pepper	54	124	45	50	213	94
Cardamom capsule/ seed	157	13	20	0	63	71
Cinnamon	119	73	43	0	88	88

Nutmeg - mace	49	5	1	0	5	22
Nutmeg - seed	39	2	0	0	0	16
Coriander - seed	83	38	2	17	63	54
Masala powder	309	169	0	167	138	214
Coriander - leaf	361	201	176	0	275	259
Mint - leaf	161	52	10	0	100	93
Cumin- seed	229	86	70	67	50	138
Cumin - powder	95	77	0	0	0	75
Ajowain - seed	71	2	0	0	0	29
Ajowain powder	55	0	0	50	0	23
Fenugreek seed	172	58	70	17	25	100
Mustard seed	192	119	75	0	213	146
Clove	88	68	50	0	63	73
Star anise	47	7	11	0	125	27
Asafoetida	100	0	*	*	*	33
Garlic	1667	1625	*	*	*	1636
Onion	3000	2875	*	*	*	2900

*No response was recorded

Prospectives of Spices

Spices was used in embalming, they are seen in Egyptian pyramids, they add aroma, pungency and colour to the food, used in culinary and traditional medicines. There is a new usage in pharmaceutical, cosmetic, perfume and flavor, confectionary and beverage industries and aroma therapy. There is great demand for organically produced spices. The agro-climate of Fiji is very well suitable to grow the spices listed in the Table 1. It is worth to mention about the efforts of Mr Ronald Gatty, who promoted many spices for the benefit of the Fijian farmers. There are many success stories particularly in ginger by Kaiming Agro Processors Ltd, Frespac Ltd etc., are well documented. Nadi Bay Herbs (Fiji) Ltd is another firm exclusively works on herbal spices and exports. They grow basil, pepper basil, mint, rosemary, dil, thyme, parsley, etc.., successfully in Fiji soil. These are few evidences that spices can be grown successfully in Fiji. The advantage of spices is that it can fit into several cropping systems and suitable for climate resilient and crop diversification in Fiji. The efforts should focus on multiplication of quality planting materials by rapid multiplication techniques, popularisation of spices by demonstrations by Government agencies, encouraging and supporting self help groups (SHG's) and non-governmental organizations (NGO's) in all possible ways to start spice production and on-farm processing and value addition. Providing trainings to youths and women entrepreneurs in spices production and processing. These efforts would help the agriculture development in Fiji. A systematic cultivation of ginger is existing in Fiji. There is Fiji Ginger Farmers Association and Ginger Council of Fiji Act 1996 are helps to promote ginger. Similar efforts are required for other spices also. The crops such as turmeric, black pepper, cardamom, cinnamon, nutmeg, clove, allspice, vanilla, tamarind, curry leaf, herbal spices can be targeted and may be extended to other crops in a phased manner. These holistic efforts would make Fiji to become one of the major spice exporters in future.

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RESEARCH PAPER

Properties and Potential Uses of African Tulip (*Sapthodea campanulata P.Beauv.*) in Fiji

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ABSTRACT

Commonly known as the African Tulip in the Pacific, Spathodea campanulata P.Beauv. has invaded some of the valuable agricultural lands and the natural forests in Fiji. In response, the former Ministry of Agriculture Fisheries and Forests investigated ways in which this species could be eradicated. In the process, a joint research programme was initiated by the Timber Utilization Division in partnership with the University of the South Pacific to investigate the properties of wood from S. campanulata, including its potential end uses. The study found the wood from S. campanulata to be very low density which can be used where lightness and ease of working rather than strength are the main requirements.

Keywords: Spathodea campanulata, African Tulip.

INTRODUCTION

African Tulip (*Spathodea campanulata P. Beauv.*) was introduced into Fiji in the 1930s as an ornamental tree (Labrada, 2011). It is native to South Africa and Kenya and is known as the African flame tree because of its large bright orange flowers used for beatification purposes along road sides. Other uses include medicinal use and its potential dye properties.

In 1998 the Ministry of Agriculture, Fisheries and Forests declared S.campanulata as an obnoxious weed (Forestry Facts & Figures, 1998). No commercial planting was undertaken since its introduction, however it has adopted well under Fiji climatic conditions causing the species to invade valuable agricultural and indigenous forest land.

Over the years there has been a lot of efforts to eradicate it, which led to this study to investigate its wood properties and to identify its potential uses.

2.0 MATERIALS AND METHODS

The S. campanulata samples for this study were sourced from Colo-i-Suva. The discs for the density determination were removed from the tree at 3m intervals, labeled and properly wrapped with glad wrap to prevent moisture from being absorbed or released from the discs. The discs were then transported to the Nasinu Laboratory for density determinations.

2.1 Density Measurement

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 (1), air dry density (2), green density (3) also the volume of each sample was recorded using water displacement method (Timber Utilisation Research Division, 1978) and moisture content (MC) (4).

(1) Basic density(kg/m³) = (Oven dry weight (kg))/(green volume(m³))

(2) Air dry density(kg/m³) = (Weight at 12% MC)/(Volume at 12% MC)

(3) Green Density (kg/m³) = (Green weight)/(green volume)

(4) Moisture Content(MC) = (Initial weight-oven dry weight)/(oven dry weight) x100

2.5 Green/Dry Treatment

Ten green *S.campanulata* timber samples 100mm x 50mm with a total Volume 0.05m^3 were selected for Green Treatment at solution strengths of 3.0 % *Tanalith C.* The same number and dimension of samples were also used in the dry treatment but with 1.8% *Tanalith C.*

2.6 Natural Durability

Natural Durability of a timber is determined by using graveyard trial. In this trial, twenty *S.campanulata* wood stakes, 35mm x 35mm in section, 600 mm in length are 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 specie was tested only in the graveyard trials at Nasinu.

3.0 RESULTS AND DISCUSSION

Average basic density is 239kg/m^3 with an air dry density and green density of 267kg/m^3 and 605kg/m^3 respectively. As indicated in Table 1 the density shown has a range from the maximum to minimum density value. The figures indicate that Fiji grown African Tulip has a lower air-dry density when compared to local species Waciwaci (*Sterculia vitiensis Seem.*) 370kg/m^3 and Mako (*Trichospermum richii Seem*) 390kg/m^3.

Table 1: Density of African Tulip

Density	Basic Density (kg/m³)	Air Dry Density(kg/m³)	Relative Density (kg/m³)	Green Density (kg/m³)
Average Wood Density	239	267	271	605
Minimum Wood Density	158	177	177	400
Maximum Wood Density	362	366	455	816

Shrinkage

Shrinkage from green to air dry conditions is rated medium to high-tangential 5.4%, radial 3.6% for African Tulip grown in Fiji. Table 2 indicates shrinkage figures compared to African Tulip grown in the Philippines.

Table 2: Shrinkage from Green to Air Dry of African Tulip

Source	Radial (%)	Tangential (%)	Longitudinal (%)
Fiji	3.6	5.4	0.04
Philippines	4.0	6.5	-

Seasoning

Initial moisture content could be as high as 150 – 250%. Despite this 25mm and 50m stock can be rapidly dried, however, the species is prone to warping, twisting and cupping. Proper seasoning practice is recommended.

Durability

Logs, unseasoned and seasoned timbers are not susceptible to insect attack, but are prone to moulds and Sapstain fungi when wet. Prompt extraction and conversion, followed by antisapstain dipping is required. Both heartwood and sapwood are perishable in ground contact. Based on wood density and durability tests conducted, end uses are limited to commodities for light non load bearing, out of ground contact applications, and fully protected from the weather conditions.

Working properties

S. campanulata saws and machines easily in both green and dry conditions. Dressed surfaces are generally good, although some good rough surfaces become evident during machining, which can be easily removed by sanding. The species peels and dries without difficulty but density variations are possible disadvantages.

Mechanical Properties

Based on its low density values, it is expected that strength properties are also low, making it unsuitable for uses where strength is a main criterion.

Amenability

The species can be satisfactory green or dry treated to Hazard Classes 2, out of ground contact continuously protected from the weather and Hazard 3, out of ground contact not continuously protected from the weather end-use situations (Forest Preservative Treatment Specifications, 1992). Round wood can be effectively treated to Hazard Class 4 for fence posts, otherwise live fence posts are in practice in some rural areas. The preservative treated timber should be restricted to non-load bearing applications in these hazards.

Suggested End Uses

S. campanulata is a very low density hardwood, thus is not currently a recognized commercial species. However untreated S.campanulata wood can be used very effectively in non-load bearing applications e.g. banana boxes, coffee table, artifacts, internal lining, internal door, cupboards and other uses where lightness and ease of working are required rather than strength. For ground contact uses, seasoned, peeled S. campanulata wood can be pressure treated by vacuum-pressure method using Chromated Copper Arsenic (CCA) preservatives to provide long term protection. However, this is not recommended for high value loading bearing applications.


Figure 1 Jitendra Lal of Jiten's Souvenirs with framed artifacts manufactured from S.campanulata

ACKNOWLEDGEMENTS
This research project would not have been possible without the support of the Timber Utilization & Research Division Staff for without their knowledge and assistance, this study would have not been successful. Special thanks of gratitude to Sobha Devi Kumar who was the leading research officer for this project.

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RESEARCH PAPER

Effects of Agricultural lime and organic matter on the productivity of the highly acidic tokotoko soil series of Fiji

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ABSTRACT

A greenhouse experiment was conducted to evaluate the liming values of $CaCO_3$, poultry manure (PM) , and mill-mud (MM) on the acid Tokotoko soil, using growth of a four week cropping of maize (Zea mays L.) seedlings and selected chemical properties of soils collected 28 days after application (and before seed sowing) as indicators. Results indicated that the seedling heights were not affected ($P < 0.05$) by $CaCO_3$, PM and MM applications. The higher dry matter weights were observed in PM- amended soil, which were higher ($P < 0.05$) than in $CaCO_3$, - amended soil. The $CaCO_3$, application rates increased ($P < 0.05$) soil pH, % total N, exchangeable Ca and reduced extractable Fe and Mn. The PM and MM applications also increased soil pH, % total N and exchangeable Ca. Extractable P levels were higher in PM and MM than in $CaCO_3$, - amended soil. Exchangeable K level increased ($P < 0.05$) in MM –amended soil compared to PM and $CaCO_3$ - amended soil. The study clearly demonstrated the potential of managing acid soil infertility by addition of either $CaCO_3$, PM or MM. It was shown that PM and MM could be used as alternatives to $CaCO_3$, which is relative expensive and not readily available in Fiji.

Key words: Liming materials, maize (Zea Mays L.), evaluate

1.0 INTRODUCTION

Soil acidity limits plant growth in many parts of the humid tropics. Soil acidity is caused by factors, which are influenced by the low pH. It is characterised primarily by toxic concentrations of aluminum (Al) and manganese (Mn) and secondarily by deficient concentration of calcium (Ca), magnesium (Mg), potassium (K) and possibly phosphorus (P).

More than 50 percent of soils in Fiji are highly weathered, strongly acid and consists predominately of oxidic and kaolinitic minerals, and are predominately variable charge in nature (Morrison, 1992). Some Fijian soils have been limed to reduce soil acidity and Al toxicity problems, but there is little information on the effect that liming has on the chemical characteristics of the soil. Most studies that were carried out in Fiji were mainly focused on the effect of lime on yields of different crops and very little research was carried out on the effect of liming on chemical characteristics of the soil.

Soil acidity is usually corrected by application of agricultural lime which increases soil pH (Abruna et al., 1975), precipitates Al (Farina et al., 1980) and Mn (Hue et al., 1987), and increase Ca (Kunishi, 1982) and available P (Awan, 1964). However, liming may intensify K deficiency if low or no K fertilizer is added, mainly because of the displacement of exchangeable K by Ca. Furthermore, commercial liming material are relatively expensive are only available in selected agricultural stores. Hence, alternatives to liming using locally available resources such as poultry manure and mill-mud must be sought. Mill-mud is a by-product from sugar mills and is the residue from various mill operations.

The objective of this study was to conduct a greenhouse experiment under more controlled conditions to compare the effects of lime, poultry manure and mill- mud on plant height, dry matter yield and nutrient content of maize seedlings, and on selected soil chemical properties of an acid Tokotoko series from Fiji.

2.0 MATERIALS AND METHODS

The neutralizing power of agricultural lime ($CaCO_3$), poultry manure and mill mud was evaluated in the greenhouse, using the topsoil of an acid Tokotoko series. In the un-amended state, the soil chemical parameters were as follows: pH (1:1 in water) 5.1; organic C 2.0%; total N 0.19%; Olsen P (available) 7mg/kg; 21.5 and 0.17 cmol (+)/kg ammonium acetate extractable Ca and K respectively and 36 and 48 mg/kg DTPA – extractable Mn and Fe respectively

The soil in the pots received the following treatments: 5 and 7.5 Mg/ha $CaCO_3$ (or 12.1 and 18.1g $CaCO_3$ per 3 kg soil); 5 and 7.5 Mg/ha poultry manure (PM, or 12.1 and 18.1g PM per 3 kg soil) and 5 and 7.5Mg/ha mill mud (MM, or 12.1 and 18.1g MM per 3 kg soil). An un-amended control was included for comparisons.

The seven treatments were replicated four times and the pots were arranged in the greenhouse using the randomised complete block design (RCBD). The treatments were left to react with the soil for four weeks before the maize seeds were sown. During this period, the soils in the pots were watered frequently to maintain near field capacity

The maize plant heights were individually measured in each pot twice during growing period. The first measurement was taken when the plants were two weeks old and the second measurement will was at 4 weeks or just before harvesting. After harvest, the maize aboveground biomass was oven-dried at 70o C for 48 hours and their dry weights were recorded.

2.1 Chemical analysis of soils and indicator plants

Just before the sowing of maize seeds, soil from the pots was sampled and a portion of each was air-dried and sieved through a 2mm sieve. The soil pH (1:5) was measured 30 minute after mixing 10g soil with 50ml of distilled water. Organic C was determined by the Walkley- Black dichromate method (Nelson and Sommers, 1982) Total N of the sieved soils was analysed using the semi micro Kjedhal method. Exchangeable bases (Ca and K) were determined from neutral 1M Ammonium acetate with a mixture of strontium and caesium (Sr/Cs). Soil phosphorus was extracted using sodium bicarbonate ($NaHCO_3$) extraction method of Olsen et al. (1954), and then measured colorimetrically. Soil Mn was extracted with pH – 7.3 diethylenetriaminepenta - acidic acid (DTPA) solution (Norvell, 1984), than measured undiluted on an AAS. The dried seedling tops harvested were finely ground and their Ca, K, Mn and Fe concentration were determined by ashing 1.00g and dissolution in 2M HCl. The method for this determination is based on that of Prasad and Spiers (1978). After dissolution, the sample was made up to 50mls with distilled water. The aliquots were analysed undiluted for Mn and Fe with Verian Atomic Absorption Spectrophotometer (AAS). For Ca and K, the aliquot was mixed with 5 ml 10,000 mg/l Lanthanum solution before being measured on AAS.

Phosphorus was determined colorimetrically on a Perkin Elmer UV/Vis spectrometer Lambda 20, using the reagent of Murphy and Riley (1962). Nitrogen of the ground plant samples was determined by the semi-micro Kjedhal method. This method is derived from those described by Blackmore et al, (1987).

2.2 Statistical analysis

All measured parameters from the experiment were subjected to analysis of variance. Where statistical significance were found, Tukey's t-test was used to compare the effects of the seven treatments on the parameters that were measured.

3.0 RESULTS AND DISCUSSION

Seedling height of maize plants were not affected ($P < 0.05$) by $CaCO_3$, PM and MM applications. (Table 2). The higher dry matter weights were observed in the PM-amended soil, which were higher ($P < 0.05$) than the $CaCO_3$ - amended soil. On the other hand, no differences ($P < 0.05$) were found between the two organic sources with dry matter weight. Higher maize P and K concentrations were observed in the PM and MM– amended soil as compared to the un-amended control and the $CaCO_3$ - amended soil. In general, liming decreased plant K and P slightly when compared to the control, where PM and increased them (Table 2), perhaps as a result of direct contribution upon decomposition of PM and MM. The data seem to suggest that improved supply of P and K in the PM and MM-amended soil resulted in better P and K nutrition for maize seedlings (Table 3). Soil extractable P and exchangeable K were linearly correlated with dry yield of maize seedling tops. About 54 % of yield variations were explainable by soil extractable P levels, and 53 % was explainable by soil exchangeable K levels. Furthermore, multiple regression analysis showed that about 67 % of the variations in seedling top dry yield could be accounted for both extractable P and exchangeable K levels. Similar results were reported by Hunter et al (1995), where increased dry seed yield of sweet corn, field grown on an acid Oxisol in Samoa, were attributed to increased P and K nutrition resulting from organic matter application.

Table 1. Height, dry matter weight and chemical composition of seedling tops of maize in response to $CaCO_3$, PM and MM applications

Treatments	Height (cm)		Dry weight of tops. (g/pot)	Chemical composition					
	2 weeks	4 weeks		N	P	K	Ca	Mn	Fe
				(%)				(mg/kg)	
Unamended Control	33a[1]	43a	1.3c	2.7	0.2	3.6	0.6	50.0	1119
5.0 Mg ha^{-1} PM	38a	45a	3.1a	3.8	0.2	4.6	0.4	33.0	1384
7.5 Mg ha^{-1} PM	38a	45a	3.1a	4.1	0.3	5.4	0.5	35.0	1644
5.0Mg ha^{-1} MM	36a	47a	2.5ab	2.2	0.3	3.0	0.5	42.0	1589
7.5Mg ha^{-1}MM	34a	47a	2.6ab	2.1	0.3	3.1	0.5	32.0	764
5.0Mg ha^{-1} $CaCO_3$	34a	37a	1.8bc	4.5	0.1	2.8	0.7	40.0	1859
7.5Mg ha^{-1} $CaCO_3$	35a	40a	1.8bc	3.5	0.1	2.3	0.8	28.0	1059

1 Mean of the same column followed by different letter (s) are different at P = 0.05 using Tukey's t-test

The $CaCO_3$ application rates increased ($P < 0.05$) soil pH, % total N, exchangeable Ca and reduced ($P < 0.05$) extractable Fe and Mn (Table 3). The PM and MM application also raised ($P < 0.05$) soil pH, % total N and exchangeable Ca. Highest extractable P levels were observed in the PM and MM – amended soil, which were higher ($P < 0.05$) than the $CaCO_3$ – amended soil. Exchangeable K levels were increased ($P < 0.05$) with the additions MM as compared to the application rates of $CaCO_3$ and PM. It is well documented that liming increase soil pH, but the raising of soil pH due to PM and MM is less expected. However, such pH increases due to OM additions to acid soils have been reported by Asgar and Kanehiro (1980), Hue and Amien (1989), Hue (1992), and Hunter et al. (1995). Exchangeable K and extractable P levels were significantly lower in the $CaCO_3$ – amended soil (Table 3), perhaps due to the displacement of exchangeable K and Ca, and precipitation reaction due to high Ca levels in the soil, respectively.

Table 2. Effects of $CaCO_3$, PM and MM applications on selected soil properties of the acidic Tokotoko series

Treatments	pH (1: 1)	Organic C	Total N	Exchangeable Ca	Exchangeable K	Extractable P	Extractable Mn	Extractable Fe
		(%)		cmol (+) kg^{-1}		mg kg^{-1}		
Un-amended Control	5.1e[1]	2.0c	0.19c	21.5e	0.17cde	7c	36ab	48b
5.0 Mg ha^{-1} PM	5.9d	2.1c	0.21bc	26.3de	0.50b	26b	38a	54ab
7.5 Mg ha^{-1} PM	6.1bc	2.2c	0.30a	35.6c	0.57a	42a	37ab	51ab
5.0Mg ha^{-1} MM	6.2b	2.9a	0.27abc	22.5e	0.23c	37a	32b	54ab
7.5Mg ha^{-1}MM	6.0cd	2.5b	0.27abc	30.3cd	0.21cd	37a	32b	56a
5.0Mg ha^{-1} $CaCO_3$	6.8a	2.3bc	0.29ab	42.0b	0.13e	11c	20c	26c
7.5Mg ha^{-1} $CaCO_3$	7.0a	2.1c	0.28ab	50.1a	0.16de	9c	13d	26c

1 Mean of the same column followed by different letter (s) are different at P = 0.05 using Tukey's t-test

4.0 CONCLUSIONS

The results from this experiment clearly demonstrated that acid soil infertility can be corrected by either $CaCO_3$ lime, PM or MM additions. It was also demonstrated that PM and MM may be used as alternatives to $CaCO_3$ lime in alleviating soil acidity problems, especially when the latter are relatively expensive and may not be readily available in Fiji.

The organic amendments (PM and MM) could supply, in addition to liming effect (increased soil pH and exchangeable Ca), considering amount of nutrients (particularly, P and K) to crop, which may in turn results in good yields.

It is suggested that the beneficial effects of PM and MM on acid soil infertility be investigated further under field conditions to confirm the present findings, before a recommendation is given to farmers who use the expensive agricultural $CaCO_3$ lime, to try out organic matter such as PM or MM, as an alternative to liming.

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RESEARCH PAPER

Calorific Values of Fiji's Commercial Native Timber Species

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ABSTRACT

Research is a vital component of the Ministry of Forestry's efforts in the sustainable management of the country's diminishing forest resources. The research studies undertaken over the years have enabled the Ministry to make informed decisions relating to best practices on areas such as silviculture, harvesting, and timber processing and use. One of the major outcomes of research is in the area of enhanced livelihoods brought about by the increasing effectiveness in the way we utilize our forest resources. Recently, the Timber Utilisation & Research Division, in collaboration with students from the University of the South Pacific (USP), carried out a research study to determine the calorific values of our commercial native timber species. The objective was to evaluate the suitability of the species for fuelwood, biotech energy industries and for the export of pellets. The species studied, including bauvudi, dakua makadre, kaudamu, kauvula, masiratu, moivi, sacau and yasiyasi, were harvested from the Ministry of Forestry research area in Nakavu and were milled at the Timber Utilisation & Research Division facility in Nasinu. The tests showed that higher density species, generally, have lower calorific values than the lower density species. However, the differences in values were not large indicating that there are other wood characteristics than density which have a stronger influence on calorific values.

Keywords: Forest Resources, Human Intervention and Development, Biotech Energy Industries.

INTRODUCTION

Fuelwood is still the most common source of energy for most people, especially in the rural areas. With the price of fuel and gas continuing to rise, and with the need to discourage the use of such fuels to reduce our greenhouse gas emissions, more and more people are going to turn to trees for their energy sources. However, one of the problems faced is the over exploitation of our forests especially for fuel wood purposes.

To ensure efficiency in the use of fuel wood and also to facilitate effective production of wood-based fuels like charcoal and densified pellets, there is an urgent need to properly identify our native species which can best serve as fuel wood and also as raw materials for other products by evaluating their calorific values.

Calorific value is the amount of heat generated, produced, liberated from one kilogram of specific substance. Its unit is Joules /Kilogram.

The main objective of this research is to determine the calorific values of some of our commercial species as the first step towards identifying the best available species for fuel wood, recognizing that other properties are also important, which may also need to be evaluated.

2.0 MATERIALS AND METHODS

2.1 Source & Extraction of Different Species

Logs used for this study originated from Nakavu, the Ministry of Forestry research area (19826905°E, - 2056975°S) in the province of Namosi. The location of compartment 12 where the logs were sourced from is indicated in Fig 2. The compartment is situated at the Southern corner of the NFMPP-Area. In total, compartment 12 covers an area of 32.43 ha.

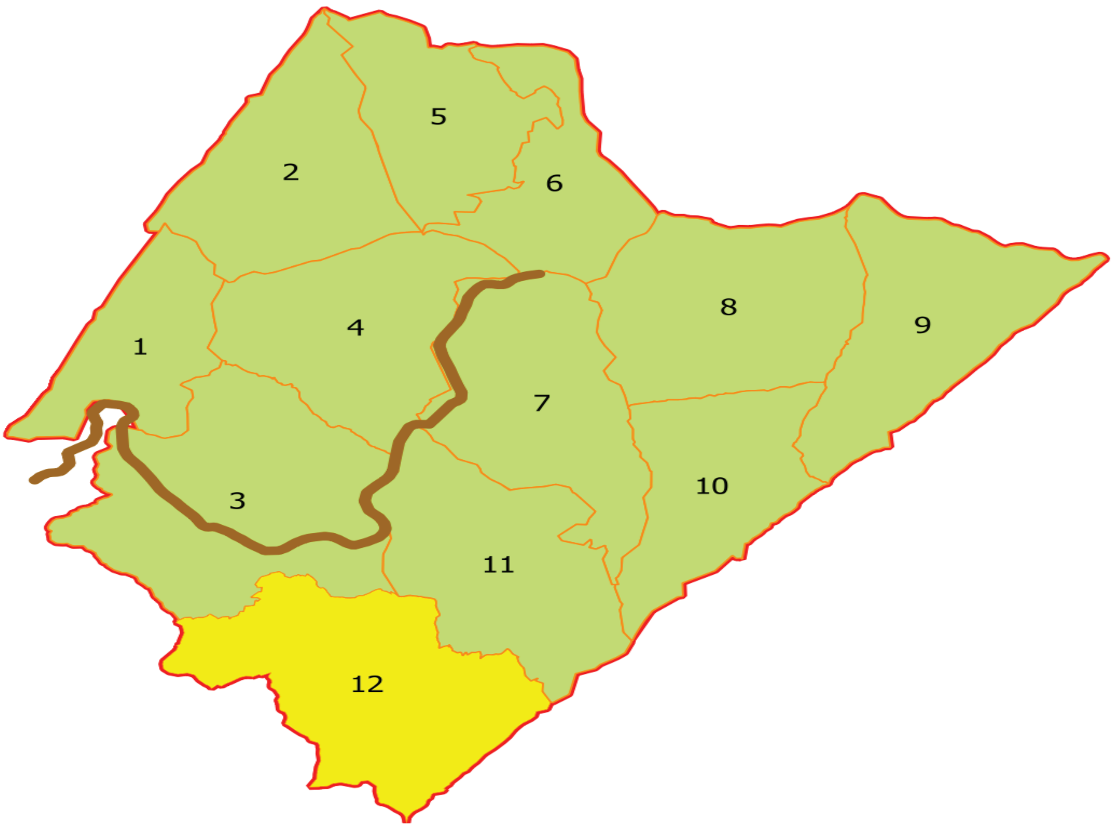

Figure 1: Shows the Compartment 12 (Extraction Site)

All the trees with diameters of 35 cm and above were selected for harvesting from the site.

The species that were sampled and taken to USP for testing included, bauvudi (Palaquim sp A.C Smith) S.P Darwin, dakua makadre (Agathis vitiensis Seem) Benth & Hook. f. ex Drake, moivi (Kingiodendron platycarpum B.L. Burtt), sacau (Palaquim hornei Hartog ex Baker) Dubard, masiratu (Degeneria vitiensis I.W. Bailey) A.C. Sm, kauvula (Endospermum macrophyllum Muell.) Pax & K.Hoffm, yasiyasi (Syzgium sp

L.M.Perry), kaudamu (Myristica castaneifolia A. Gray), (Keppel,Gunnar et al; Ghazanfar, Shahina A.et al, 2011).

2.2 Methodology

Sawmill off-cuts or wastes are normally used locally as firewood. In this calorific tests, samples from the selected commercial species were dried to a moisture content of between 22% - 30% before they were sliced to very thin pieces called "biscuits". The biscuits were grinded using a Tabletop Hammer Mill (Grinder) with a 2mm gauge sieve to filter off the bigger pieces. The filtered products were packed and labelled as shown in Figure 2.

The grinded samples were then filled in a clean crucible as shown in Figure 3, and placed on a digital scale enclosed with glass as shown in Figures 4 and 5 to capture accurate readings of the weight of the wood.A string called the firing wire was inserted in the wood using a pair of tongs as shown in Figure 6. The string helped in igniting the wood in the presence of oxygen. The firing wire should be properly covered otherwise the pieces of wood will not ignite.

A combustion chamber was used to burn the samples of wood as shown in Figure 7 and after combustion was completed the reading was recorded as shown in Figure 9.

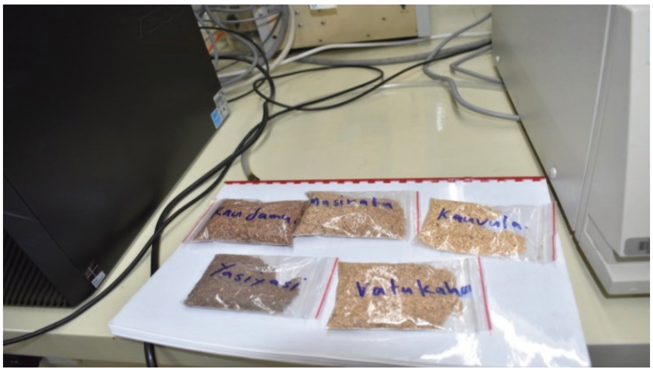

Figure 2: Shows the Wood Samples ready for Testing. (Peters et al, 2005)

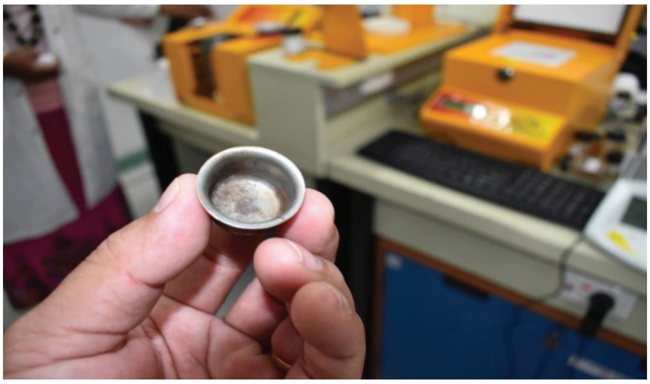

Figure 3: Shows Empty Crucible before filling with wood samples. (Peters et al, 2005)

Figure 4: Shows a Forestry Research Staff weighing the wood samples in the crucible. (Peters et al, 2005)

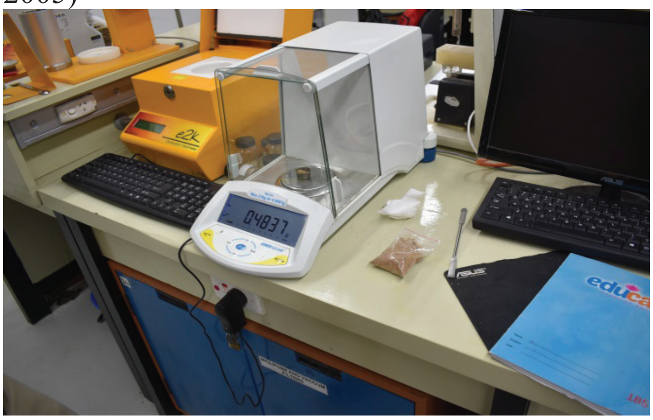

Figure 5: Shows the weight of the samples been displayed on the screen. (Peters et al, 2005)

Figure 6: Shows the Forestry Research Staff burying the firing wire under the wood samples. (Peters et al, 2005)

Figure 7: Shows the wood samples in the calorific tester. (Peters et al, 2005)

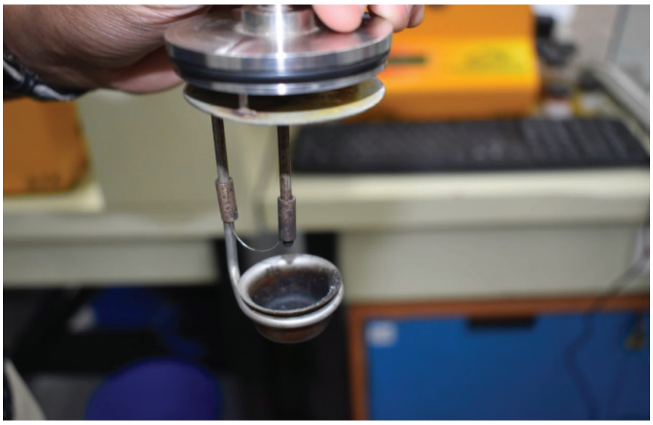

Figure 8: Shows the wood samples completely burnt. (Peters et al, 2005)

Figure 9: Shows the reading on the screen after combustion. (Peters et al, 2005)

3.0 RESULTS

Table 1 Native Species tested Results

Wood Name	Calorific Value (MJ/kg)	Density (kg/m^3)	Description
Bauvudi (Palaquium vitilevuense)	17.171	560-580	Light hardwood, easy to burn
Dakua Makadre (Agathis vitiensis)	17.918	540	Light Hardwood, easy to burn
Moivi (Maniltoa sp & Cynometra sp)	17.718	930 - 980	Heavy Hardwood, very difficult to burn
Sacau (Palaquium hornei)	18.297	890	Heavy Hardwood, very difficult to burn
Masiratu (Degeneria vitiensis)	18.195	410	Light Hardwood, easy to burn
Kauvula (Endospermum macrophyllum)	17.539	480	Light Hardwood and easy to burn
Yasiyasi (Cleistocalyx sp & Syzygium sp)	17.998	890	Heavy hardwood, very difficult to burn.
Kaudamu (Myristica sp)	18.190	580	Light Hardwood and easy to burn

The above results indicate that a species density does not seem to have a direct influence on its calorific value. For example, moivi which has the highest density value of 930-980 kg/m3 has a calorific value of 17.718 MJ/kg which is lower than that of masiratu (at 18.195 MJ/kg) with a density of 410kg/m3. However, the calorific value of masiratu is very close to the value for sacau (at 18.297 MJ/kg) which is a high density species (at 890 kg/m3). Overall, the results confirm other studies that there is no significant relationship between density and calorific value (Chandrashekar et al, 2010). However, there is a need to carry out further studies and also including additional species to validate the results obtained.

4.0 DISCUSSIONS

The above results showed that additional studies will need to be carried out to investigate other properties which will be important to confirm our species selection. Other studies have identified the chemical composition relating to lignin and binder content as an essential factor of influence. According to (Kaltschmitt et al., 2009), lignin has a higher calorific value of 27.0 MJ/kg when compared with cellulose and hemicelluloses at 17.3 MJ/kg and 16.2 MJ/kg respectively.

Therefore, the higher the lignin and extractive content of a material, the higher the respective calorific value. The higher heating values of the wood samples reflect the higher value of lignin relative to cellulose and hemicellulose.

In addition, extractives have been found to have raised the heating values of wood samples. In this regard, softwoods are considered to have greater higher heating values because of their resin or extractive contents. Chandler et al (1983) reported the higher heating value as 7,720 calories per gram (13,896 Btu/lb).They also described terpenes and resin as the two classes of extractives that significantly affect the fire behaviour of forest fuels.

5.0 RECOMMENDATIONS

According to the research done there is a need to increase the number of harvested species or even the total 33 commercial species to be tested to get a much more accurate data.Also to have an equal number of heavy hardwood, medium hardwood, light hardwood and also softwood samples tested. Then a detail comparision could be done according to the four categories above.

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RESEARCH PAPER

Perception of Market Vendor Farmers on Postharvest Handling Practices in Fresh Produce Value Chains in Fiji

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ABSTRACT

The Market Vendor Farmers (MVFs) perception of postharvest along the value chains was 18.26%. The fact that perceived postharvest loss is 18.26% is that the produce does not stay on the farm for longer period of time. In addition, MVFs harvest and largely retail produce themselves provide the opportunity to effectively handle these produce along the value chains. This appreciation goes a long way in explaining why MVFs identified such a high level of need for postharvest training and capacity building in view of reducing postharvest losses. This finding also provides information on the widely held view that MVFs or market vendors only purchase produce from growers and retail in the municipal markets, they are often unaware of the extent of the scale of postharvest loss, and therefore disengaged in seeking appropriate remediation. This research endorses the contributions of national government and international agencies in promoting reduction of postharvest losses in an effort to make improved quality of fresh fruit and vegetables readily available to consumers. The efforts to address the importance of improved pre-harvest, harvest and postharvest handling practices have been minimal thus more effort is needed to promote this issue.

Keywords: fresh produce, market vendor farmers, value chain, postharvest, customers

1.0 INTRODUCTION

Globally, 40 to 50% of the production of root crops, fruit and vegetables are lost or wasted each year which if avoided could feed around 1.9 billion people (at a 2100 kcal/cap/day food value level) (Kummu et al., 2012). Food loss and wastage occurs along food value chains (Lipinski et al., 2013; Parfitt, Barthel, & Macnaughton, 2010). Loss along the horticultural postharvest value chain is a major contributor to food losses in developing countries (Kumar, 2016) which lacks cold chains for local produce. Approximately, one third of all fruits and vegetables produced are never consumed by humans contributing to postharvest loss amounting to 1.3 billion tons per year (Gustafsson, Cederberg, Sonesson, & Emanuelsson, 2013). Horticultural postharvest losses aggravate food shortages, reduces real income for all consumers and producers (Zorya et al., 2011), results in wasted investment that reduces the economic wellbeing of actors in the food value chains (Lipinski, et al., 2013), results in wastage of expensive inputs, such as fertilizer, irrigation water, and human labour which could have been used productively otherwise (Kummu, et al., 2012; Zorya, et al., 2011).

In Fiji a number of crops are cultivated for local and export markets. The national government over the years has heavily invested towards increasing agricultural productivity of growers. Apart from promoting production for food security, efforts have been made in developing and improve pathways for horticultural export markets. Much of this work sought to overcome challenges in Fiji associated with insecure land tenure (Chand & Duncan, 1997; Lal & Reddy, 2002), lack of institutional credit facilities (Asafu-Adjaye, 2007; Kaumaitotoya, 1997), lack of skills of scientific methods of vegetable production, poor marketing facilities with lack of storage and preservation facilities for fruits and vegetables, high costs of agro-inputs (Food & Study, 2007).

Municipal fresh fruit and vegetable markets in Fiji continue to be the primary choice for consumers to purchase fresh fruits and vegetable contributing to income generation and employment for local market vendors (Baxter, 2017; Dewey, 2011; Nand, 2006). There are largely two types of vendors in the markets, vendors that source from farmers and the farmer-cum-vendors referred as Market Vendor Farmers (MVFs). One value chain involves growers, wholesalers and market vendors. The second value chain is exclusively a farmer who sells produce directly to consumers from the fresh fruit and vegetable markets. With increasing demand for quality fresh fruit and vegetables from local consumers, there is an increasing realization of the need to improve associated postharvest handling value chain systems.

Detailed biophysical analysis of a tomato postharvest value chain, commercial loss was shown to be 32.9% (Kumar, 2016). Ninety-eight percent of farmers from the central division and 88% percent of farmers from the Sigatoka valley had never attended or received any previous postharvest training with the majority (89 to 90%) of farmers surveyed proposed that the need for postharvest training (Underhill, Zhou, & Kumar, 2017). While farmers were aware of the need for postharvest capacity building they were provided with very limited postharvest training (Kumar, 2016).

Where farmers are able to adopt improved postharvest technologies, there is substantial improvement (25 to 30%) in income in Vietnam, Lao PDR and Cambodia (Weinberger, Genova Ii, & Acedo, 2008). Primarily, with previous work undertaken to quantify postharvest tomato loss in Fiji (Underhill & Kumar, 2014; Underhill, et al., 2017); it is important to examine the MFVs perception of postharvest handling practices and subsequent losses along the fresh produce value chains in Fiji. The specific focus of the study is to identify and document MFVs activities, postharvest handling practices and related postharvest losses of fresh fruits and vegetables. While the MVFs harvest and largely retail produce themselves, it provides an opportunity to effectively handle these produce along the value chains.

2.0 MATERIALS AND METHODS

Quantitative investigation was undertaken using a semi-structured interview-based questionnaire, consistent with previous studies undertaken by (Kumar, 2016). To validate responses, interviews were undertaken on-farm, in the market and before workshop sessions to allow for a diagnostic review of potential on-farm, during transportation and during retailing handling practices and available infrastructure. Participation was voluntary to ensure participant responses were accurately interpreted and documented with prior briefings provided to potential participants outlining the nature and reason for the study.

To obtain a proportionate sample, this study was conducted in 14 locations on the islands of Viti Levu, Vanua Levu and Levuka, Fiji. The survey involved 67 of the 595 MFVs from 14 training centers around Fiji. To ensure consistency of the research tool, the designed questionnaire was randomly field-tested and refined using 8 MFVs. This study specifically focused on MFVs, classified by Dewey (2011), stating that there are varied types of vendors from fresh fruits and vegetable to sale of dry produce. By targeting MFVs in this study, the intent was to exclude fulltime vendors who buy and sell at these markets but capture the value chain activities from farm to point of sale. A focus on MFVs is consistent with previous study by Dewey (2011) to highlight the socio-economic issues of these vendors.

3.0 RESULTS

3.1 Socio-demographic characteristics of MVFs

According to the survey, 30% were male and 70% female MVFs (Table 1). Majority of these MVFs were married (82%). Age of growers comprised of four groups; less than < 20, 21 to 35, 36 to 50, 51 to 65 and > 66 years old. More than half of MVFs (51%) are in 36 to 50year category. Majority (94%) of the MVFs are Indigenous Fijian with 28% of Fijians of Indian origin. The majority (64%) of MVFs have attended secondary school, with 12% indicating tertiary level education.

The MVFs have been in the business for a number of years. More than 50% have less than 5 years of retailing experience, 24% have 6 to 10 years whilst 16% have 11 to 16 years of retailing experience. The MVFs tend to have some form experience in farming, the 27% of the MVFs having less than 5 years of experience, 19% having 6 to 10 years' experience and a further 11 to 15, 16 to 20 and more than 21years having an average of 18 years' experience.

The number of days per week of marketing at the municipal market was documented for these MVFs. A quarter (25%) of the MVFs did their marketing business 6 days a week. Only 10% sold their produce once a week which was on Saturday. Overall, Saturday is the preferred day of marketing produce at the municipal market. The once a week MVFs mostly sell their produce in open allocated areas (Figure 1). For some MVFs, days apart from retailing is cultivating the crops for market ready.

Figure 1: The MVFs retailing once a week mostly sell their produce in open allocated areas

Table 1 Socio-demographic characteristics of Market Vendor Farmers in Fiji

Activity	Category	Per cent (%)
Gender	Male	30
	Female	70
Ethnicity	Indigenous Fijian	84
	Indo Fijian	28
	Other minority	3
Age	<20	1
	21-35	18
	36-50	51
	51-65	27
	>66	3
Marital Status	Single	18
	Married	82
Education Level	Primary	24
	Secondary	64
	Tertiary	9
	Technical	3
No. of Years as Market Vendor	<2	24
	2-5	27
	6-10	24
	11-16	16
	>16	9
Years of Farming	<5	27
	6-10	19
	11-15	18
	16-20	18
	>21	18
No. of days/ week retailing in Market	1day/week	10
	2days/week	19
	3days/week	19
	4days/week	8
	5days/week	19
	6days/week	25

3.2 Postharvest loss of MVFs along the value chains

The MVFs perception of postharvest loss of fresh fruits and vegetables along chain is 18.96% which is presented in Table 2. Most postharvest loss (14.6%) is thought to occur on the farm. The transportation loss is 2.27% and loss during retailing is 2.09%. The on-farm loss is attributed to pre-harvest, harvest and postharvest practices of the MVFs. The MVFs perception of on-farm loss mostly occurs at harvesting of the produce while using forks and knifes.

Table 2: Market Vendor- Farmers perception of postharvest losses along the value chains

Stages of loss	Per cent (%) loss
On-farm Loss	14.60
Transportation Loss	2.27
Loss during retailing	2.09
Total Postharvest loss	18.96

3.3 Harvesting

The method of harvesting either by hand or mechanically can result in significant postharvest losses of fruits and vegetables (Kader and Rolle 2004). The MVFs perception of harvesting and postharvest were documented. Factors such as time of harvesting, person harvesting, mode of on-farm transportation, availability of storage sheds, and mode of transportation to the market determines the quality of produce a MVFs is able to market. The MVFs manually harvested vegetable such as tomatoes, used knife for harvesting bananas, knives and digging for cassava and taro.

3.4 Time of harvest

The time of harvesting also has a significant influence on product quality. The time of harvest was categorised in five groups; early morning (before 7am), mid-morning, midday, afternoon (after 2pm) and anytime (Table 3). Harvesting is generally recommended to be carried out early morning whilst the temperature is still low and produce is cool. Harvesting is most commonly carried out primarily in the afternoon (43%). The harvesting was done in the afternoon so that MVFs could avoid the high temperatures (mid-day) and transport the produce to the market the following morning. Fewest growers, 3% conduct harvesting activities during mid-day due to other farm activities.

It was observed that most MVFs harvest in the afternoon and ready pack for transportation to the next morning. This indicates that the produce is not cooled after harvesting and could be more prone to quality deterioration and postharvest loss.

Table 3: Harvesting time of produce by MVFs in Fiji

Time of harvest	Per cent (%)
Early morning	34
Mid-morning	4
Mid-day	3
Afternoon	43
Anytime	15

3.5 Person harvesting the produce

Fruits and vegetables are manually harvested by; Market Vendor-Farmers, Family labour only, or Market Vendor-Farmer together with family labour. Harvesting of produce is dominated by Market Vendor-Farmer (58%), Table 4. A quarter of the time family labour assists in harvesting of produce.

Table 4: Person harvesting the produce

Person harvesting	Percent of person (%)
Market Vendor-Farmers	58
Family labour only	25
Market Vendor-Farmer and family labour	16

3.6 Availability of on-farm storage shed

Almost all of the Market Vendor-Farmers (Table 5) do not have dedicated postharvest on-farm storage facilities; instead produce was stored in a range of multiple purpose structures or transported to the market after harvesting. On-farm storage sheds are dominantly open shed structures, having a roof and without side walls, very few of structures had a permanent corrugated roof and concrete floors indicating well-constructed shed. Apart from utilising on-farm, MVFs used their house or verandah to store produce.

Table 5: Percent of MVFs having on-farm produce storage shed

Availability of on-farm storage shed	Per cent (%)
Yes	27
No	73

3.7 Mode of transporting of produce to market

Most (48%) MVFs transported produce as part of a mixed horticultural consignment using hired vehicles, Table 6. In Viti Levu, these vehicles are utility trucks (two to three tonnes), the vast majority of which being open tray design that afforded little protection to produce in transit. These trucks had either metal or wooden floor trays. A comparatively small percentage (12%) of MVFs used their own vehicle to transport their produce to the market. Interestingly in an earlier study the main type of market transport was hired 'carrier' which served the dual purpose of transporting passengers and large quantities of produce (Baxter 1980). In the absence of utility trucks, transporting produce by bus (40%) is the most important mode of transportation. This dual purpose transport system mindset to some extent still exists where passengers are seen sitting on and around perishable produce.

Table 6: Mode of transporting produce used by MVFs

Transport mode	Per cent (%)
Own vehicle	12
Hired vehicle	48
By bus	40

3.8 Postharvest practices, knowledge and training of MVFs

While 94% of MVFs surveyed identified a need for postharvest training (Table 7), little postharvest training and capacity building appears to have been undertaken. Only 13% stated that there was postharvest training undertaken in their area. There is a high level need for postharvest capacity building which highlights a clear disconnect in relevant extension support opportunities for these MVFs. This postharvest training provided much needed of information to these MVFs thus they have strongly requested for further specialised training especially in the produce hey cultivate.

Table 7: Postharvest training and capacity building of MVFs in Fiji

Activity	Yes (%)	No (%)
Have you previously done any postharvest training?	13	87
Do you think MVFs need postharvest training?	94	6

4.0 Discussion

There is large number of female MVFs compared to male MVFs. This finding is consistent to (Dewey, 2011) where vast majority of whom are women. It was noted that income from the produce sales is utilized for purchase of farm inputs and household expenses. The MVFs perception of postharvest along the value chains was 18.26%. In another study the postharvest harvest loss along the value chains averaged 32.9% (Underhill & Kumar, 2014). The value chains differ in the sense that MVFs are involved at all stages of the chains until the produce is sold to customers. The fact that perceived postharvest loss is 18.26% is that the produce does not stay on the farm for longer period of time. In addition, MVFs harvest and largely retail produce themselves provide the opportunity to effectively handle these produce along the value chains. This appreciation goes a long way in explaining why MVFs identified such a high level of need for postharvest training and capacity building in view of reducing postharvest losses. This finding also provides information on the widely held view that MVFs or market vendors only purchase produce from growers and retail in the municipal markets, they are often unaware of the extent of the scale of postharvest loss, and therefore disengaged in seeking appropriate remediation.

Detailed notable differences in the socio-demographics and on-farm postharvest practices of MVFs, the similarity in overall perceived postharvest loss is interesting. MVFs tend to be middle-aged (35 to 50yrs), married and more female dominated cohort, most having secondary level of education, more farming experiences than marketing experiences and using family labour. The nature and interactions of such socio-demographic factors influence resultant postharvest handling practices. This may partially explain a greater reliance on family labour and conversely why approximately 50 percent MVFs retail less 3 days each week. At least a quarter of the MVFs did their marketing business 6 days a week qualifying them as full time market vendors as municipal market operate 6 days a week. Clearly more work is required to better understand how socio-demographic as well as socio-economic contributors may shape on resultant postharvest handling practices.

This research endorses the contributions of national government and international agencies in promoting reduction of postharvest losses in an effort to make available improved quality of fresh fruit and vegetables. The efforts to address the importance of improved pre-harvest, harvest and postharvest handling practices have been minimal thus more effort is needed to promote this issue.

The results lead to the following recommendations. Firstly, there is need to prioritize postharvest handling practices to promote quality farm produce with prolonged shelf-life. A better quality fruit and vegetables with prolonged shelf-life could provide an opportunity for MVFs to explore high end markets (hotels and resorts). Secondly, there is need for cost effective packing and packaging materials for MVFs who are transporting the produce for longer distances in open tray trucks and bus. It was noted that MVFs used bags for packaging. Having smaller bags would ease in handling of the produce (lifting and carrying on shoulders). Some of the MVFs are utilizing the plastic crates for which cost-analysis (returning with the empty crates when initially a truck was hired to get the produce to the market) could be explored. The MVFs indicated the willingness to attend postharvest handling training. Finally, with the absence of cold chain in Fiji, there is potential for a temperature managed municipal market outlets to maintain the quality and self-life of fresh produce. These facilities are beyond the purchasing power of MVFs, thus the involvement of national government and/or private sector or a grower co-operative for providing these facilities would be beneficial particularly in urban markets where retail prices may merit such investments. In view of this cost-benefit analysis is needed for this type of investments.

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RESEARCH PAPER

Properties and Potential Uses of Tadalo (*Pagiantha thurstonii)*

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ABSTRACT

The study undertaken was part of a Ministry of Forestry Research Programme on Lesser Known Species (LKS). Stocking of Fiji's native forests is relatively low at 40-50 cubic meter per hectare (Margules et al, 1987) and the Ministry of Forestry, through the research programme, is working on including the LKS to increase the stocking level. The desired stocking level of more than 80% as based on the researched conducted (Hawthorne,J.W. et al, 2011). The study focused on investigating the physical, mechanical and processing properties, and potential uses of *Pagiantha thurstonii,* known by a number of local names, depending on where the species is found in Fiji. This study will support improving selective logging in the country by increasing the range of preferred species to be logged, which will protect Fiji's biodiversity and contribute to the sustainable management of its native forests. At the same time, the study will contribute to the improvement of livelihoods of our local communities through their engagement in small micro entrepreneurship using LKS. Above all, the study will support the enhancement of the forestry sector's contribution to our National Gross Domestic Product (GDP), which is our ultimate goal.

Keywords: Lesser Known Species, small micro entrepreneurship, volume yield.

1.0 INTRODUCTION

The group of species collectively known as LKS includes species that have not been studied to determine and confirm their potential end uses. On the basis of the national forest inventory (NFI) 2007 data, four (4) LKS were identified by the Ministry of Forestry which included kuluva (*Dillenia biflora* A.Gray) Martelli ex Dur and Jacks, kaukaro (*Semecarpus vitiensis* A.Gray) Engl, dulewa(*Xylopia pacifica* A.C.Sm) and dalovoci(*Hernandia olivacea* Gillespie*)*. From this list, kuluva (*Dillenia biflora* A.Gray) Martelli ex Dur and Jacks and dulewa (*Xylopia pacifica* A.C.Sm) have been researched and results published. The results indicated that both species are suitable for light construction and furniture, including other uses where light work is required. This would open up new opportunities for sawmillers and joinery shops, in terms of using other commercial species.

Kaukaro (*Semecarpus vitiensis* A.Gray) Engl has not been studied because it is poisonous which could cause body parts to swell when in contact. Dalovoci (*Hernandia olivacea* Gillespie), on the other hand, had limited availability.

Pagiantha thurstonii is locally known as tadalo, drega, tabuameikalavo (Kubulau), tabuakeirakalavo (Koro), da,alu (Cakaudrove), tabuasere, tabuaneirakalavo (Verata), vuetinaitasiri, tabuairakalavo (Beqa), tarawaukeirakavo (Bau), vudikeilewalewadrua (Macuata), (Keppel, Gunnar et al; Ghazanfar, Shahina, A.et al, 2011). The *P.thurstonii* species was selected for study due to its availability and the need to obtain more information on the species properties and potential end uses.

2.0 GENERAL CHRACTERISTICS OF *Pagiantha thurstonii*

2.1 PHYSICAL PROPERTIES

Pagiantha thurstonii (Tadalo) grows up to 30m, and is distributed around 30m to 1,100m elevation throughout the islands, including Viti Levu and Vanua Levu. It has grey-brown, rough bark covered with small growths and longitudinal cracks. The cut bark has a brown outer layer, over a yellow inner layer, covering a light yellow wood with pinky-brown spots. It exudes copious white latex that does not harden soon after exposure. The oppositely arranged leaves with short stalks have thick and leathery blades that are of different sizes and shapes on the same tree and even on the same leafy branch. Leaf blades ranges from 7cm to 22cm long and from 3cm to 12cm wide. The pure white, fragrant flowers are borne in bunches (Tabunakawai et al, 1996)

Figure 1: Trunk of *Pagiantha thurstonii*

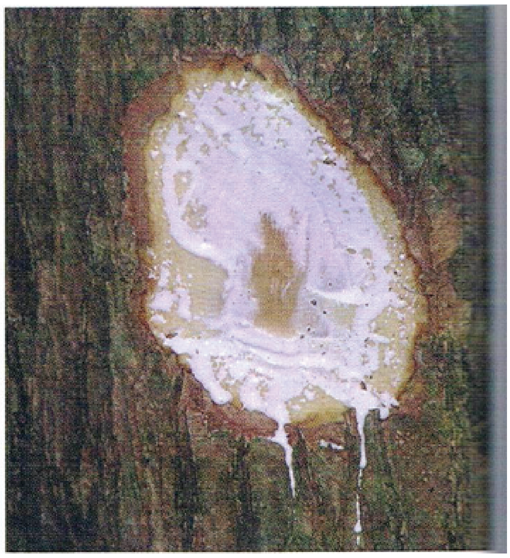

Figure 2: Slash of the bark of *Pagiantha thurstonii showing white resin*

2.0 MATERIALS AND METHODS

Five (5) *P. thurstonii* trees were selected and marked before felling at Namuavoivoi (19903250.6E,-1888557.8S), Bua Province. Vanua Levu was selected as the source of the study materials due to the significant interest expressed by the Divisional Forestry Officer Northern Division regarding the potential end uses for Tadalo. A harvesting contractor had confirmed the availability of tadalo within his area of operation in Namuavoivoi in Bua. The diameter at breast height (dbh) was measured using a diameter tape during the identification and marking process. Only the trees with 35cm dbh and above were selected for harvesting. After felling, the mid-diameter and the length of each tree were measured and recorded. Discs for moisture content and density determinations were removed from the tree at 3m intervals for every tree from 1 to 5 (Dranibaka, S. et al; Tabua, K. et al, 2013) The discs were labeled and properly wrapped with glad wrap to prevent moisture loss. The discs were then taken to the laboratory in Nasinu for further testing

Table 1: Extracted Logs with their measurements

Log #	dbh(cm)	Length(m)	Log Vol(m^3)
Tadalo 1	35	4.4	0.423
Tadalo 2	38	7.0	0.794
Tadalo 3	35	7.2	0.693
Tadalo 4	40	4.7	0.591
Tadalo 5	35	6.4	0.616
TOTAL			**3.117**

2.2 Density Measurement

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, oven dry weight (12% m.c.), green volume and oven dry volume (12% m.c.) of each piece were measured and recorded to determine green density, basic density and the air dry density. Volume determinations for the samples were recorded using the water displacement method (Division, Timber Utilisation Research, 1978) and moisture content (MC) (4) (Center, Timber Industry Training, 2012)

2.3 Sawmill Conversion

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

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 ($d \geq 50cm$) while the 'through and through' method was used for logs with small diameter ($35cm \leq d > 50cm$) (Dranibaka, S. et al; Tabua, K. et al, 2013). The timber sizes ranged from 50mm x 25mm to 200mm x 50mm with lengths ranging from 0.6m to 4.5, 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)

2.4 Dipping

Twenty (20) 100 x 25 pieces were selected for the dipping trial. The chemicals used in this process were Antiblu and Vacsol (Gremm Chemicals). The active ingredient for the Antiblu chemical is cholothalonil and carbendazim whereas for Vacsol, permethrin. Three (3) different concentrations each for Antiblu and Vacsol were used to determine the most effective concentration to reduce mould, stain and decay (Table 2)

Table 2: Concentration of Antiblu and Vacsol tested

A	B	C	Control
Antiblu-1.0% Vascol-0.4%	Antiblu-1.5% Vacsol-0.4% (recommended)	Antiblu-2.0% Vacsol-0.4%	-
5 samples	5 samples	5 samples	5 samples

2.5 Green Treatment

10 green *P.thurstonii* timber samples (Total Volume 0,05m^3) were selected for Green Treatment at solution strength of Tanalith NCA 3.0% (H3).

2.6 Natural Durability

Natural durability of a timber species is determined by using graveyard trials. In this trial, 20 *P.thurstonii* wood stakes, 25mm x 25mm in section, 30cm in length are inserted to the ground so that half of the length of the stake is buried. The average time taken for the stakes to fail is used to assign a natural durability rating. The species was tested only in the graveyard trials at Nasinu

3.0 RESULTS AND DISCUSSION

The average density of *P. thurstonii* at 12% moisture content is 541kg/m^3 %, ranging from 466kg/m^3 to 627kg/m^3 (see Table 3 below), and is classified as a light hardwood species, the same class as mahogany (*Swietenia macrophylla*) and kaudamu (*Myristica sp.*). It was also noted that in green form the moisture content was in excess of 100% moisture content, making the species very susceptible to mould, soft rot and eventually decay if not adequately dried before use.

Table 3: Result of Density and Moisture Content per Tree

Tree No.	Disc No.	Samples No.	M.C (%)	Density @ 12% M.C
T1	A	T1/A/1	118.3	528.8
		T1/A/2	105.5	538.2
		T1/A/3	108.7	542.8
		T1/A/4	112.3	548.5
	C	T1/C/1	100.1	536.3
		T1/C/2	99.5	540.7
		T1/C/3	95.2	550.7
		T1/C/4	115.7	528.1
T2	A	T2/A/1	156.6	470.4
		T2/A/2	146.6	466.6
		T2/A/3	200.6	501.1
		T2/A/4	117.3	514.9
		T2/A/5	112.2	527.6
		T2/A/6	120.0	518.1
	B	T2/B/1	108.1	526.8
		T2/B/2	112.2	527.0
		T2/B/3	111.5	527.2
		T2/B/4	106.4	551.5
	C	T2/C/1	109.2	518.3
		T2/C/2	104.4	517.6
		T2/C/3	102.4	528.4
		T2/C/4	101.3	537.8
T3	A	T3/A/1	90.1	575.8
		T3/A/2	87.7	599.7
		T3/A/3	85.8	605.5
		T3/A/4	87.8	599.4
	B	T3/B/1	77.1	627.1
		T3/B/2	78.6	611.4
		T3/B/3	96.9	582.4
		T3/B/4	86.7	574.4
		T3/B/5	84.2	599.0
		T3/B/6	116.3	555.9
	C	T3/C/1	103.7	552.2
		T3/C/2	82.5	577.9
		T3/C/3	78.6	613.2
		T3/C/4	114.6	560.4
		T3/C/5	128.7	552.8
T4	A	T4/A/1	108.6	554.9
		T4/A/2	102.0	600.7
		T4/A/3	127.2	365.2
		T4/A/4	107.2	553.8
		T4/A/5	104.6	596.4
	B	T4/B/1	107.8	543.2
		T4/B/2	99.9	567.2
		T4/B/3	115.2	560.8
		T4/B/4	122.3	478.9
		T4/B/5	104.9	562.0
		T4/B/6	95.3	574.2
T5	A	T5/A/1	115.5	502.4
		T5/A/2	100.7	548.0
		T5/A/3	111.0	540.0
		T5/A/4	117.2	552.6
		T5/A/5	114.8	512.8
		T5/A/6	98.8	553.1
		T5/B/1	108.8	496.7
		T5/B/2	101.6	534.4
	B	T5/B/3	103.7	526.1
		T5/B/4	116.3	472.5
		T5/B/5	94.1	534.5
	C	T5/C/1	98.9	501.6
		T5/C/2	94.0	526.2
		T5/C/3	110.1	468.9
		T5/C/4	100.0	512.4

Table 4: Density Moisture Content Results

Moisture Content	107%
Basic Density	483kg/m³
Green Density	996kg/m³
Density @ 12%	541kg/m³

3.1 Sawmilling Properties

Table 3 below shows that the average sawn timber recovery achieved for *P.thurstonii* during the study was 32.01%, and depending on the tree being studied, the recovery ranged from 13.17% to 46.36%. As expected, the largest recovery was achieved with the log with the largest diameter and was also straight i.e. T4. It was evident that taper and bent were impacted quite alot on timber recovery e.g. T2 and T5.The *P.thurstonii* species was easy to saw as the blades ran through the logs smoothly during the ripping process. Traces of white resin could be seen during sawing, but this did not adversely affect process at any time.

Table 5: Recovery Table

Tree no.	**Diameter (cm)**	**Length (m)**	**Input (m^3)**	**Output (m^3)**	**Recovery (%)**	**Remarks**
T1	35	4.4	0.423	0.168	39.72	
T2	38	7	0.794	0.217	27.33	Bend Logs
T3	35	7.2	0.693	0.232	33.48	10% Rot
T4	40	4.7	0.591	0.274	46.36	
T5	35	6.4	0.615	0.081	13.17	Taper and Bend Logs
Total			**3.116**	**0.972**	**32.01**	

3.3 Dipping

The recommended Antiblu & Vacsol concentration for *P.thurstonii* is Antiblu 1.5% and Vacsol at 0.4%.

Table 6 below outlines the assessments results attained from the monthly dipping asessments.

Table 6: Table of Assesment Results

Dipping Assessment Date	**A Antiblu- 1.0% Vacsol-0.4%**			**B Antiblu- 1.5% Vacsol-0.4%**			**C Antiblu 2.0% Vacsol-0.4%**			**Control**		
	M (%)	**S (%)**	**D (%)**	**M (%)**	**S (%)**	**D (%)**	**M (%)**	**S (%)**	**D (%)**	**M (%)**	**S (%)**	**D (%)**
11/06/15	-	-	-	-	-	-	-	-	-	-	-	-
09/07/15	-	-	-	-	-	-	-	-	-	-	-	-
13/08/15	-	-	-	-	-	-	-	-	-	5	-	-
10/09/15	5	7	-	5	4	-	5	5	-	10	10	-
15/10/15	10	15	-	7	10	-	7	10	-	10	15	-
19/11/15	15	20	-	10	10	-	10	10	-	10	15	-
10/12/15	15	25	-	10	10	-	15	10	-	20	25	-
14/01/16	15	25	-	10	10	-	20	10	-	25	25	-
18/02/16	10	30	-	15	10	-	15	15	-	20	30	-
17/02/16	10	30^+		15	10	-	15	15	-	20	30	-
14/04/16	10	30^+		15	10	-	15	15	-	25	30^+	-
12/05/16	15	30^+		15	10	-	15	15	-	25	30^+	-

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

3.4 Green Treatment

All samples that were submitted for laboratory analysis of *P.thurstonii* did not pass H3 treament chemical loading requirements. It istherefore recommended that the specie is initially dried to 25% moisture content before the timber is pressure treated.

3.5 Natural Durability

The graveyard trial was suppposed to be assessed after six (6) months of exposure but unfortunately this did not take place because our trial was destroyed by Cyclone Winston in February, 2016. In the absence of any conclusive test results, and, on the basis of the performance of the stakes during the initial stages of the trial and also on the basis of the wood properties reported above, it would probably be safe to classify the species as perishable to non-durable for now.

Figure 3 Shows the trials for *Pagiantha thurstonii*

3.6 Potential Users

Tadalo species is classified as a light hardwood species and can be recommended for end use such as furniture and for light construction applications. It is not recommended for load bearing applications such as bearers and roof beams.

RECOMMENDATIONS

According to the research of *P. thurstonii*, the data collected is only for the north side of Fiji,therefore further research is needed to compare the species properties in other regions.

ACKNOWLEDGEMENTS

The research on *P.thurstonii* would not have been possible without the assisstance support from all the staffs of the Timber Utilisation Division. A sincere thanks to Mr.Marika Rawasoi who has left the Ministry to join the Fiji Military Forces.The remarks from the chief Editor were also very helpful in improving and supporting this documents.

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RESEARCH PAPER

Soil Fertility and Productivity Decline Resulting from Twenty-Two Years of Intensive Taro Cultivation in Taveuni, Fiji

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ABSTRACT

Soil degradation is the loss of actual or potential productivity and utility of the soil and it implies a decline in the soil's inherent capacity to produce economic goods and perform environmental regulatory functions. With short-term observations, the transient phenomena can be missed or misinterpreted. In general, observations made over a long period allow more rigorous conclusions with regards to decline in soil fertility.

Soil data for "22-year period" was retrieved from the archival files at the Koronivia Research Station while other important information were gathered through survey questionnaire and ministry officials based on the Island. The effects of 22 years continuous cropping of taro on selected soil chemical properties and yields were studied on the island of Taveuni, Fiji. The high native fertility levels and production potential of Taveuni Andosols declined rapidly when the forest cover was replaced by the annual crop of taro. This was particularly evident from the trend analyses of the nutrient elements which, altogether with soil pH and taro yields, revealed significant declines, with the exception of exchangeable K. Significant associations between and dependence of taro yields on soil pH, Olsen P, exchangeable Ca and exchangeable Mg were also observed. In addition, significant changes in these four chemical parameters were observed when the pre and the post cultivation levels were compared. Olsen P and exchangeable Mg were identified to be the most limiting nutrients for the taro soils of Taveuni. The archival database provides an important tool for looking at soil test trends over time on taro commercial sites.

Key words: taro, forest, soil degradation

1.0 INTRODUCTION

Soil is a non- renewable and fundamental resource that plays a significant role in providing humans with productive agricultural crops, food security and many socio- economic benefits. However due to intensive land use change, agricultural practices, export opportunities and climate change, soil is being degraded and lost unprecedented rates around the globe. This is particularly the case in Asia and the Pacific, where land degradation due to depleted soil quality and fertility and soil erosion.

Successful agriculture requires the sustainable use of soil resource, because soils can easily lose their quality and quantity within a short period of time for many reasons. Agricultural practice therefore, requires basic knowledge of sustainable use of the land. Success in soil management to maintain soil quality depends on the understanding of how the soil responds to agricultural practices over time (Negassa, 2001). Revising these trends lies in the enhancement of sustainable development of the agricultural sector. However, the basis of this sustainable agricultural development is good quality of soil, since maintenance of soil quality is an integral part of sustainable agriculture.

Although soils in the tropical regions are highly diverse, with some soils having a high production potential, there are many areas where the soil resources suffer from serious limitations hindering agricultural production and development. Some tropical soils have a very low chemical fertility, are extremely acidic and contain toxic substances (Young, 1999).

Soil fertility degradation by nutrient depletion, mostly caused by erosion but also by removal of nutrients in crops, is one of the threats that taro production systems in Taveuni are facing (Kumwenda et al., 1996). Soil erosion is obviously the most visible and sometimes most destructive form and has received considerable attention in Fiji's land use policy.

Taro is Fiji's largest agricultural export after sugar (FAO, 2012a). Fiji's annual taro export for the last few years has been around 10,000 tonnes, earning about FJD 19-20 million annually with about 65% going to New Zealand and the balance to Australia and the USA (McGregor, 2011). Taveuni accounts for 70% of Fiji's taro exports (Sun Fiji Newsroom, 2009).

Despite taro (Colocasia esculenta) being the staple diet for Fijians for centuries, its cultivation as a highly significant export crop began only in 1993 when the taro leaf blight disease decimated the Samoan taro industry (McGregor, 2011). Fiji took advantage of the opportunity and captured the market for the same variety of taro internationally, especially Australia, New Zealand and United States. The taro exports increased from 3,000 tons in 1994 to 10,000 tons in 2009 (Ministry of Primary Industries-Taveuni Annual Report, 2010). However, the island's taro exports stagnated during recent years due to declining productivity and increasing production costs (McGregor, 2011).

After 22 years of intense taro cultivation and with little or no fallow practice, due to scarcity of land resources and other economic factors, the fertility and the productivity of the Taveuni taro soils will predictably decline due to cultivation, soil erosion and nutrient uptake.

This study is to investigate the existence of any temporal association between selected soil chemical indicators and taro yields over a period of 22 years for the island of Taveuni.

2.0 MATERIALS AND METHOD

2.1 Study area

The fieldwork for this research was carried out on the island of Taveuni, located in the north eastern Fiji group. The whole island of Taveuni, was divided into three rainfall zones that characterise the island. The three rainfall zones are the dry zone in the north, the intermediate zone and the wet zone towards the southern end of the island. This form of stratification was necessary to assess soil fertility decline as it defines the spatial boundaries of the system under study.

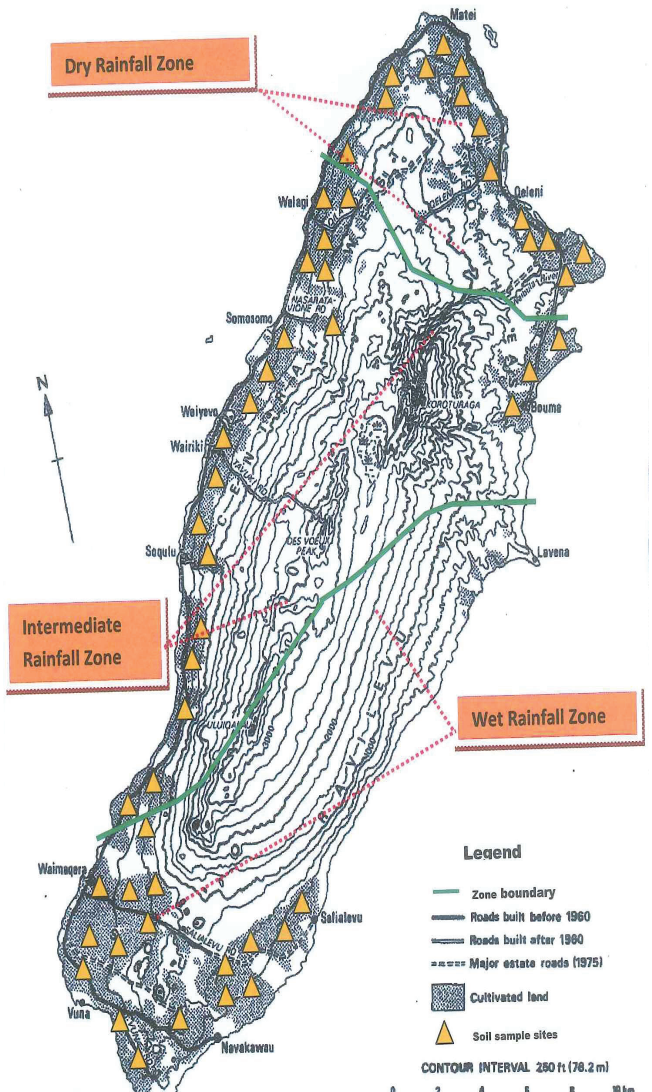


Figure 0.1

Soil samples collected over the archival period were from 0-20 cm depth. During the initial years of the inception of taro program in Taveuni, about a total of 400 samples were received with 40%, 30% and 30% from the dry, wet and intermediate zones, respectively. However, as the area under cultivation increased and more intensive cultivation was practised, problematic areas were identified and up to 1000 samples were analysed annually with 34%, 36% and 30% from dry, wet and intermediate zones, respectively. These samples were analysed at Koronivia Research Station for the following determinations: pH (soil:water ratio of 1:5), organic carbon using the Walkley-Black (1934) method, available P by Olsen et al. (1954) described by Blackmore et al.(1987) and exchangeable cations by 1 M NH4OAcextraction at pH 7 (Daly et al., 1984 and Blackmore et al., 1987).

Taro production data consisting of exportable yield and rejects of the export variety (Tausala) for a period of 20 years were collected from the Ministry of Primary Industry, Taveuni office archival sources to assess the effect of change in soil fertility on the yield of the crop.

3.0 STATISTICAL ANALYSIS

Data collected were subjected to determine mean differences between the production strata with respect to fertility indicators and taro yield data. Regression analyses were carried out to ascertain any significant dependence of taro yield on individual soil fertility and meteorological variables. Multiple linear regression analysis was used to derive a predictive model using indices that were individually significant with the yield. Only coefficients significant were retained in the model. All the data were analysed using the Discovery Edition of the Genstat statistical software package.

4.0 RESULTS AND DISCUSSION

4.1 Soil chemical indices

4.1.1 Soil pH

The general trend of Soil pH for the entire island of Taveuni for the 22 year review period is given in Figure 4.3 (a) below.

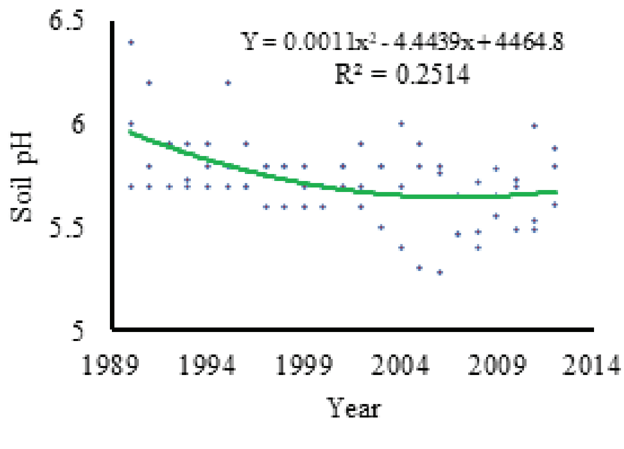


Figure 1. Soil pH trend for Taveuni

Trend analysis revealed a significant decline (R^2=0.25; P<0.01) in the mean soil pH for Taveuni over the 22 year review period. The initial decline can be attributed to the commencement of intensive cultivation of the newly cleared forest sites while the latter fluctuations tend to reflect the use of chemical fertilisers for the taro crop, and application of agricultural lime during the alternating fallow periods. The survey data reveals that 100% of the farmers from all the strata did not carry out any application of fertiliser or lime until year 2000, depending entirely on the natural levels of soil fertility. However, nearly 90% of the total farmers surveyed depended on fertiliser and lime applications to sustain yields thereafter. Liming did not result in an apparent trend of increasing soil pH as any increase in soil pH could have been counterbalanced by heavy application of mineral fertilisers, particularly urea and blended complete fertilisers. Another reason could have been the low rates of spot application of lime due to the predisposing economic climate that the farmers work within. Furthermore, high rainfall could also have been the contributing factor for inefficiency of lime in correcting the soil pH, as leaching losses tend to be higher with high rainfall. Longu and Dynoodt (2008) reported that long-term annual applications of urea resulted in significant increase in soil acidification and decreased exchangeable bases in soil. Adams (1984) confirms that the acidity produced by 1 kg N in urea is 71g H+, which is equivalent to about 3.6 kg CaCO3.

4.1.2 Total soil nitrogen

The general trend of Total N (%) for the entire island of Taveuni for the 22 year review period are given in Figure 4.4 (a) and (b) below

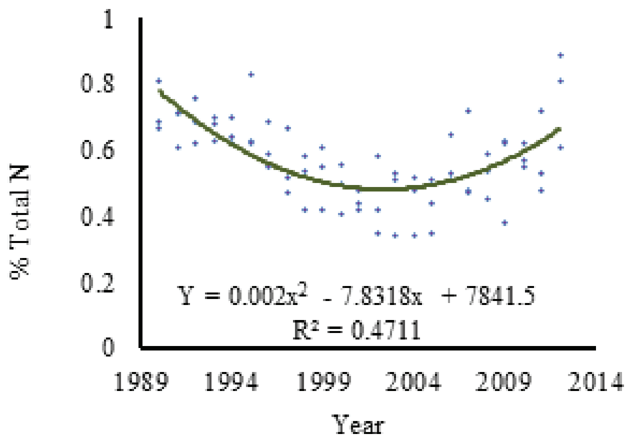


Figure *2.* Total N trend for Taveuni

Trend analysis revealed a significant decline (R^2=0.47; P<0.01) in the mean total N over the 22 year review period. The initial decline can be attributed to the decline in the native reserves of organic matter following commencement of intensive cultivation of the newly cleared forest sites while the latter increase tends to reflect the use of chemical fertilisers for the taro crop, and application of agricultural lime during the alternating fallow periods resulting in more plant biomass that gets returned as organic matter to the soil. In intensive cropping systems, where a non-tillage system is adopted, depletion or loss of organic matter has been reported (Johnson et al., 2006), which may result in N deficiency.

4.1.3 Olsen available phosphorus

The general trend of Olsen P (mg/kg) for the entire island of Taveuni for the 22 year review period is given in Figure 4.5 (a).

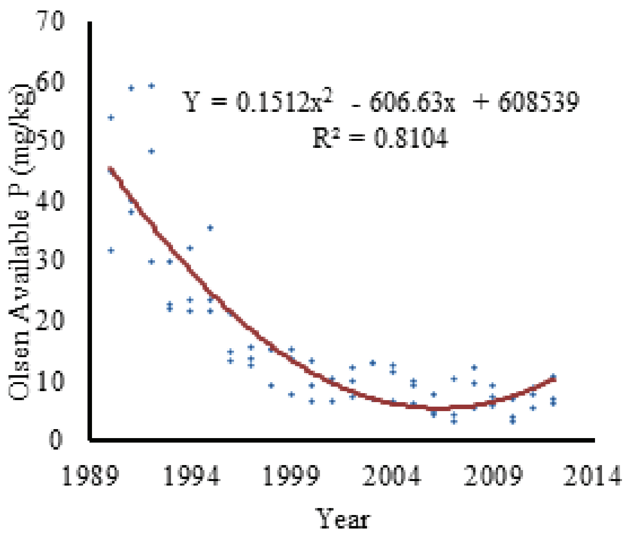


Figure 3. Olsen P. trend for Taveuni

Trend analysis revealed a significant decline (R^2=0.81; P<0.01) in the mean levels of Olsen available P for the 22 year review period. The sharp initial decline can be attributed to the effect of continuous cultivation that aggravates organic matter oxidation. In addition, it may have resulted from the decline in soil pH leading to accelerated fixation of soil P. Taveuni soils, being of volcanic origin, have a high tendency to fix soil P and this could be the reason for poor response of the soils towards P fertilisation and liming during latter years of cultivation. Fageria et al. (2004) reported that most of the acidic soils have very low levels of native fertility, especially in terms of phosphorus. Holfords (1977) reported that when P fertilisers are applied to replenish soil fertility, about 70-90% of the P fertiliser is adsorbed and becomes locked in various soil P compounds of low solubility.

4.1.4 Exchangeable K

The general trend of K (cmol (+)/kg) for the entire island of Taveuni for the 22 year review period are given in Figure 4.6 (a)

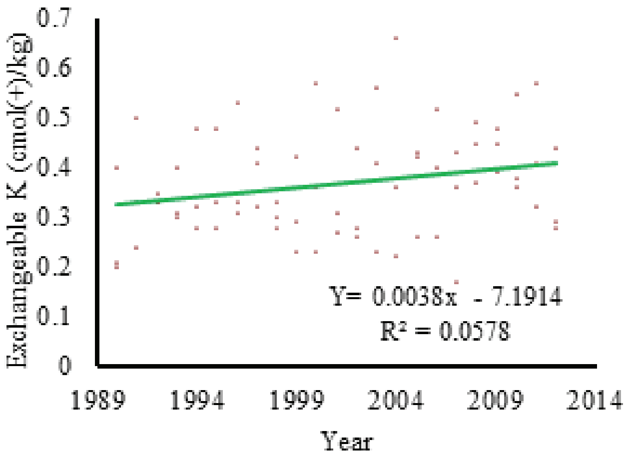


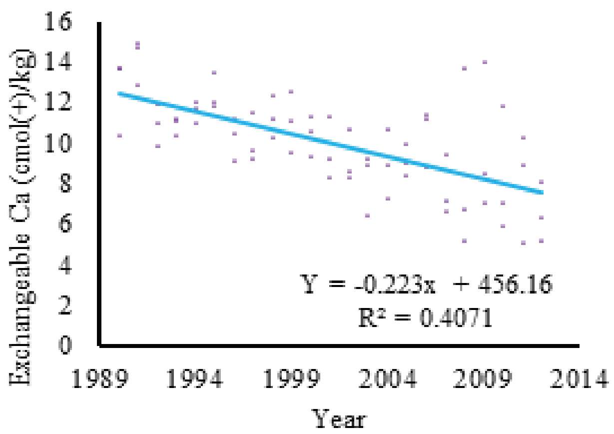
Figure 4. Exchangeable K trend for Taveuni

There were no significant differences (P=0.255) in the exchangeable K levels. In China, the increase in total K and available K could be explained by unbalanced fertilisation strategy in the area, which was commonly practiced by the farmers (Niu et al., 2011). Niu et al. (2011) further stated that according to farmers' opinion, the more K fertilisers were used, the higher yields could be achieved, but this could also result in strong K accumulation in the soils.

4.1.5 Exchangeable Ca

The general trend of Ca (cmol (+)/kg) for Taveuni for the 22 year review period are given in Figure 4.7 (a) and (b) below.

Figure 5. Exchangeable Ca trend for Taveuni



Trend analysis revealed a strong significant decline (R^2=0.41; P<0.01) in the exchangeable Ca for the 22 year review period. The initial decline can be attributed to the decline in the native reserves of organic matter and accelerated leaching of the Ca following continuous cultivation of the newly cleared forest sites with no external inputs, while the latter fluctuations tend to reflect the application of agricultural lime by some farmers during the alternating fallow. Horsley et al. (2000) reported similar trends about the depletion of available soil Ca due to nutrient removals by forest harvesting and leaching induced by acid deposition and aluminium (Al) mobilisation in acidified soils. This has led to a heightened interest in the role of base cations, such as Ca, in forest health and productivity.

4.1.6 Exchangeable Mg

The mean exchangeable Mg (cmol(+)/kg) trends for the three taro production zone and the general trend for the entire island of Taveuni for the 22 year review period are given in Figure 4.8 (a) and (b) below.

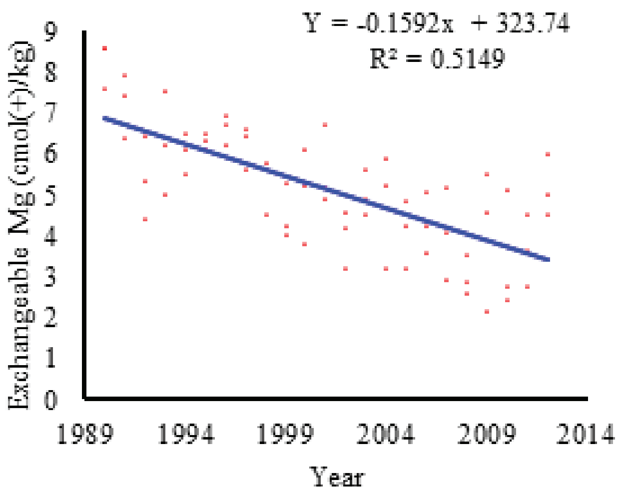
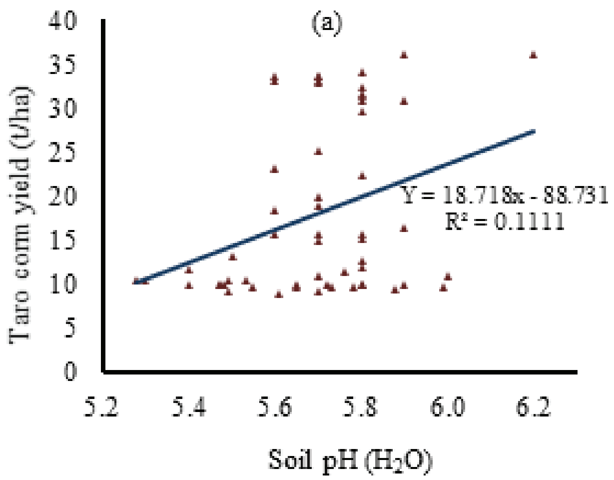


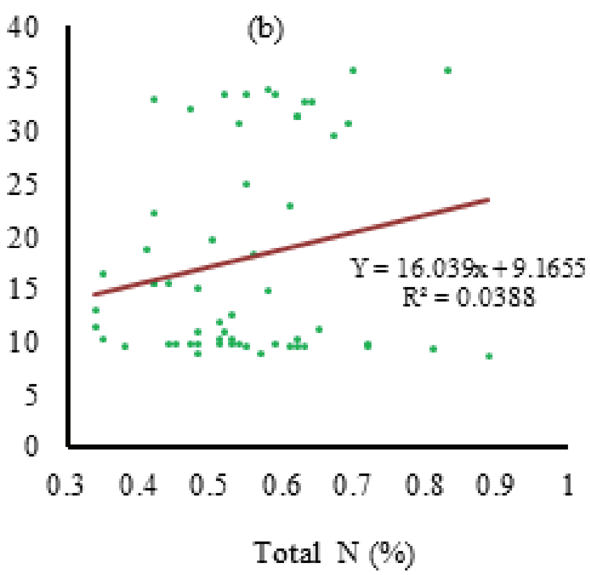
Figure 6. Exchangeable Mg trend for Taveuni

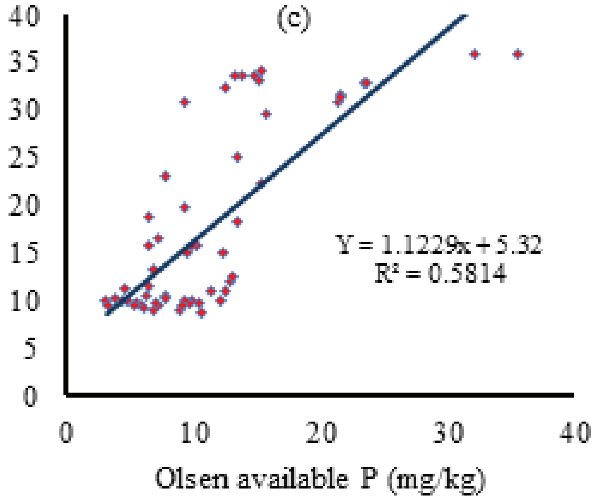
Trend analysis revealed a strong significant decline (R^2=0.51; P<0.001) in the mean levels of exchangeable Mg for the 22 year review period. The declining trend can be attributed to crop uptake and accelerated leaching of Mg following continuous cultivation of the newly cleared forest sites with no external inputs, as well as leaching loss, before any lime application occurred. The agricultural lime applied was mainly in the form of calcium carbonate, not Mg-containing dolomitic limestone, so is not expected to raise Mg levels. Also, displacement of exchangeable Mg by Ca in lime may lead to higher Mg leaching. Similar results were reported by Adejuwon and Ekanade (1975) who reported that decline in exchangeable Mg levels could be attributed to organic matter diminution and some may be washed off by surface erosion following the exposure of forest cover.

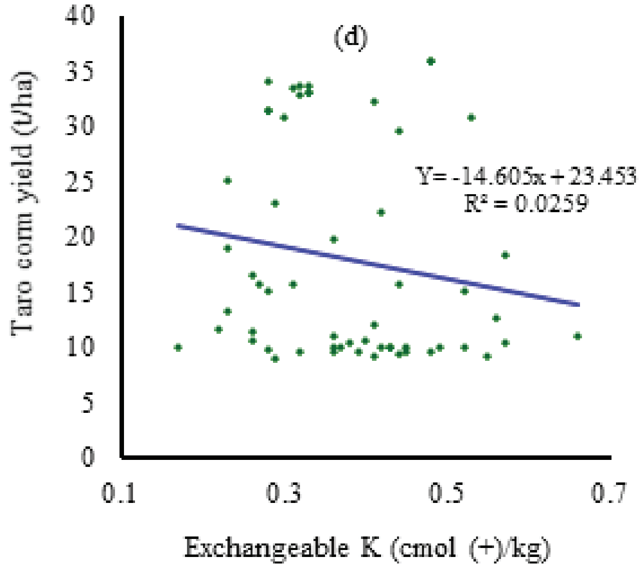
4.2 Relationship of selected chemical indices to taro corm yield

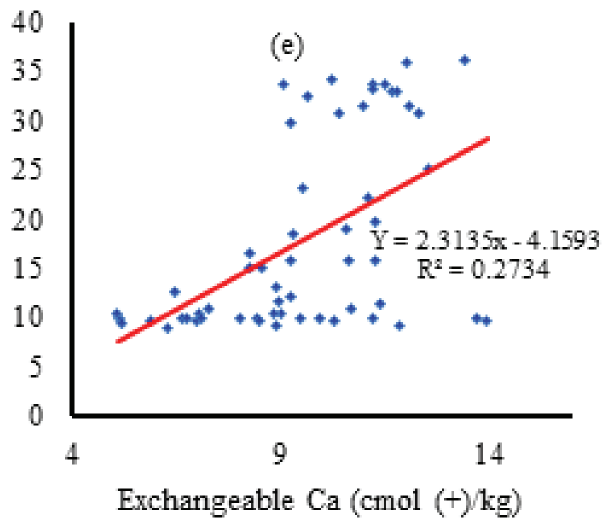
The relationship between individual chemical indices and the yield if taro are given in Figure 7 (a-f) below.











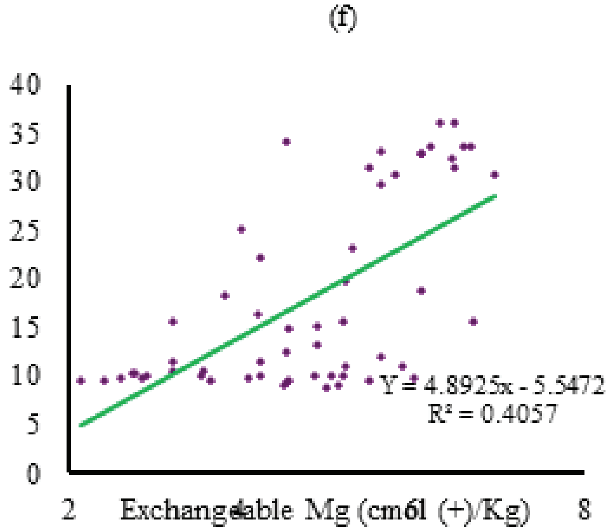


Figure 7. Regression of taro yield on (a) soil pH; (b) Total N (%); (c) Olsen available P (mg/kg); (d) Exchangeable K (cmol(+)/kg); (e) Exchangeable Ca (cmol(+)/kg); and, (f) Exchangeable Mg (cmol(+)/kg).

The linear regression analysis of yield data of taro against the individual soil chemical indices for the 20 year review period (Figure 4.12 a-f) revealed significant dependence of yield on soil pH (R^2=0.11; P<0.011); Olsen available P (R^2=0.58; P<0.001); exchangeable Ca (R^2=0.27; P<0.001); and, exchangeable Mg (R^2=0.41; P<0.001). On the contrary, Total N (R^2=0.04; P<0.14) and exchangeable K (R^2=0.03; P<0.23), did not significantly influence the yield of taro. In general, soil total N is not a good predictor of crop yield as this variable does not reflect N availability to plants.

Multiple linear regression analysis was then carried out using only the chemical indices which significantly influenced taro yields, that is, soil pH, Olsen available P, exchangeable Ca and Mg. This showed a highly significant overall relationship (R^2=0.65, P<0.001) between the yield and the interactive response of the four parameters. However, the estimation of parameters revealed that only Olsen available P and exchangeable Mg had a significant effect in predicting the yield of taro as outlined in Table 1 below:

Table 1. Estimates of parameters for multiple linear regression analysis

Parameter	Estimate	S.E.	t-value (df=52)	P – value
Constant	36.9	28.7	1.29	0.204
Ca	0.639	0.424	1.51	0.138
Mg	2.395	0.814	2.94	0.005
P	0.868	0.147	5.91	<0.001
pH	-8.13	5.33	-1.52	0.133

It can therefore, be said that the yield of taro can reasonably be estimated using the following predictor equation based on soil chemical indices:

Y= 36.9 + 0.868 (Olsen P) + 2.395 (Exchangeable Mg)

N=20; R2=0.65; P< 0.001

5.0 CONCLUSIONS

Sustainability, although a dynamic concept, implies some sort of equilibrium or steady state. The analyses presented in this research work has shown that many soil chemical properties significantly change with time, and it can be argued that land-use systems in which significant soil fertility decline takes place are not sustainable in the long term. This research has used a set of basic soil chemical properties (pH, total N, Olsen P and exchangeable cations) to investigate changes under taro cropping systems in Taveuni, Fiji, over a 22 year period of intensive cultivation with little to no fallow.

This was particularly evident from the trend analyses of the nutrient elements which, altogether with soil pH and taro yields, revealed significant declines over the 22

year cropping period, with the exception of exchangeable K. Significant associations between and dependence of taro yields on soil pH, Olsen P, exchangeable Ca and exchangeable Mg were also observed. The increased use of inorganic fertilisers and lime was deemed necessary towards the latter years of the research period in an attempt to sustain yields and continuing research needs to be undertaken to ascertain any resultant significant changes

6.0 RECOMMENDATIONS

1. The balanced and efficient use of plant nutrients from both organic and inorganic sources, at the farm and community levels, should be emphasized; the use of local sources of organic matter and other soil amendments should be promoted; and successful cases of integrated plant nutrient management should be analyzed, documented, and disseminated.
2. More closer cooperation and coordination between farmers and researchers to exchange information and disseminate developed technologies that take into account immediate farmer immediate needs along with longer-term soil fertility and agricultural sustainability requirements
3. Participatory forms of design, testing, and extension of improved plant nutrient management strategies that build upon local institutions and social organisations, including trained farmer groups should be promoted.
4. Improvement of security of access to land leases on long terms is critical for the intensification of fertiliser use and the successful promotion of integrated plant nutrient management approaches.

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RESEARCH PAPER

Improving the Cultivation of Sweet Potato production in Fiji

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ABSTRACT

Sweet potato *(Ipomea batatas)* is an important crop of Fiji. It is a short term (3-5 months) crop and is resilient to dry conditions and cyclones. The coloured varieties have a low glycemic index which is important to human health. The average yield of the traditional varieties is in the range of 13-22 t/ha. The annual production of the sweet potato in Fiji during the period 2010-2016 ranged between 7053-8581 metric tonnes per annum. Sweet potato production is around 5 % of the total production of the root crops in Fiji. The major challenges in cultivation and production of sweet potatoes in Fiji were observed to be the poor yield, more vegetative growth, high incidence of pests and diseases, and poor quality of tubers. The markets demand a consistent supply of good quality tubers. Production of sweet potato chips requires low sugar tubers. Efforts have been made to improve the production technologies of sweet potato. This paper discusses the current status of production of sweet potato in Fiji and the improvements in production technologies which mainly include the introduction of drought-tolerant varieties, production of sweet potato slips as planting material, rooting of sweet potato vine cuttings before planting and transplanting of seedlings from 1-2 node cuttings.

Keywords: *Sweet potato slips, Rooted cuttings, Storage roots, Nutrition, Harvesting Index, glycemic*

index

Introduction

Sweet potato, [*Ipomoea batatas* (L.) Lam.] is a member of the Convolvulaceae family. Amongst the approximate 50 genera and more than 1000 species of this family, only *Ipomoea* is of major importance as a food crop (Woolfe 1992). It is an economically important crop grown in over 110 countries with an annual world production estimated to be around 130 million tonnes, with China being the leading producer.

Today sweet potato ranks as the fifth most important food crop in developing countries after rice, wheat, maize, and cassava (International Potato Center, 1998). Its wide adaptability on marginal land and rich nutritional content provide an enormous potential for preventing malnutrition and enhancing food security in the developing world. Sweet potato is relatively drought-tolerant compared to other crops, grown on residual soil moisture during dry months. Many studies showed that severe drought affects sweet potato by retarding growth, reducing root yield, dry matter and affects root quality mostly by weevil damage.

Over the past few years, there has been a significant amount of interest in the cultivation of this crop by local farmers throughout Fiji. One of the major constraints to sweet potato production, however, is the availability of good quality planting material, lack of prospects for export markets and value addition. The agronomic practices of farmers also contribute to the inferior quality of material utilised in their production system. Farmers generally use longer vines 30-40 cm as planting material, which are obtained from planting materials multiplication blocks and from research stations of the Ministry of Agriculture. This method uses quite a lot of plant material that, if taken from older portions of the sweet potato vine maybe a potential source for insect pests and diseases. Repeated use of vines as planting material has been shown to promote increased weevil infestation in sweet potato tubers (Ray *et al,* 1983). There is very little information on the studies carried out in the past in Fiji on the use of rooted vines as planting materials.

Sweet potato is very beneficial to the human diet as it is a good source of energy. The yellow, orange flesh varieties contain a large amount of carotenoids. Bisone and Maretzki (1982) reported that an average sweet potato serving of 3 1/2 ounces (100g) contains 140 calories. A portion of this size supplies seven per cent of your daily carbohydrates requirements and thirteen per cent of your daily fibre needs. Orange flesh varieties are rich in beta – carotene, and purple flesh varieties are rich in anthocyanins, both of which are popular dietary antioxidants. Besides, all sweet potatoes are low in glycemic index, meaning that they are broken down slowly into sugars in the body (Teow, et.al 2007). Foods with a high glycemic index such as potatoes, or baked goods containing large amounts of refined sugar, cause blood sugar levels to spike.

The Ministry of Agriculture in Fiji maintains around 44 sweet potato accessions in the research collections, only nine of these are local varieties and five are commonly cultivated by farmers. The five common varieties are Honiara (purple skin & white flesh), Vulatolu (white skin & white flesh), Kabara (white skin & purple flesh), Carrot (orange skin & orange flesh) & Papua (purple skin & yellow flesh). The rest of the accessions are the introduced varieties from the International Potato Centre (CIP) in Peru. Most of the these varieties are currently evaluated in Fiji on various ecological zones to test their adaptabilities to various conditions, storage roots production, taste and other value addition potentials. In addition to this, some of the world's improved varieties were also introduced including Costanero, Beauregard & VSP sweet potatoes.

By introducing new technologies and improved production practices, the yield potential of this crop can be enhanced. To improve sweet potato production, the Ministry of Agriculture has implemented several measures to improve its cultivation in Fiji. These include the introduction, conservation & management of sweet potato genetic resources through various means such as field germplasm, tissue culture and nursery methods. Some new cultivation techniques that have been tried at the research stations include the following: *Production of Sweet Potato Slips and Rooted and Unrooted Sweet Potato Vines Cuttings as Planting Materials; & the Potting and Transplanting Technique of Sweet Potato Vines.* These new techniques not only ensure better storage root production of sweet potatoes but also helps in controlling the spread of sweet potato weevil, scab and other important pest and diseases.In addition to this the Ministry of Agriculture is working with the Ministry of Health in Fiji through the National Food Nutrition Centre in promoting sweet potato cultivation in the peri-urban areas under the centre's "Grow Your Own Food Program" to promote healthy eating through home food gardening. Cultivation of sweet potato is part of the program due to its health benefits such as the orange and purple flesh varieties using simple cultivation techniques that can be used in urban centres. These techniques include the box methods, use of nylon bags, planter's pots, empty drums, styrofoam, etc to grow sweet potato and also promote its health benefits.

Fig. 1 Simple backyard techniques at Koronivia Research Station

Multiplication and distribution programme to be designed in Fiji to improve the quality of planting material within the local production system. The material is delivered to the farmers as two-week-old rooted two-node cuttings. If planting material is cut into two-node segments and allowed to develop roots in a shaded area or nursery, more plants can be generated from that same amount of material.

2.0 Status of Production of Sweet Potato in Fiji

Sweet potato can be planted and harvested at any time of the year in Fiji Sweet potato, is often used as an emergency crop during natural disasters such as cyclones and floods as it can be easily harvested, stored and prepared.

Commercial sweet potato production in Fiji is mostly concentrated in the flat lands of Muanaweni in the lower Naitasiri Province, the Sigatoka Valley, and Nadi areas. In the outer islands of Fiji such as the Lau group, Yasawa, Lomaiviti, Beqa, Kadavu and Vanua Levu, sweet potato is grown as a staple crop Some farmers cultivate sweet potato as a subsistence crop.The average yield of sweet potato with traditional practices is 18 – 20 t/ha, while for the semi-mechanized method is 20 – 25 t/ha. This also depends on the varieties grown by farmers, as these varieties come in different sizes and weight of the storage roots.

Many varieties of sweet potato are available in the Pacific (SPC, 2012). These vary in sizes, shapes and colour of the tubers, taste, nutritional value, maturity period, yield, resistance to pests and diseases and leaf structure.

Globally the two types of sweet potato are dry–fleshed and moist fleshed (Miller *et.al*, 2003). Popular moist-fleshed varieties include Beauregard, Hernandez, Jewel, Caroline Ruby, Cordner, Porto Rico 198 and White Delight. In Fiji, nine varieties are available for cultivation by farmers, although only five of these are commonly eaten.

Table 1.0 Performance of Local Varieties & Selected Introduced Varieties in Fiji

Varieties	Origin	Time to maturity	Tuber skin & flesh colour	Eating quality	Environment susceptibility	Av. Yield t/ha
Honiara	Local	4 months	Purple skin white flesh	Very good	Drought tolerant	22t/ha
Papua	Local	4 months	Purple skin yellow flesh	Excellent	Drought tolerant	20.5t/ha
Kabara	Local	3 months	White skin purple flesh	Excellent	Drought susceptible	15t/ha
Talei	Nigeria	3 months	Purple skin white purple	Very good	Drought tolerant	17t/ha
Carrot	Local	3 months	Orange	Very good	Drought tolerant	15t/ha
Local purple	Local	6 months	White	Very good	Drought tolerant	16t/ha
Bua	Local	4 months	White	Good	Drought susceptible	13t/ha
Korolevu red	Local	3 months	Purple	Very good	Drought tolerant	14.5t/ha
Vulatolu	Local	4 months	White skin white flesh	Very good	Drought tolerant	17.6t/ha
IB/US/18 Beauregard	CIP, Peru	3.5 months	Brown skin orange flesh	Excellent	Drought tolerant	21.8t/ha
IITA/TI/B11	CIP, Peru	3 months	Brown skin light orange flesh	Good	Drought tolerant	16.5t/ha
Costanero	CIP, Peru	4 months	Purple skin orange flesh	Very good	Drought & salt tolerant	12.5t/ha
W 226	CIP, Peru	3 months	Light purple skin yellow flesh	Good	Drought tolerant	12t/ha
AVRDC/CN	CIP, Peru	4 months	Brown skin yellow flesh	Good	Drought tolerant	9.5t/ha
IB/PR/13	CIP, Peru	4 months	Purple skin light orange flesh	Very good	Drought tolerant	10.3t/ha
W222	CIP, Peru	3 months	Brown skin pale orange flesh	Good	Drought tolerant	9.7t/ha

Table 2 Production of Root Crops in Fiji from 2010 - 2016

Crops	2010		2011		2012		2013		2014		2015		2016	
	Prod (Mt)	No. of Farmers	Prod (Mt)	No. of Farmers	Prod (Mt)	No. of Farmers	Prod (Mt)	No. of Farmers	Prod (Mt)	No. of Farmers	Prod (Mt)	No. of Farmers	Prod (Mt)	No. of Farmers
Cassava	51,716	31,940	69,819	26,707	36,267	15,391	74,239	25,725	77,721	32,956	74,612	30,902	63,677	26,463
Taro	61,138	30,801	67,197	26,562	60,000	16,750	87,044	23,406	62,748	24,141	60,928	26,677	38,379	30,213
Xanthosoma	2,261	14,079	6,571	12,825	3,721	3,388	5,888	4,854	3,596	4,188	3,772	3,053	5,447	3,820
Sweet Potato	7,464	10,410	7,053	14,473	7,851	7,438	8,546	4,969	8,581	6,887	8,364	4,766	7,724	5,046
Yams	1,700	12,317	5,933	10,061	5,026	2,387	4,976	2,087	5,474	2,612	5,197	1,212	3,512	1,842
Kava	2,786	17,859	2,175	12,677	3,102	12,177	3,733	11,368	3,871	10,918	6,443	13,845	7,595	10,896
Grand Total	**129,383**	**117,735**	**161,339**	**103,723**	**119,296**	**57,741**	**190,334**	**72,516**	**167,544**	**81,778**	**165,424**	**80,604**	**132,882**	**79,162**

Source: Economic Planning and Statistics, MOA Fiji 2016

The data shows the trend of root crops production for seven years from 2010 – 2016. The amount of sweet potato produced in Fiji is relatively small compared to major root crops such as taro and cassava. Most of the sweet potato produced in Fiji is sold in local municipal markets and consumed locally.

The Ministry of Agriculture in Fiji recommends that land preparation to start as early as March – April and planting of sweet potato to commence at the start of the cool season in May. Sweet potatoes grow best in loamy soils. The best soil types are well-drained, fine sandy, or clay loams. Light, loamy soils usually result in roots with better shapes than those grown in heavy or clay soils, which results in rough, irregular roots. Avoid soil with high nitrogen, as this will encourage more vine production and less storage tuber production. Two production systems are common in Fiji: at subsistence level, the use of mounds at 80 cm between rows and 40 cm between plants and in semi-commercial to commercial farming, sweet potatoes are planted on ridges using the spacing of 1 m between rows and 0.4 m between plants.

Fig. 2 Mechanized production
Fig. 3 Traditional production using mounds

3.0 Marketing of Sweet Potato

Most of the sweet potato produced in Fiji is sold locally at municipal markets. A total of 5,308 kg of sweet potato was exported from Fiji in 2011 to countries such as Nauru, Kiribati and Tuvalu. A small amount of sweet potato was imported from 2013 - 2016 mostly from New Zealand, Hong Kong and China by Flour Mills of Fiji (FMF). FMF was testing some varieties from these countries and is looking at processing low sugar sweet potatoes for chips. Figure 1.0 showed that Fiji produces an average of fewer than 10,000 tonnes of sweet potato annually.

Other prospects for markets is available in Fiji such as the Air Terminal Services (ATS), hotels in Nadi and Sigatoka areas and restaurants to promote coloured varieties of sweet potato to ensure if this can be captured in the local menus. Few producers in Nadi, for example, the Nawaka Youth Project, grew the carrot variety (orange flesh) and this was sold to Castaway Island Resort from 2016 – 2017. The project was badly affected by the sweet potato weevil and affected the quality of sweet potato supplied.

The challenge to hotel industries is ensuring consistent production & supply by farmers, good quality sweet potato is produced, good pricing systems for farmers and a suitable variety. For processing and value addition purposes, FMF has indicated the availability of the market for sweet potato chips. The constraint is finding a suitable variety that is of low sugar content. To address this constraint, production, pricing can be negotiated.

4.0 Challenges to Production

Production of sweet potato in Fiji faces a lot of challenges, and these need to be addressed to make this industry viable in Fiji. Some of the challenges for sweet potato in Fiji are lack of policy direction making it a low priority crop compared to other root crops such as taro, cassava and yams. There are prospects to derive relevant policies and industry planning to develop the industry into an agro-based level in Fiji. Sweet potato is a short term crop; it is resilient to cyclone damage and drought, quick turnover and can be grown all year around. Farmers can grow two crops in a year. In addition to this Fiji lacks marketing strategy for sweet potato.

The other production challenges are the lower yields, poor quality tubers, more vegetative growth and high incidence of pest and diseases. This can be caused by some factors discussed below:

Choice of sites for planting & selection of healthy planting materials:
Site selection is very important in any crop development. Sandy loam soil rich in organic matter is ideal for sweet potatoes and the site for its cultivation may be selected accordingly. Heavy clay soils may be avoided for its cultivation. Alluvial soil on the river banks is best for growing sweet potato. Selection of healthy vine cuttings about 30 – 40 cm is recommended. Avoid obtaining vine cuttings towards the base of the plants to avoid the spread of sweet potato weevil and other diseases.

High nitrogen level in the soil:
Soil sampling is recommended for farmers for any crops to be planted. It is best to know the fertility status of the soil before planting. Sweet potato does not produce good quality tubers with soil high in nitrogen level; this encourages vegetative growth and poor storage root formation.

Mono – cropping and lack of intercropping and crop rotation
Sweet potato in Fiji must not be mono – cropped, it should be rotated with crops such as taro, okra or maize. Growing sweet potato on the same piece of land can lead to the build-up of pest and diseases as after sweet potato is harvested, mini tubers and vines remain in the soil and not removed by farmers. This provides an environment for the weevil population to build up awaiting the next crop pf sweet potato.

Pest and disease incidence from sweet potato weevil and scab disease
Sweet potato weevil *Cylas formicarius* is considered to be the most serious pest of sweet potato, with reports of losses ranging from five to more than 80 % (Pestnet, 2017). Losses increase, the longer the crop remains in the ground unharvested. The impact on yield depends to a great extent on the soil and weather. Light sandy soils and low rainfall increases the chances of heavy infestations. There is also evidence that red-fleshed low dry matter varieties are more susceptible to infestation.

Use of traditional varieties and lack of improved varieties
Currently, only five local varieties are commonly grown by farmers. Efforts are underway through research and development on the evaluation of introduced, resilient & high yielding varieties from abroad and trials have been conducted in the north, central and western division of Fiji.

Use of traditional way of growing sweet potato using unrooted vine cuttings:
Sweet potato farmers in Fiji rely solely on the current recommendation on the use of unrooted vine cuttings of about 30 – 40 cm with 4 – 6 nodes. The current practice is outdated and is subject to changes. Research has started in Fiji on the use of sweet potato slips as a source of clean planting materials. The sprouts or slips produced from storage roots prove excellent planting material for commercial farmers worldwide (Khan et al. 2008). Storage roots have some advantages over cuttings: these include, the longer period of storage and, root selection can be from shapes and sizes which better maintain genetic integrity thereby maximising the subsequent crop's potential yield. Slip cuttings from storage roots may be produced from a maximum of six harvests depending upon cultivar, root size and vigour (age) of the bedding storage roots (North Carolina Sweet Potato Commission, 2011).

5.0 New Production Technologies on Sweet Potato

Introduction of resilient and high yielding varieties with nutritional benefits, evaluation of drought-tolerant varieties in the dry zones of Fiji, and development of new cultivation techniques have been experimented in Fiji to improve quantity and quality of production of the sweet potato. . In addition to this, the Australian Centre for International Agricultural Research (ACIAR) funded a regional project through Integrated Crop Management (ICM) for the control of sweet potato weevil in the Pacific. This is to encourage farmers to grow sweet potato as a short term crop.

The new improved production technologies recommended for the farmers in Fiji are described as under: technologies are currently evaluated in Fiji in an effort to change the production systems, enhance resilience, increase productivity, reducing the incidence of pest and diseases, promoting nutritional benefits, product development and developing marketing opportunities.

Production of sweet potato slips as a source of clean planting materials:

Koronivia Research Station and Dobuilevu Research Station in Fiji have worked on the production of sweet potato slips as a source of clean planting materials. Clean tubers free of diseases are carefully selected. The selected tubers shall be of , medium-size of about 10 – 15 cm length and 6 cm width. These can be raised in pots, trays and prepared seedbeds. If using seedbed, tubers can be arranged 6 cm apart and partly covered with soil.

Using slips has a lot of advantages over normal vine cuttings as these can be stored for long periods, seed root selection can be made on size and shape, which better maintains genetic integrity and maximizes the subsequent crop's potential yield. Sprouts or slips can be cut from a seedbed up to four times. Collecting of plant material from a seedbed takes less time than from a commercial crop and helps to minimize the spread of pest and diseases.

Sweet potato slips or sprouts can be grown to a height of 20 – 25 cm within five weeks; this can be either directly planted to prepared mounds and ridges or soaked in water for a week to induce root development and planted. Better root development in sweet potato slips ensures higher yields.

Rooting of sweet potato cuttings before planting:

This is a simpler method that farmers can use; it requires a good healthy selection of vine cuttings from mother plants. Vines can be tied into a bunch of 20s and dipped into buckets, containers, drums containing clean water. Vines need to be upright and soaked in water for up to 1 – 2 weeks until roots start to develop from the nodes. Once the roots have developed, vines are ready for planting.

Transplanting methods – raise seedlings of 1 – 2 node cuttings:

This method can be used by bigger producers, who can afford extra costs on nursery management of sweet potato seedlings. This method requires the use of 1 – 2 node cuttings from the sweet potato vines. The best portion of the planting materials is 35 cm from the apex of the vine. Sweet potato varieties come in different internode specifications, some varieties have thick and short internodes, and other varieties have long and thin internodes. For short internodes, 1 - 2 node cuttings can be used, while 1 node cutting for long internode varieties. Seedlings can be raised for 2 months in the nursery as this will ensure that good selection is carried out before transplanting.

Plant Variety Selection:

It is vital to properly select good characteristics of sweet potato varieties for suitable conditions in Fiji. Farmers and extension staff are trained on the understanding of the various characteristics of sweet potato that suits certain conditions. Varieties come in various specifications: spreading and erect types, short and long internodes, thin and thicker vines, arrangement of tubers at harvest and other growth characteristics. Sweet potato varieties with short and thick internodes and erect types are suitable for the wet zones, while the long and thin internodes and spreading types for the dryzones. A variety with good harvesting index of 0.5 and above is recommended for planting. Harvesting index (HI) is the ratio of the total vine weight plus total tuber weight upon the tuber weight. HI indicates how the plant converts nutrients into tuber development. A lower HI indicates low tuber development and more vegetative growth.

6.0 Conclusions

Sweet potato is resilient to adverse weather conditions, has a short duration, possesses nutritional benefits and can be processed into various value-added products. These characteristics make it an ideal crop for Fiji. The production problems have been addressed by the introduction of new improved varieties and development of improved cultivation technologies. Changing the production system in Fiji and the development of market access requires a holistic approach between all stakeholders in the industry. New improved production technologies currently developed are a way forward that will contribute to the enhanced production of sweet potato in Fiji.

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RESEARCH PAPER

Vermiculture for Sustainable Agricultural Development in Fiji Islands

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ABSTRACT:
Vermiculture employ earthworms for decomposition of organic waste for production of organic manure. The importance of earthworms is known since time immemorial and it is considered natural plough by the farmers. Earthworms are one of the most important fauna of agro-ecosystems which dominate the biomass of invertebrates in many soils of temperate and tropical regions of the world. The benefits are now globally realized that earthworms can contribute much to the management of different pedo-ecosystems. They are useful in land reclamation, soil improvement and organic waste management in addition to their use as a protein-rich source of animal feed. Earthworms eat and mix large amount of soil or in burrows, depending upon the species concerned. Their casts contain high concentration of organic material, silt, clay and cations such as iron, calcium, magnesium and potassium. Earthworms also release nitrogen in to soil in their casts and urine. Earthworms change the physical characteristics of soil by aerating during rain or irrigation. Earthworms thus enhance incorporation and decomposition of organic matter, increase soil aggregate, improve porosity and water infiltration and increase microbial activity.

Vermiculture may be a boon for Fiji which is a small Island nation located in the South Pacific, 3000 km east of Australia and 1930 km south of the equator. It is endowed with excellent climate which is very much suitable for vermicomposting. The land and climate of Fiji are very good for growing horticultural crops such as vegetables and fruits. Fiji farmers use imported chemical fertilizers which is costly resulting farming as an expensive venture. The export market for organically produced crops is increasing worldwide providing excellent opportunity to the farmers to use organic manure produced locally. To meet the farmers' demands of organic manure there is a vast scope of Vermiculture. The availability of plenty amount of plant biomass, number of suitable earthworm species and excellent tropical climate are in favor of simple Vermiculture technology. The products of vermicomposting such as earthworms, vermicompost and worm meal benefit the farmers by enriching the soil fertility, reducing the use of imported chemical fertilizers and the organically produced crops fetch higher price in the national and international markets. The use of worm meal as a cheap source of poultry, fish and pig feed value the farmers who rely on the costly animal feed mostly imported from foreign countries. This paper deals with various aspects and components of Vermiculture technology and suggests measures for successful implementation under Fiji condition.

Key Words: Vermiculture, earthworm, pedo-ecosystem, Island

Introduction

Earthworms are one of the most important fauna of agro-ecosystems and they dominate the biomass of invertebrates in many soils of temperate and tropical regions of the world. The importance of earthworm was realized by Aristotle about 2,350 years ago when he said, "Earthworms are intestines of the earth." During the twentieth century this statement has been verified and found correct. More than hundred years ago, Darwin (1881) realized the value of earthworms and he stated that "No other creature has contributed to building of earth as earthworm." The benefits are now globally realized that earthworms can contribute much to the management of different pedo-ecosystems. They are useful in land reclamation, soil improvement and organic waste management in addition to their use as a protein-rich source of animal feed.

The studies made during 20th century on various aspects of earthworm have made it possible to use earthworms at commercial scale to convert organic wastes in an ecologically safe method that leads to an environmentally safe product (Chaulagain *et. al.,* 2017). The importance of organic farming and sustainable agriculture world over have escalated the implication of Vermiculture many folds. Vermiculture and vermicomposting are very narrowly related. Vermiculture is the raising and production of earthworms and their by-products while vermicomposting is the use of earthworms to convert organic waste into fertilizer. Vermiculture is basically the science of breeding and raising earthworms. It defines the thrilling potential for waste reduction, fertilizer production, as well as an assortment of possible uses for the future (Entre Pinoys, 2010). The process of composting organic wastes through domesticated earthworms under controlled conditions is called Vermicomposting (Nath, 2006). Composting with worms avoids the needless disposal of vegetative food wastes and enjoys the benefits of high quality compost. This is a nutrient rich organic substance that can be added to soil to increase its organic matter content and available nutrients. The demand for vermicompost is ever increasing by the organic farmers which are to be supplied locally for use in the organic farms in various countries.

Worldwide, organic agriculture is growing rapidly, with international retail sales of over US$ 46 billion in 2007, doubling the 2002 market value (Mapusua, 2009). Organics is the fastest growing sector in the global food industry and holds a big potential for agriculture in the Pacific. The Fiji Organic Association (FOA), established in 2006, is a non-profit organization that provides guidance on organic farming practices in Fiji. The number of islands of Fiji such as Taveuni, Cicia etc. has launched a novel business in organic produce that could prove to be a template for other developing communities around the world. Some of these islands declared their farming as chemical free and fully organic and are now producing food that's attracting the interest of foreign buyers. Currently Fiji is exporting organically produced fruit, fruit juices, herbs, spices, noni products, vanilla and virgin coconut oil to Australia, New Zealand, New Caledonia, USA, UK etc. The steadily growing consumer demand for organic commodities provides a viable opportunity for Pacific Island Countries (PICs) farmers and processors to benefit from this expanding international market. However, the development of the organic sector requires selected material inputs for use in farming and specific policy and institutional standards in order to meet international market requirements. Though the PICs traditional farming practices are very much in line with organic agriculture practices as even today many communities still have agriculture systems based on 'age-old' practices which ensure environmental integrity and do not use chemical inputs. But for commercial production of these products for export to overseas markets as 'organic' they must be certified and sufficient in quantity to meet the market demand. One of the very important inputs of organic farming is the organic manure which is required in large quantity for application in the crop fields to achieve higher yield potential of various crops. Vermiculture may be a viable alternative to produce vermicompost in large quantities to meet the demands of organic farmers of Fiji. This paper outlines the Vermiculture for Sustainable Agricultural Development in Fiji Islands.

Location, Size, and Extent of Fiji

The geographical coordinates of the location of Fiji is 18 00 S and 175 00 E. Fiji is a group of islands or an archipelago situated in the South Pacific Ocean about 4,450 km south west of Hawaii, 1,770 km north of New Zealand and 3000 km east of Australia and approximately 1,930 km south of the equator, comprises some 850 islands, of which only about 110 are inhabited (Fig.1). The Fiji archipelago is a part of the Oceanic group of islands. The island of Rotuma, added to Fiji in 1881, is geographically separate from the main archipelago and has an area of 44 km^2. The total area (including Rotuma) is 18,270 km^2. Fiji (not including Rotuma) extends 595 km south east–north west and 454 km north east–south west. The two largest islands are Viti Levu (Great Fiji), with an area of 10,386 km^2, and Vanua Levu (Great land of the people), with 5,535 km^2, and between the two of them make up 87% of Fiji's total landmass. Fiji's total coastline is 1,129 km.

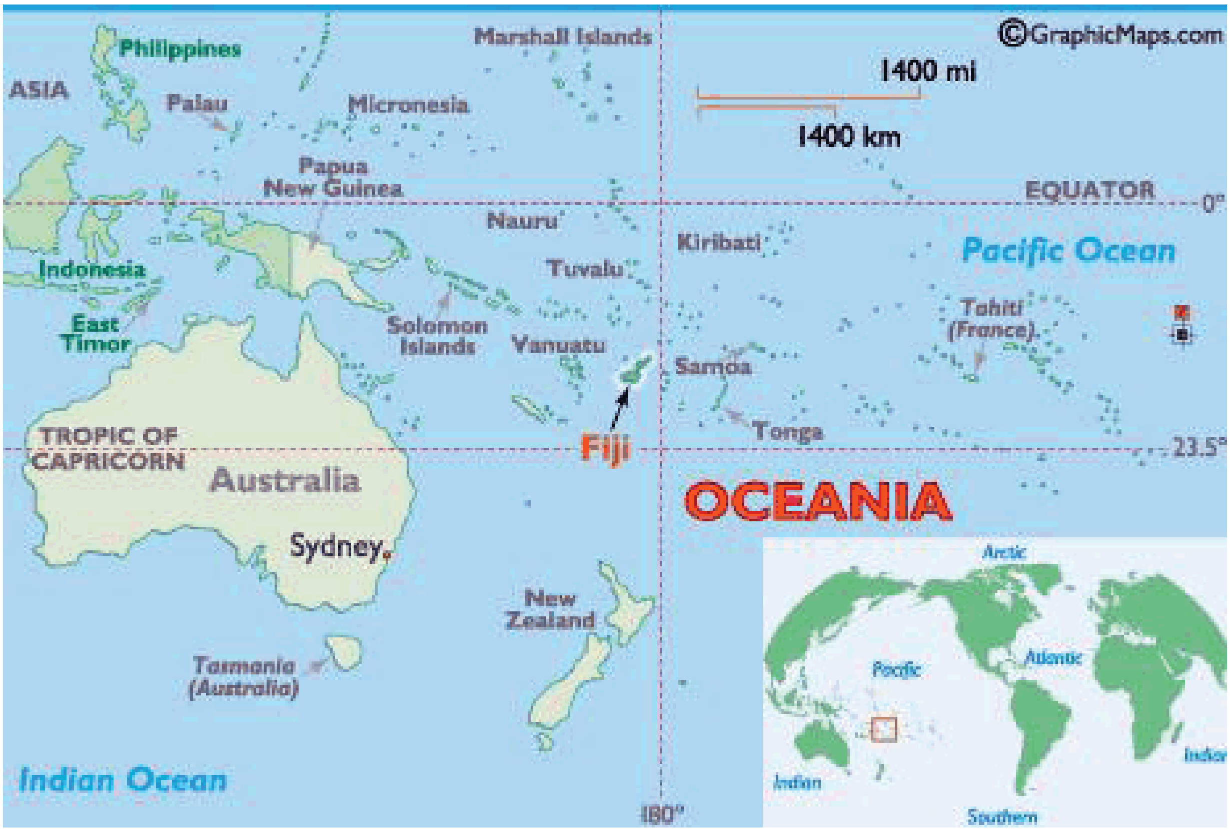


Fig.1. Location of Fiji in Indian Ocean and Oceania. (http://www.mcatoolkit.org/)

Physiography

The physiography of Fiji Islands is illustrated in Fig.1, 2 and 3. The location, latitude, longitude and altitude of Fiji Islands are explained with the help of color pattern. The larger islands were formed due to volcanic activity. The comparatively smaller ones are made of coral reefs and thus unsuitable for habitation. There are about 1000 small rivers in Fiji; the largest is Rewa River in Viti Levu which is around 128 km. Mount Tomanivi, located on the main island of Viti Levu, is the highest point at 1,324 m, and the lowest point is the Pacific Ocean (0 m).

These mountainous islands were formed around 150 million years ago through volcanic activity, and are subsequently covered in thick tropical forests. Most of Fiji's mountains are dormant or extinct volcanoes. The mountainous rugged relief of Fiji makes agriculture difficult in Fiji. So the economy depends on the resources from the forest and the surrounding water bodies. Perhaps what Fiji is most famous for, however, are its crystal clear waters, coral reefs and white sand beaches that draw in thousands annually.

Fig.2: Location of FijiIslands in Oceania and Pacific Ocean showing low, hilly and mountain ranges with the help of colour pattern.

Topography

The larger Fiji islands are volcanic, with rugged peaks and flatland where rivers have built deltas. Coral reefs surround the islands. Viti Levu's highest point, Tomanivi, is 1,323 m.About 28 other peaks are over 910 m. The lowest point is at sea level (Pacific Ocean). The main river, the Rewa, is about 150 km long, but only navigable by small boats for 113 km (Fig.3).

Environment

The main challenges to the environment in Fiji are deforestation, soil erosion, and pollution. Approximately 30% of Fiji's forests have been eliminated by commercial interests. The rainfall pattern, the location of agricultural areas, and inadequate agricultural methods contribute to the loss of valuable soils. Fiji is also concerned about rising sea levels attributed to global warming caused by the burning of fossil fuels in the industrial world. The land and water supply are polluted by pesticides and chemicals used in the sugar and fish processing industries. The nation has about 28.76 cu km(6.9 cu mi) of water with roughly 60% used for farming purposes and 20% used for industrial activity.

the island's unspoiled landscape, reefs, and waters, as well as indigenous flora and fauna. According to a 2006 report issued by the International Union for Conservation of Nature and Natural Resources (IUCN), threatened species included 5 types of mammals, 13 species of birds, 6 types of reptiles, 1 species of amphibian, 8 species of fish, 2 types of mollusks, and 66 species of plants. Threatened species included the Fiji banded iguana and crested iguana, the Fiji petrel, the insular flying fox, and the Samoan flying fox. The bar-winged rail has become extinct.

Climate

Fiji's climate is warm and tropical year-round, even in the islands' "winter" months with gentle trade winds tempering the heat and humidity. It enjoys a tropical climate, with warm dry winters and

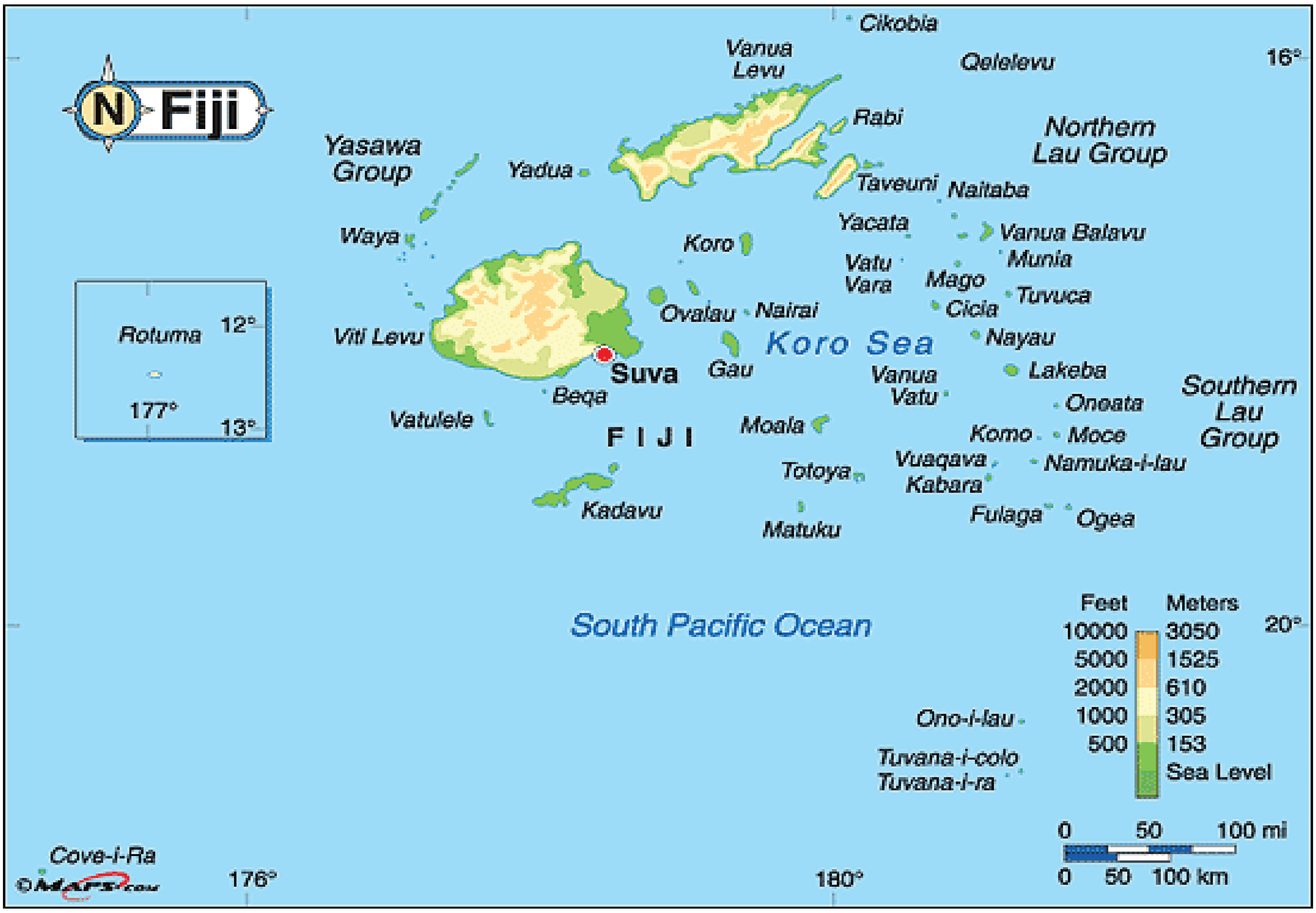
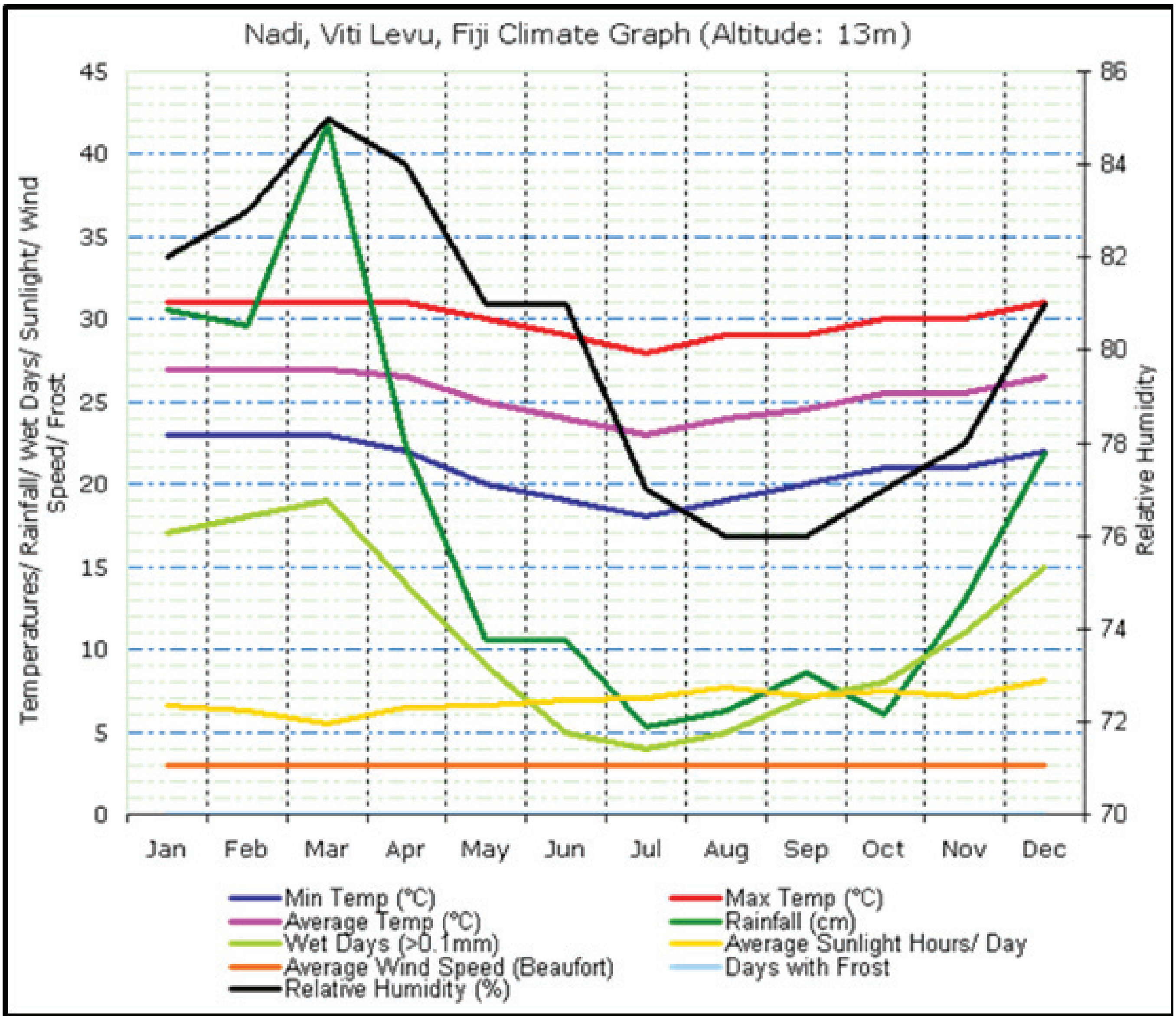


Fig.3. Distribution and topography of Fiji Islands in South Pacific Ocean showing latitude, longitude and altitude with the help of colour pattern.

Fiji's natural environment is protected by the National Trust, which under the 1981–85 development plan began to establish national parks to conserve

hot wet summers. Each of the main islands are divided by mountain ranges, and both have a "wet" side to the south and east, and a "dry" side to the north and west. The country has two distinct seasons – a warm wet season from November to April and a cooler dry season from May to October. Fiji seasons are just the opposite of those in the **North-**

ern Hemisphere, as spring is Sept-Nov, summer is Dec-Feb, fall is (Mar-May) and winter is (Jun-Aug). The average amount of rainfall, temperature, amount of sunlight, wind speed, and how much frost Fiji gets is illustrated in Fig.4.



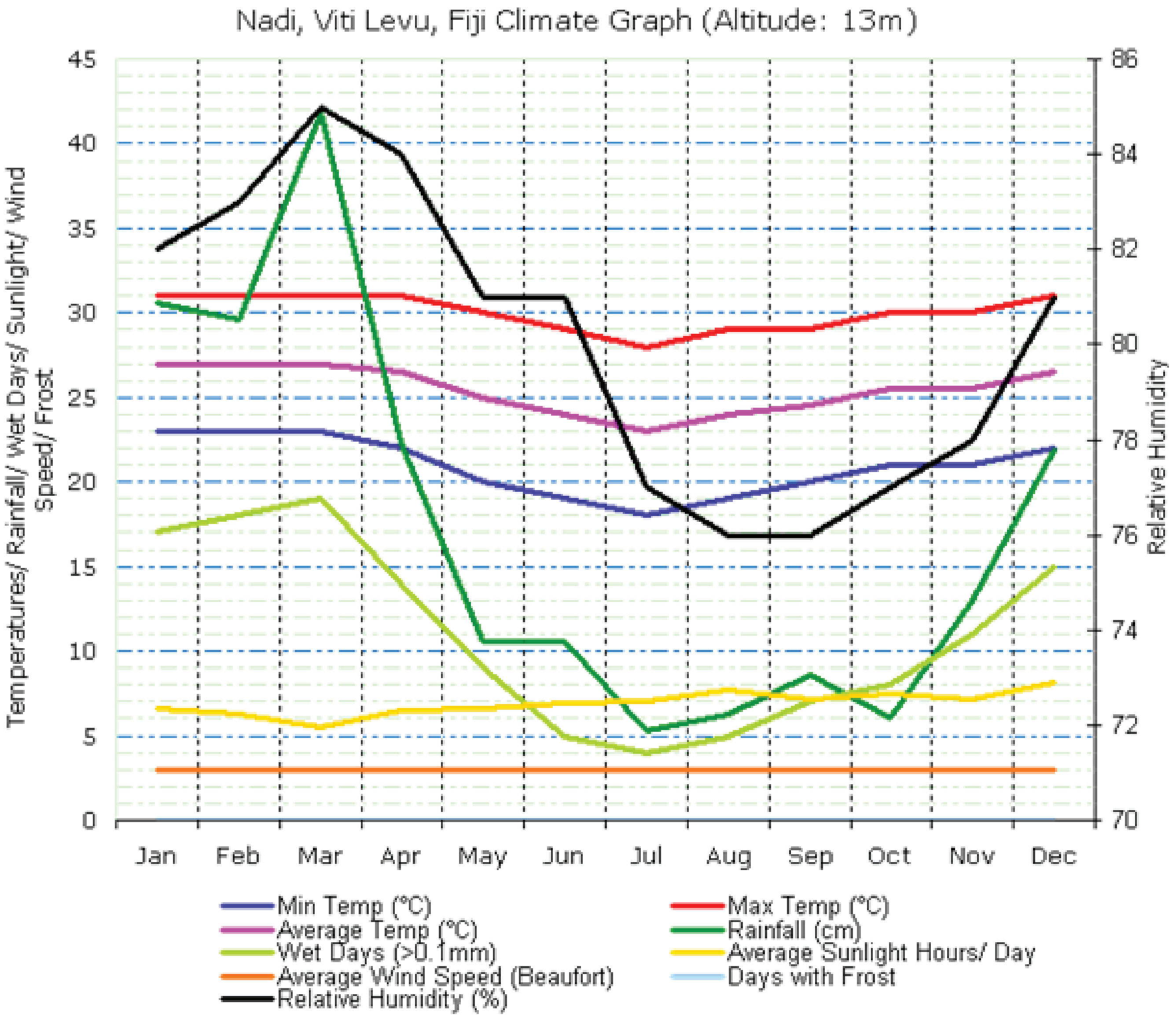
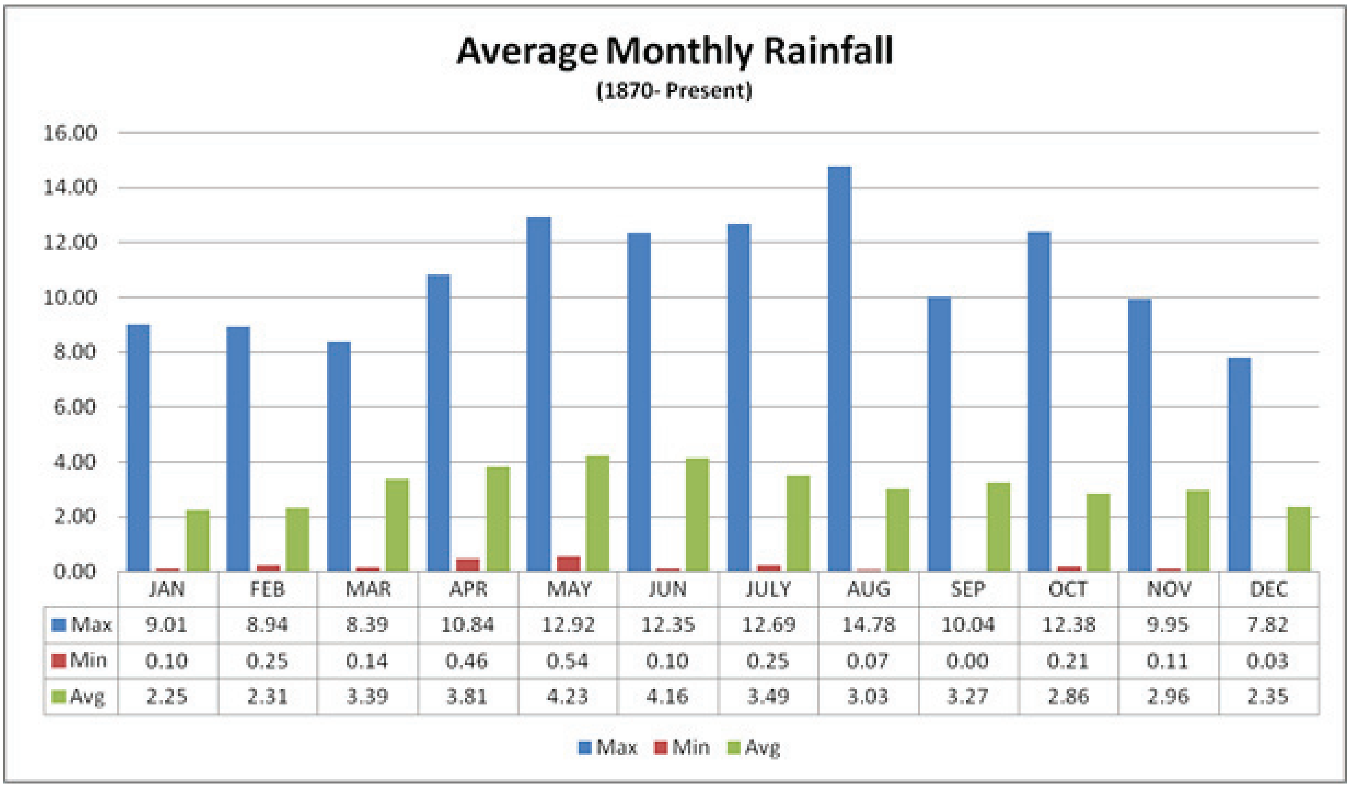


Fig.4. Average monthly meteorological parameters observed at Nadi, Viti Levu, Fiji.

Fiji does have a wet season. The rainy season is normally from November to April and results from the southerly movements of the South Pacific Convergence Zone. The wet season is characterized by heavy, brief local showers and contributes most of Fiji's annual rainfall(Fig.5).



	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Max	9.01	8.94	8.39	10.84	12.92	12.35	12.69	14.78	10.04	12.38	9.95	7.82
Min	0.10	0.25	0.14	0.46	0.54	0.10	0.25	0.07	0.00	0.21	0.11	0.03
Avg	2.25	2.31	3.39	3.81	4.23	4.16	3.49	3.03	3.27	2.86	2.96	2.35

Fig.5.Average monthly rainfall.

Fiji receives 2,540 mm of annual rainfall. Annual rainfall on the main islands is between 2000 mm and 3000 mm on the coast and low lying areas, and up to 6000 mm in the mountains. Typically the smaller islands in Fiji receive less rainfall than the main Island with various amounts according to their location and size, ranging from 1500 mm to 3500 mm. Cyclones do occur in Fiji and are normally confined to wet season. Much of Fiji's rainfall is associated with the movement of the South Pacific Convergence Zone which is closest to Fiji in the wet season. This band of heavy rainfall is caused by air rising over warm water where winds converge, resulting in thunderstorm activity. It extends across the South Pacific Ocean from the Solomon Islands to east of the Cook Islands with its southern edge usually lying near Fiji. Rainfall across Fiji can be highly variable. On Fiji's two main islands, Viti Levu and Vanua Levu, rainfall is strongly influenced by high mountain peaks up to 1300 m. On the southeastern slopes of Viti Levu, near Suva, the average annual rainfall is about 3000 mm. In contrast, the lowlands on the western side of Viti Levu, near Nadi, are sheltered by the mountains and have an annual average rainfall of 1800 mm with a well-defined dry season favourable to crops such as sugar cane. Fiji's climate is also influenced by the trade winds, which blow from the east or south-east. The trade winds bring moisture onshore causing heavy showers in the mountain regions. Fiji's climate varies considerably from year to year due to the El Niño Southern Oscillation. This is a natural climate pattern that occurs across the tropical Pacific Ocean and affects weather around the world. There are two extreme phases of the El Niño Southern Oscillation: El Niño and La Niña. There is also a neutral phase. In Suva, El Niño events tend to bring dry seasons that are drier and cooler than normal, while La Niña events usually bring wetter than normal conditions.

The summer month's maximum temperature averages are about 31°C. The winter month's maximum temperature averages are about 29°C. In the winter temperatures are still very warm during the day! However, the evening breezes can be cool. Temperatures at sea level range from 20–29°c (68–85°f); easterly trade winds blow during the greater part of the year. Around the coast, the average nighttime temperatures can be as low as 18°C and the average maximum day-time temperatures can be as high as 32°C. In the central parts of the main islands, average nighttime temperatures can be as low as 15°C. The average temperature in Fiji is 25°C, but it can climb to above 30°C in summer (December and January) and sink to 18°C in winter (July and August). Maximum temperatures in Fiji rarely move out of the 31C to 26C range all year round.A cooling trade wind blows from the east south-east for most of the year. It usually drops to a whisper in the evening and picks up again by mid-morning.

Fijian winter is the dry season from May to October so outside activities are more pleasant attracting more tourists especially in June and July. Southeast trade winds from March to November bring dry weather and the rainy season runs from December to April. Annual rainfall is well distributed and averages 305 cm in Suva. At sea level on the leeward sides of the islands there are well-defined wet and dry seasons, with a mean annual average of 178 cm of rain. The cyclone season, from November to April, brings storms that generally cause extensive property damage and loss of crops as well as numerous deaths. On average there are 15 cyclones per decade, and two to four actually cause severe damage. They occur from November to April and with greatest frequency in January and February. There is more risk in the outlying northwest island groups.

Flora and Fauna

The larger islands have forests on the windward side and grassland on the leeward slopes. Mangroves and coconut plantations fringe the coasts. Among indigenous fauna are bats, rats, snakes, frogs, lizards, and many species of birds. A red and white flowering plant called the tagimaucia is found only on the banks of the Tagimaucia River in the mountains of Taveuni island.

Origin of Vermiculture Technology:

Vermiculture or Vermifarming, as a commercial practice, was first started by Canadian earthworm collectors in 1950s to meet the market demand of fish bait for fishing hobbyists. It was gradually developed and popularized as an industry, and in 1970 it spread to other countries like Mexico, England, U.S.A. and Japan, for their bait markets. Subsequently it gained recognition in South East Asian countries such as Philippines, Indonesia, Honk Kong, Malaysia and Taiwan with the hope of Dollar earnings (Nath, 2006). Incidentally, worm growers and scientists identified the potentials of earthworms for production of worm meal as a rich source of proteins for animal feed as a supplement to expensive fish meal for animal feed industries. While raising earthworms the worm growers collected large quantities of worm cast or worm excrements. Eventually, they found that earthworms could be cultured on organic wastes, and while doing so, converted large quantities of organic wastes into energy rich resources in the form of worm cast, which they called vermicompost (Nath, 2006). Now the Vermiculture Technology or Vermin-technology is perfected in several countries suiting to the local conditions.

Modern environmentalists, ecologists and zoologists recommended that earthworms can be used to combat environmental pollution. Earthworms have tremendous ability to compost all biodegradable materials. Wastes subjected to earthworm consumption decompose 2-5 times faster than in conventional composting. The organic wastes are de-odorized, pathogenic microorganisms are destroyed and 40-60 % volume reduction takes place during the process of decomposition.

In U.S.A. and U.K. earthworms are also used as stabilizers of sewage sludge and as water purifiers in trickling filters of sewage plants. They are also used in processing potato and Cassava wastes. In India, where fishing is not a recreational hobby, worm culturing was developed in research institutions under research programs. The technology was developed in the 1980s and was released for the first time from the Directorate of Research, U.A.S., Bangalore, in 1984 for public use and the products of the technology were named V-COMP E.83 UAS for vermicompost and V-MEAL P.83 UAS for worm meal.

This technology depends on the feeding, excreting and breeding potentialities of the worms. Fast growing species of worms are voracious feeders and prolific breeders. They are also surface dwellers, organic matter feeder and surface casters. These worms feed on partially decomposed organic matter. Their digestive tracts act as grinding mills converting the wastes into granular aggregates, which are egested as worm cast. It is estimated that the earthworms feed about 4-5 times their own bodyweight of material daily. Thus one kg of worms decomposes approximately 4-5 kg of organic wastes in 24 hours (Nath, 2006).This technology is suited for Indian farmers and can be promoted as an integrated agricultural technology in Fiji, so that Fijian farmers can use the agricultural, animal and plant waste as resource to produce organic manure for their organic farming which is becoming very popular.

Methodology

Selection of earthworm species for Vermiculture

The species of earthworms used in India and other countries and also available in Fiji have the greater possibility of their use for successful vermicomposting. The species of earthworm suitable for Vermiculture is listed in Table 1.

Table 1: Species of earthworms suitable for vermiculture

Family	Fiji Islands	India	Other countries
Moniligastridae	*Drawida barwelli* Beddard	*Drawida willsi*	-
Acanthodrilidae	*Amynthas critics* *A. capulatus* A.*esafatae* Beddard *A. gracillis, A. taitensis*	*Octochaetona surensis* (Michaelsen)	-
Glossoscolecidae	*Panoscolexcorethrunus*		
Eudrilidae	-	*Eudrilus eugeniae* Kinberg	*Eudrilus eugeniae* Kinberg
Lumbricidae	-	*Eisenia foetida* (Savigny)	*Eisenia foetida* (Savigny), *Lumbricus rubellus* Hoffmeister, *Dendrobaenarubida* Stop-Bovitz, *Allolobophorasubur* *Bicunda. chlorotica*
Megascolecidae	*Metaphirehaulleti,* *Perionyx excavates* (Perrier), *Pheretima darnleiensis* Fletcher, *P. Montana,* *P. bicinta, P. godeffroyi,* *P. sedguickisedguicki,* *Polypheretima neglecta* Easton,*P. taprobanae*Easton	*Perionyx excavatus* (Perrier) *Lampito mauritii* Kinberg	*Perionyx excavatus* (Perrier)
Octochaetidae	Dichogaster affinis D. damonis	Dichogaster curgensis Michaelsen	-

Collection of earthworms The earthworms ,*Perionyx excavates* (Perrier), were collected from near the Crop Farm CAFF, FNU, Koronivia. The worms were recovered from the soil by removing the decomposing plant leaves under the tree and the collected earthworms were kept in plastic containers along with soil and carried to the site of vermicomposting for their release in vermicomposting pit.

Composting Materials

The wide varieties of organic materials are recommended for use for composting in India (Nath, 2006). The following types of wastes are available in Fiji which can be used as food for earthworms to produce vermicompost:

Leaf litter of easily available plants such as grasses, kudzu also called Japanese arrowroot (group of leguminous plants in the genus *Pueraria*), crop weeds, fallen leaves of mango, guava, neem, etc. Cattle dung, horse dung, goat and sheep droppings, poultry and duck droppings, etc.

Agricultural wastes such as sugarcane trash, bagasse, banana stems, decomposing vegetables and fruits, coir pith, etc.

Waste paper, waste cardboard, saw dust, rags, etc. Sewage sludge, breweries sludge and biogas sludge, wastes from fruit and vegetable preservation industries.

City refuse, after removing non-degradable materials such as rubber, plastic, glass, metals, stones, etc.

Substrate

Among the various animal excreta cow dung is one of best food for earthworms while among the plant based wastes cut grasses and edible leguminous plant kudzu which are climbing, coiling, and trailing perennial vines and considered invasive and noxious weeds are easily available in plenty allover Fiji. The kudzu plant climbs over trees or shrubs and grows so rapidly that it kills them by heavy shading(Fig.6). The cow dung and cut grasses or chaffed foliage of kudzu are the good substrate for the earthworms in the ratio 1:1 for Vermiculture.

Fig.6. Kudzu (*Pueraria*spp.)- a leguminous vine weed, its flower and pods.

Selection of Site

The suitable place for vermiculture is under the tree shade or inside hut at elevated site which is free from water logging and unexposed to scorching sun light.

Housing

Indoor culturing of worms is recommended to protect the worms from excessive sunlight and rain. They can be raised in abandoned cowsheds, poultry sheds, basements and backyards.

Containers

Earthen pots, cement tanks, plastic trays, plastic tubs and wooden boxes of various sizes can be used for Vermiculture (Fig.7). The depth should be about 30 cm.

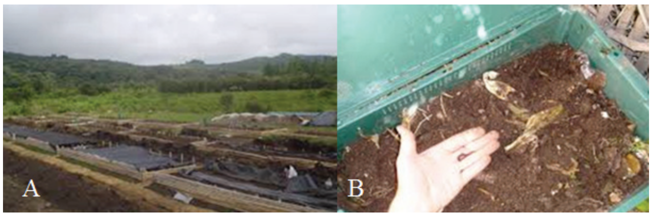


Fig.7. Vermiculture containers: A. Cement tanks for large scale; B. Plastic trays for small scale.

Bedding and feeding materials

Organic wastes of animals such as dung, vegetables and agricultural wastes, leaf litter, banana stems, coir pith, rags, kitchen waste, waste paper etc. can be used.

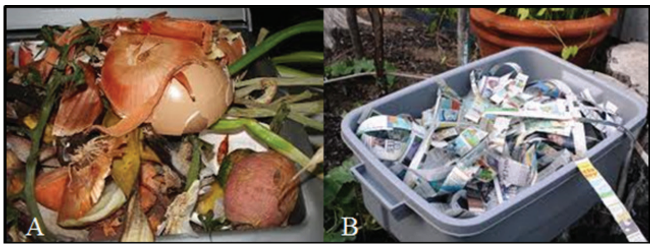


Fig.8. Composting materials: A. Kitchen waste; B. Waste paper.

Preparation of Vermi-beds

The Vermiculture may be started in small scale in the house for the kitchen garden and also in the earthen pits are cemented tanks of variable sizes according to need and availability of space and substrate. It can be done in plastic trays also inside the house with holes in the bottom of the tray for aeration. The previously built and used cemented or plastic Vermiculture beds should be cleaned properly before reuse.

Predigestion of substrate

The earthworms can easily feed and digest soft composting materials. Raw wastes or fresh wastes are not suitable for vermicomposting as earthworms cannot feed on hard food items. Hence predigestion of the raw substrates is essential for the process of composting. All the composting materials are shredded, chaffed or cut into small pieces and properly sprinkled with clean water and thereafter stored in a conical shape covered with thick black polythene sheet for about 2 to 3 weeks based on environmental conditions to ensure partial fermentation to make these soft enough to be fed by earthworms. The predigested partially decomposed substrate serves best food for earthworms.

Substrate Application

The composting materials as substrate are added to the prepared vermi-beds. These materials may be taken as mixture or separately. The care should be taken that no plastic or polythene and iron piece or particle should be mix with the substrates. The earthworms cannot digest the plastic or polythene and the iron will damage their digestive system. A cement tank (1mx1mx0.30 cm) layered with stones for 3cm to let water flow down; overlaid with 500 g of husk to prevent escape of worms followed by 3cm of sand to serve similar purpose and finally covered with the predigested substrate and 2.5 kg of soil mixture. About 1000 ml of water is sprinkled on the surface daily as per the environmental conditions to maintain moisture which is essential for worm growth.

Introducing the earthworms

Sixteen species of earthworm belonging to three families are available in Fiji (Table 1). Among these *Perionyx excavates* (Family: Acanthodrilidae) is a good vermicomposter species which has also been used in India and many other countries successfully. Generally earthworms are introduced 10 days after putting the substrates into the vermi beds. The earthworm is introduced @ 1 kg live weight per 100 kg of substrate in one vermibed to decompose within two weeks. The earthworms have tendency to move downwards. Aerobic decomposition lasts for 7 – 14 days depending on the materials used and the ratio of the earthworms to the substrate. During this period substrate should be moistened (not soggy) regularly to provide the right moisture for the earthworms to grow and multiply.

Fig.8. Earthworms and their introduction in vermi beds.

Process of Vermitechnology

The bedding and feeding materials are mixed, watered and allowed to ferment for about two to three weeks in large cement tanks. During this period the material is overturned three or four times to bring down the temperature of the material and to assist in uniform decomposition. When the material becomes quite soft it is transferred to the culture containers and worms, a few days to a few weeks old, are introduced in to them. A container of 1m x1m x 0.3 m holds about 30 to 40 kg of the bedding and feeding materials. 1000 to 1500 worms are required for processing the material. The material should have 40-50 % moisture, and a pH of 6.8 to 7.5, and may be maintained at 20-30^{0}C. The worms live in the deeper layers of the materials. They actively feed and deposit granular worm cast on the surface of the materials. The worms are allowed to feed on the materials until the entire material is converted into a highly granular mass. Depending on the softness of the material the worms takes about 15-20 days to convert the entire material into vermicompost. The worm takes 7 weeks to reach adulthood. From 8th week onwards they deposit cocoons. A mature worm can produce two cocoons per week, resulting in about 1200-1500 worms per year. The population doubles in about a month's time. Each cocoon produces 3-7 young ones after an incubation period of 5-10 days depending on the species of worms, and environmental condition of the bedding materials.

Recovery of vermicompost and harvesting of worms

The vermicompost is almost ready 45 -60 days after the release of earthworms in the vermibed. This is evident by its physical appearance as judged by the development of the dark brown coloured loose granular mass with uniformly disintegrated structure (Fig.9. A and B).At this time watering is stopped, after one or two days the compost is removed from the cement tank together with the worms, heaped on a plastic sheet and kept in the shade. This involves separation of worms from the cast manually. For this purpose the contents of the containers are dumped on the ground in the form of a conical mound and allowed to stand for about 12 hours (Fig.9.B). Most of the worms move to the bottom of the mound to avoid light and for shelter.

The worms collect at the bottom in the form of a ball. At this stage, the vermicompost is removed to get the worms while the worms are collected for preparation of worm meal. The vermicompost collected is dried, sieved through a 2 mm sieve to separate the compost (Fig.9.C), young ones and the cocoons. The compost is then packaged; cocoons and young ones are used for seeding of new culture beds. The vermicompost recovered is rich in available macronutrients, organic carbon, enzymes and microbes such as actinomycetes and nitrogen fixers, and is used as organic fertilizer. The partially or un-decomposed materials are again used in the second cycle of vermicomposting.

Fig.9. Vermicompost with earthworms, vermicompost mound and sieved vermicompost for packaging.

Advantages of Vermiculture and Vermicomposting

Vermiculture and vermicomposting is one of the most valuable ecological endeavors we have engaged in as it caters not only environmental protection but also helped to produce vermicompost to replace chemical fertilizer and a cheap source of animal protein to substitute fish meal. Vermiculture is eco-friendly since earthworms feed on anything that is biodegradable, vermicomposting then partially aids in the garbage disposal problems. No imported inputs required, worms are now locally available and the materials for feeding are abundant in the locality as market wastes, grasses, used papers and farm wastes. It is also highly profitable, both the worms and castings are saleable (www.bpi.da.gov.ph, 2010).

Vermicompost does not have any adverse effect on soil, plant and environment. It improves soil aeration and texture thereby reducing soil compaction. It improves water retention capacity of soil because of its high organic matter content. It also promotes better root growth and nutrient absorption and improves nutrient status of soil, both macro-nutrients and micro-nutrients (Punjab State Council for Science and Technology, 2010).

Precautions for Vermiculture and Vermicomposting

Vermiculturists should also be aware of the several precautions in doing such process to ensure that the project would turn out successful and fruitful. From our hands-on experiences, vermicompost pit should be protected from direct sun light so that the earthworm would survive. Direct heat possibly causes the worms to die. Spray water on the pit as when required to maintain moisture level because vermi worms are fond of it. We should also protect the worms from ant, rat, bird and excessive rain.

Conclusions

The Vermiculture and vermicomposting activity is a worthwhile and exciting venture. The outcome of vermicomposting is concluded as below:

1. Vermiculture is a substantial way of reducing wastes, producing fertilizers and maintaining the balance of the ecological environment;
2. Vermicomposting can produce high-quality fertilizers which are better compared to other commercial fertilizers in the market;
3. Vermiculture converts farm wastes into organic fertilizer, making it an environment-friendly technology;
4. Vermiculture increases crop yield and lessens dependence on chemical fertilizers thus mitigating

climate change;

5. Vermiculture can be made into a livelihood program and become a source of extra income through selling the vermicast and also the earthworms;

6. Taking worms out of their natural environment and placing them in the vermi beds creates a human responsibility. They are living creatures with their own unique needs, so it is important to create and maintain a healthy habitat for them to do their work. If the right ingredients are supplied and care is taken, earthworms will thrive and make compost for ecofriendly and sustainable farming.

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SHORT NOTE

Economically Important Curcuma Species in the Fiji Islands

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ABSTRACT

The genus Curcuma belongs to the family Zingiberaceae has 93 species distributed in tropical and subtropical regions of the world, out of which few are economically useful. The true turmeric (Curcuma longa L.) is an important member of the genus naturalized in Fiji. Presence of two more species namely Curcuma amada Roxb., and Curcuma aeruginosa Roxb. are recorded in Fiji Islands. Curcuma amada is called 'White turmeric' or 'Mango Ginger'. True turmeric and Mango Ginger are exported from Fiji to Australia, America etc.,. All the three species can be easily distinguished by their rhizome inner colours, true turmeric has yellow to orange colour, mango ginger has white to light yellow colour and fresh cut rhizomes have the flavour and the colour of tender mango and Curcuma aeruginosa has bluish-green colour. All the three are used in food preparation and medicine.

Keywords: Curcuma, Curcuma longa, Curcuma amada, Curcuma aeruginosa, mango ginger, turmeric, true turmeric, white turmeric.

INTRODUCTION

Curcuma is an important genus in the family Zingiberaceae. Various species have been used medicinally, as a yellow dye for cloth, and as spices for flavoring and coloring food since time immemorial. Its generic name originated from the Arabic word kurkum meaning "yellow," and most likely refers to the deep yellow rhizome color of the true turmeric (Curcuma longa L.). Besides C. longa, there are several species of economic importance as medicine, such as Curcuma aromatica Salisb., Curcuma amada Roxb., Curcuma caesia Roxb., Curcuma aeruginosa Roxb., and Curcuma zanthorrhiza Roxb.. Others are beautiful and splendid plants of great ornamental value, such as Curcuma alismatifolia Gagnep., Curcuma elata Roxb., and Curcuma roscoeana Wall. Locals and tribal people in most Asian countries use Curcuma species in religious rituals, as a foodstuff, and as medicinal plants (Skornickova et al. 2007a). There are 93 species belong to Curcuma genus is available in the world now (WFO 2020). It is found throughout south and south-east Asia with a few species extending to China, Australia and the South Pacific (Skornickova et al. 2007b). The highest diversity is concentrated in India (over 40 species -Velayudhan et al. 1999; Sasikumar 2005) and Thailand (38 species - Sirirugsa et al. 2007). Sasikumar (2005) reported that Curcuma species exhibit inter- and intra-specific variations for the biologically active principles coupled with morphological variations with respect to the above-ground vegetative and floral characters as well as the below-ground rhizome features besides for curcumin, oleoresin and essential oil contents. The Pacific Bulbs Society (PBS 2020) has listed around 15 Curcuma species which are mainly grown for their foliage and flower.

Curcuma is gaining importance world over as a potential source of new drug(s) to combat a variety of ailments as the species contain molecules credited with anti-inflammatory, hypocholestraemic, choleratic, antimicrobial, insect repellent, antirheumatic, antifibrotic, antivenomous, antiviral, antidiabetic, antihepatotoxic as well as anticancerous properties. Turmeric oil is also used in aromatherapy and in the perfume industry. Though the traditional Indian Ayurvedic system of medicine and Chinese medicine long ago recognized the medicinal property of turmeric in its crude form, the last few decades have witnessed extensive research interests in the biological activity and pharmacological actions of Curcuma, especially the cultivated species. Turmeric powder obtained from rhizomes of Curcuma longa or related species is extensively used as a spice, food preservative and colouring material, in religious applications as well as a household remedy for bilary and hepatic disorders, anorexia, diabetic wounds, rheumatism and sinusitis in India, China and South-East Asia and in folk medicine. Cucuminoids, the biologically active principles from Curcuma, promise a potential role in the control of rheumatism, carcinogenesis and oxidative stress-related pathogenesis. Curcuma longa L. syn. Curcuma domestica Val., true or common turmeric, is the most economically valuable member of the genus. In Fiji, during field survey 2019-2020, the following species are recorded.

CURCUMA SPECIES OF FIJI

Curcuma longa L.

In Fiji, Seemann (1862, 1869), Silas (1938), Parham (1939) and Smith (1979) have recorded only one species of Curcuma i.e., true or common turmeric (Curcuma longa L.). The exact details of introduction to Fiji is not known, but it was introduced in Pacific before the arrivals of British and Indian (Ritsuko and Reid 2007). Parham (1939) has noted that Avea - More often spoken of as cago, by natives, and as turmeric by Europeans who in early days used the powdered rhizome of the plant in making curry. It has always been much valued by the natives; it is known in its manufactured state as rerenga. An infusion of the root is said to be good for sufferers from bladder trouble, retention of urine and cystatis. Prasad and Singh (1980) have explained the processing of turmeric for the benefit of Fijian farmers. They found that steaming the harvested matured rhizome for 30 minutes and drying at 60°C for 28 hours gave the best-quality turmeric powder. Further they mentioned that turmeric contains volatile oil, fixed oil, resins, proteins, pentosans, starch, cellulose, mineral elements and a characteristic colouring matter called curcumin. It is used for colouring foods, oils, fats and waxes. Turmeric oil is orange-yellow in colour and consists of a mixture of an alicyclic sesquiterpene called turmerone and an aromatic ketone which are present in turmeric to an extent of 3–5 per cent. Turmeric is one of the main ingredients of curry powder and blended spice. Fiji grown turmeric is exported to Australia, New Zealand, USA, etc., Turmeric processing facility for export from Fiji was established at the Namaka Industrial Zone in Nadi by one of the exporters (Fiji Govt., 2020). Though there is a great scope for export of turmeric, still majority of turmeric is harvested wildly and not much organized cultivation. Initiating research on turmeric crop would benefit farmers and exporters and agriculture development in Fiji.

Fig.1. Curcuma longa L. (Plant and rhizome)
Curcuma amada Roxb.

It is native to India, and its common name is Mango Ginger. It is a rhizomatous aromatic herb of the family Zingiberaceae **and is cultivated throughout India, Sri Lanka, Bangladesh and in many South-East Asian countries for its** rhizomes **that are used as** flavouring for pickles and other dishes and also valued for their medicinal properties. This species of Curcuma did not find a place of flora of viti written by both Seemann (1869) and Smith (1979). The fresh as well as dried rhizomes are used for flavouring curries. The fresh cut rhizomes have the flavour and the colour of mango, hence the name mango ginger. The herb attains 60–90 cm height, leaves are long, petiolate, oblong-lanceolate, tapering at both ends, glabrous, green on both sides; flowers are white or pale yellow in spikes that occur in the centre of the leaves, lip is semi-elliptic, yellow, three-lobed, the middle lobe emarginated (Ravindran et al. 2004). The rhizome **of mango** ginger **is a popular spice and vegetable due to its rich** flavour, which is described as sweet with subtle earthy floral and pepper overtones and similar to that of raw mango. It is a delicious addition to salads and stir fries. It is used most commonly, in Thai cooking. In India, it is most widely used in chutneys and pickles. It is prepared for use in cooking like fresh ginger. There is no record or published work on it's introduction into Fiji, but it is also grown and exported. Fiji Farm Management 2014 Budget Manual has mentioned recommended turmeric varieties as white and yellow. The white turmeric variety could be a Mango ginger. Gatty (2009) in his book mentioned that it is an introduced plant to Fiji, it is "ambar" (Hindi) white-fleshed turmeric, used fresh for pickles, especially by Guajarati Indians, or raw in salads as a refreshing ingredient. He also reported that it is grown commercially by Tailevu Fijians and exported by Guajarati. The plant is shorter and flatter than true turmeric. It is also a candidate crop for commercialization in Fiji. It is also called as 'white turmeric'. Mick Vann (2008) has mentioned that people in America gets White Turmeric / Mango Ginger from Fiji.

Similar to Curcuma amada, another species Curcuma mangga Valeton and Zijp has a mango smell in the rhizome is also called Mango Ginger in south East Asian countries and this species not seen in Fiji.

Curcuma aeruginosa Roxb.

Curcuma aeruginosa is one of the oldest named species of the genus, described by William Roxburgh almost 200 years ago. The specific epithet is derived from the striking greenish blue color of the rhizome. It is quite a large and stately plant and can reach almost 2 m. This is a native of Myanmar and distributed to India, Indochina, Malaysia, Indonesia and Ceylon. In Thailand, it is commonly found in the dipterocarp forests and is also cultivated. It is distinguished from other species by its bluish-green rhizome and red corolla-lobes. The rhizome is medicinally used throughout its range of distribution (Sirirugsa et al. 2007). Its leaves have a feather-shaped dark maroon patch in the distal part of the lamina, along the midrib on the adaxial (upper) side. The leaves are glabrous on both sides. Inflorescences appear at the beginning of the rainy season during the first showers, just after the leaves begin to sprout. In South India, the leaves are used for wrapping fresh fish. The leaves are also used to cover inner surface of bamboo baskets where paddy seeds are kept for sprouting prior to sowing, because of the belief that it promotes germination. Also in South India, it is one of the most esteemed species for extracting arrowroot, since it is believed that species with the blue-colored rhizome is of the best value. In Malaysia, it is used medicinally for asthma, cough, and as a paste with coconut oil for dandruff, and in Indonesia as purgative during childbirth. The species is distributed from India and the Andaman Islands to Cambodia, Malaysia, and Java (Skornickova et al. 2007a). As such there is no common name for this species, some call it as ‘black or blue turmeric’, but actual ‘black turmeric’ is different species. In Fiji, we could see the plant of this species first at Wainadoi, by the side of Queen’s road, second time at Tutu Rural Training Center, Taveuni, it was told that plant brought from Vanua Levu.

Curcuma caesia Roxb. (Commonly called black turmeric) is also has a blue rhizome, but, the color is much brighter and deeper blue than in Curcuma aeruginosa. The leaves have a deep red-violet patch, which runs throughout the whole lamina. Curcuma caesia is not seen in Fiji.

CONCLUSION

In conclusion, in Fiji, there are two more Curcuma species namely, Curcuma amada and *Curcuma aeruginosa* aside, from the commonly known species, Curcuma longa are available. The efforts to collect and conserve these species, study on systematics, crop improvement and chemical quality will be useful.

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Fig. 2. Curcuma amada Roxb. (Plant and Rhizome)

Fig.3. Curcuma aeruginosa Roxb. (Plant and rhizome)

Fig. 4. Inner rhizome colour for three Curcuma species Curcuma longa L., 2. Curcuma amada Roxb., 3. Curcuma aeruginosa Roxb.

Short Note

Preliminary Survey of Sugarcane Grubs In Lautoka And Rarawai Mill Area In Fiji

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Abstract

Sugarcane grub has been a long-standing insignificant pest for the Fijian sugar industry with limited research done in the past; last being nearly a century ago.

The grubs are larvae of Melolonthinae belonging to Order Coleoptera in the Scarabaeidae Family (Veitch R. , 1922). They feed on the roots of sugarcane plants ultimately drying the shoots and leaving patches in the fields, thus, resulting in decreased yields. A preliminary survey was conducted in the two mill regions to investigate the incidence of the pest. Active method of survey was practised whereby quadrants (1m x 1m) were used. Approximately 30-40 cm depth of soil was dug out and made friable while searching for eggs, grubs, pupae and adults. Fifteen farms were randomly selected from every sugar producing district in the Viti Levu.

Grubs collected were reared in the Entomology Laboratory at the Sugar Research Institute of Fiji for further studies, a few were placed in vials and sent for species identification. This paper seeks to highlight the infestation levels through the survey data collected in 2015 and 2016.

Keywords: Sugarcane grubs, Infestation, Fiji.

Introduction

Cane grubs were initially found in a farm in Lomolomo, Drasa, causing drying of stools in patches in young cane. Later in the year, a general survey was carried out in the two mill areas in Viti Levu that included 26 Sectors. The cane grubs were identified as Rhopaea vestita, Rhopaea subnitida and Adoretus versutus belonging to Order: Coleoptera, Family: Scarabaeidae

The grubs are "C" shape, soft bodied, dark brown sclerotized head, whitish body, greyish back with three pairs of legs. The cane grub has four developmental stages namely: eggs, larva (grub), pupa and adult (beetle). The larval stage has three phases: 1^{st}, 2^{nd} and 3^{rd} instars out of which the 3^{rd} instar causes significant damage to cane. The grub burrows into the soil and dwells at 30-40 cm depth. The 1^{st} instar has fast movements while the 2^{nd} and 3^{rd} instar exhibit sluggish movements. The 3^{rd} instar feeds on the roots of sugarcane plants leaving characteristic symptoms; patches in the fields, as well as yellowing of leaves and dried stools that looked as that of a parched field. The grubs destroy the root system resulting in a chain reaction: damage of vascular bundles causes the plants to disrupt the uptake of moisture from the soil, leading to stunted growth or death of stools. The affected plant roots turn black and the spindle wilted. The affected clumps are easily pulled out.

The adults are lazy flyers and can be found underground, as well as on trees feeding on leaves. They lay eggs which are white in colour at 20 to 40 cm soil depths however past observations by Colonial Sugar Refinery (Colonial Sugar Refinery, 1924) showed that trash conservation is a deterrent for oviposition. Sugarcane grubs have been reported from many sugar producing countries, such as Australia (Sallam, 2010), Reunion Island (CIRAD, 2016), certain African nations as well as Indian Ocean Islands (Conlong & Ganeshan, 2016).

Materials and Methods

A survey was conducted in 26 sectors of the two sugarcane mill regions; Lautoka and Ba (Rarawai) mill in Viti Levu. Fifteen farms were randomly selected from each sector except Drasa Sector where few farms were chosen with the history of grub damage.

Active method of collection was adopted whereby 10 quadrants, 1m x1m, were randomly placed in the field, approximately 30-40 cm of soil/roots underneath the stools, that were within the quadrant were dug. Soil and roots were inspected for eggs, larvae, pupae and adult beetles.

Grubs found were placed in a plastic container with soil from the surrounding, and later brought to the Entomology laboratory and mixed with peat moss. These cane grubs were reared in the laboratory for further studies. Many of the grubs shrivelled and died. It was observed that the grubs were susceptible to mites. Those that were able to develop normally were studied and a few were sent for species identification to Mauritius (MSIRI) and Australia (SRA).

Passive method of collection, light trapping, was also carried out for a month in the initial stages, however, this method of collection was later shelved due to practical reasons.

Results and Discussion

The cane grubs did not cause an extensive damage in the sugarcane fields, with an exception of two farms in Drasa, where the cane production was reduced due to non-germination and drying of young stools due to grub feeding activities.

The overall population of the cane grub was very less as indicated in figure 2 above, however, a risk of sudden outbreak in the coming years is a possibility due to their life cycle and favourable conditions. Unlike Robert Veitch's reports in the 1920's (Veitch R. , 1922), there was no infestation of cane grubs in Sigatoka. This may be due to the large extent of farming in those days as well as to the current industrialization and shift from sugarcane to other cash crops and tobacco farming.

***The Lautoka mill area excluded the Qeleloa sector.**

***The Rarawai mill area survey did not include: Yaladro, Malau, and Nanuku sector.**

As mentioned by Robert Veitch (Veitch R. , 1922) frequently a species is either so scarce or so little given to attacking living plant tissue that its presence exercises practically no effect on the crops, and indeed such a species is usually noticed by entomological investigators only; on the other hand certain species sometimes occur in such numbers and are so destructive to the underground portion of the plant that they are included among the most serious enemies of the agriculturist.

Conclusion

It can be concluded from this survey that the existing cane grub population is not significant in a holistic view, however, more research will be done, such as frequent ploughing of infested fields to expose many of the grubs to predation by mynah birds. (Veitch R. , 1919), to minimize the losses incurred in the highly infested fields and study the species of grubs found in different localities. Plans are in place to survey the infested farms again to ascertain the seasonal population fluctuations of the grubs and any possibilities of its spread to neighboring farms.

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SHORT NOTE

Rhinoceros Beetle Rapid Damage Assessment and Remedial Actions Implemented – Taveuni

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Abstract

A Rapid Damage Assessment (RDA) of coconut rhinoceros beetle (*Oryctes rhinoceros*) (CRB) damage to coconut palms on the island of Taveuni, Fiji, was conducted in January 2017. Digital photographs, logged with GPS, were taken from the main roads and tracks through coconut growing areas of Taveuni and subsequently sorted into categories of damage (Zero, Low, Medium and High). Thirty-five percent of images showed palms with medium or high levels of damage. Damage was mapped using GPS tags and Picasa 3 software. Analysis showed that evidence of damage was distributed throughout the island, but medium and high damage occurred principally in zones in the North, South West and South of the island. The survey provided a baseline for the level of damage on Taveuni to identify areas to focus remediation activities and monitor changes to protect emerging coconut industries.

Keywords: Coconut rhinoceros beetle (*Oryctes rhinoceros*), CRB, Taveuni, Rapid Damage Assessment,

1.0 INTRODUCTION

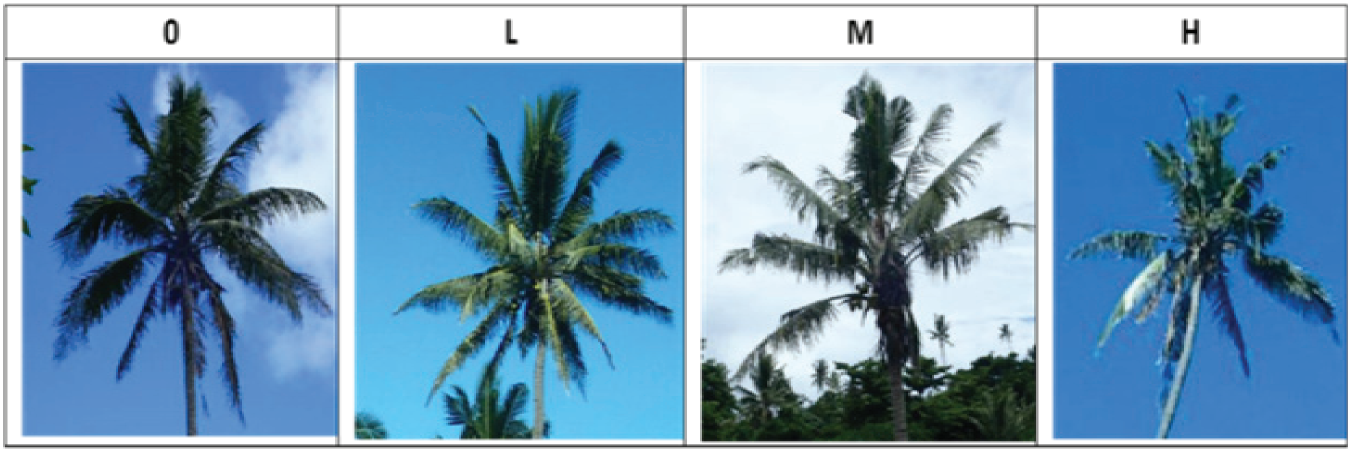
The development of processing systems and markets for virgin coconut oil provides a new opportunity for coconut producers in the Pacific islands (McGregor and Sheehy 2017). However, the destruction caused by Cyclone Winston in 2016 resulted in loss of production of coconut oil through dropping of nuts and damage to fronds. In the worst cases, the tops were blown from the palms or the palm stems had been snapped. Palms began to recover after the cyclone, but the rotting trunks and organic debris provided breeding sites and a source of food for larvae of the coconut rhinoceros beetle (*Oryctes rhinoceros*) (Bedford 2013).

Fig 1. Life stages of the coconut rhinoceros beetle (larva pupa and adult).

The Fijian island of Taveuni is an important centre for production of coconuts but was badly affected by the cyclone. High densities of larvae were found in decaying coconut trunks in some areas and it was expected that beetles would start to emerge from these sites in the next months.

Damage to the coconut palm is caused by the adult beetle boring into the growing point of the palm. This results in a characteristic cutting of the emergent fronds giving a tattered appearance of the palm crown (Fig 2) easily distinguished from other causes (such as stick insects or cyclone).

A Rapid Damage Assessment survey was organised to identify areas of the island with high damage from the beetles, raise awareness of the beetle problem and allow the Plant Protection team of the Ministry of Agriculture to plan for trapping beetles, clean-up of breeding sites and introduction of biocontrols where necessary to reduce the impact of the emergent population.



Scale Categorisation	
0	No CRB damage symptom evident
L	Light damage, notching or tip damage < 10% foliar damage
M	Multiple fronds affected, notching and breakage. 10 - 30% foliar loss
H	Multiple fronds affected with significant notching and breakage. >30% foliar damage

Figure 3. Example of Rapid Damage Assessment Scale

Fig 2. Rhinoceros beetle damage to coconut palm

MATERIALS AND METHODS

The Rapid Damage Assessment survey was carried in the island of Taveuni from January 25 to January 28, 2017. Digital photographs were taken from the road and tracks around Taveuni (from the moving vehicle or stationary observation spots) to capture images of the crown(s) of coconut palms to determine levels of damage caused by CRB. An Olympus TG4 camera was used with settings of Automatic, High Quality (image 4608x3456 pixels, 2.9 MB) and GPS label. Images were viewed on a computer screen and those not showing clearly the crown of the palms were rejected. A master file of all acceptable photographs was assembled and damage categorised according to the following scale based on the worst affected palm in the frame. A data base of 548 photographs from the survey is held at AgResearch. (Jackson – Pacific Biocontrol/Cyclone Winston/Damage Assessment/Taveuni Jan 2017). Palm trees in the photographs were graded for damage into four categories (Zero, Low, Medium, High), according to the damage scale below (Fig. 3).

Only palms where the crown could be clearly visualised were assessed and the grading was given according to palm with the highest level of damage in the image.

The survey covered the main coconut growing areas accessible from the road network. Damage was mapped onto the template of Taveuni using GPS tags on the photograph and Picasa 3 software.

RESULTS AND DISCUSSION

3.1 *Damage severity and distribution*

The survey showed that CRB damage was widespread in Taveuni with 90% of images showing some evidence of CRB damage. However, most palms (65%) were recorded with zero or light damage whereas medium and heavy damage was recorded on 35% of the palms (Table 1).

Table 1: Grading and Percentage of Palm Damage

Grading	Number of Palms	%
0	54	10
L	296	55
M	150	28
H	38	7

Mapping of each of the CRB damage grading categories onto the map of Taveuni (Fig 4) showed that damage was distributed around the island, but medium and high damage occurred principally in zones in the North, South West and South of the island.

3.2 Damage type

Damage was evident on old fronds as well as the emerging fronds providing evidence of beetle presence and attack prior to the cyclone. There was no indication of severe attack to the emerging fronds at the time of the survey, but this may occur after emergence of the next generation of beetles developing in the cyclone debris. Heavy damage to young palm replants was recorded in the South of the island.

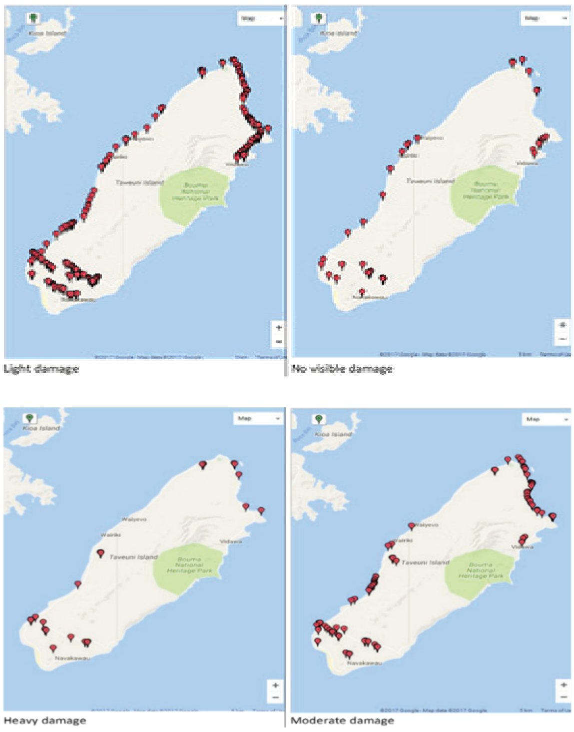


Fig 4. Distribution of CRB damage categories on Taveuni

3.3 *Remedial Actions Implemented*

A CRB management plan was initiated with 11 sites at risk from CRB selected. Awareness trainings on the proper management practices for CRB were conducted to 122 farmers at Mua, Vione, Qila, Vidawa, Navakacoa, Qali, Waitabu, Vunivasa estate, Wainiyaku estate, Delaivuna and Vuna. Posters and factsheets on 'Management of Coconut beetles' were distributed to farmers as additional information to assist them in managing the beetle and clearing of CRB breeding sites. Dead standing palms and decaying palm stems on the ground were cleared with the assistance of the farmers where 163 CRB of different stages were collected. Furthermore, new pheromone bucket traps were installed around these 11 sites while 7 virus ground traps were constructed in which 35 beetles were inoculated with virus and released into these prepared ground traps at Salialevu, Wainiyaku estate, Waitabu, Vione and Mua.

CONCLUSION AND RECOMMENDATION

The Rapid Damage Assessment and photographic analysis allowed main damaged areas to be defined quickly and allowed targeting of remediation activities in the worst affected areas. The survey also provided a baseline for CRB damage on Taveuni and a reference point for assessing the consequences of Cyclone Winston on the CRB population growth and the effectiveness of remedial actions. Implementation of a CRB management plan with monitoring of CRB by pheromone traps and damage surveys can minimise the impact of the pest on the emerging new coconut industries. Regular monitoring of CRB populations will also enable a rapid response to the damaging CRB-G strain which has invaded some Pacific Islands (Marshall et al 2017).

Fig 5. Main coconut growing areas on Taveuni damaged by CRB.

ACKNOWLEDGEMENT

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SHORT NOTE

Efficacy of three Glyphosate 36% on Merremia peltata

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ABSTRACT

Merremia peltata (L.) Merr, is a hostile plant that smothers plants covering most of the canopy layer inhibiting plant growth. It thrives under maximum exposure to sunlight and is commonly found in open forest, roadsides and hill ranges. However, it is difficult to eradicate. The trial to determine the efficacy of three Glyphosate herbicides commonly used by farmers in Fiji (Supremo, Weedmaster and Glyphosate 360) on M. peltata was conducted at Wainivesi Tailevu Province. The M. peltata plants were slashed prior to application of treatments. All plots treated with Glyphosate achieved 100% control at 3 months after treatment. Therefore slashing and application of Glyphosate 36% at 10mL/L is recommended for the control of M. peltata.

Key words: Merremia peltata, Glyphosate 36%, herbicide efficacy, Wainivesi, Tailevu Fiji

Introduction

Merremia peltata (L.) Merr (hereafter Merremia vine) belongs to the family Convolvulaceae and is native to Africa and tropical Asian countries (Indonesia, Malaysia, the Philippines and northern Queensland, Australia). It is widely distributed throughout South East Asia and the Pacific (Waterhouse and Norris 1987). With developing environmental concerns of Merremia vine, the invasive status of this species is still quite illusionary because of its origin in the Pacific. Merremia vine as climber plant requires full sunlight to grow vigorously and with any silviculture practice that reduces light availability can inhibit the aggressive growth of Merremia vine (Waterhouse and Norris 1987).

In the regions of Polynesia and Micronesia, Meremia vine has the capability of smothering trees up to 20 m in height and is of high abundance (Paynter et al. 2006). On ecological disturbed land caused by tropical cyclone and shifting cultivation Merremia vine becomes locally abundant and weedy (Kirkham- 2005; Paynter et al. 2006). Meremia vine has been accounted for one of the 24 serious weed targets for biology control exploitation in Pacific island countries and territory (Paynter et al. 2006).

In Fiji, Merremia vine was first reported as an invasive weed of agriculture in Fiji when it was found on banana plantations in 1970 (Paynter et al. 2006). In Fiji Merremia vine occurs from sea level to about 400m in forest and forest edges, on open hillsides and along roadsides. A study on cost benefit analysis on Merremia vine in eastern Viti Levu found that in 28 out of 30 villages, 42% of the respondents reported that Merremia vine contributed to the decline in the agricultural output (Daigneault et al. 2013).

The control options of Merremia vine is usually by physical and chemical means. Chemical control (herbicide application) using 2, 4-D dicamba, triclopyr, picloram and glyphosate have been reported to control Merremia vine in some Pacific Island countries (Maturin 2014; Miller 1982). However, no research has been undertaken in Fiji to determine the efficacy of these herbicides on Merremia vine. Thus this study to determine the efficacy of three commonly used glyphosate by farmers in Fiji on Merremia vine.

Materials and Method

Study site- A Merremia vine infested site was selected at Wainivesi, Tailevu Province. There were four treatments tested and replicated four times.

Herbicide application technique- Merremia vine - in each plot were slashed (Fig. 1A) and sprayed (Fig. 1B) with three glyphosate herbicides; Supremo (Hextar Chemicals SDN. BHD – Hoptiy Ltd), Weedmaster and Glyphosate (SUNJO AGRO). The herbicide application rate used for all treatments was 10ml/L water. Herbicide efficacy was assessed at four (4), eight (8) and twelve (12) weeks after application of treatments.

Figures 1A and 1B. Merremia peltata study site at Wainivesi, Tailevu. 1A) Slashing of Merremia vine in infested field. 1B). Application of herbicide after slashing of Merremia vine.

Results and Discussion

The three glyphosate herbicides, Supremo, Weedmaster and Glyphosate were very efficient in controlling Meremia vine after slashing the vines. The Merremia vines were eradicated (Fig. 2). Glyphosate 360 as systematic herbicide was more efficient through slashing technique whereby the herbicides were absorb quickly in plants and at one (1) month interval discoloration of plants were observed. The control treatment in final assessment had 80-90% regrowth after slashing indicating the vegetative growth potential of Merremia vine.

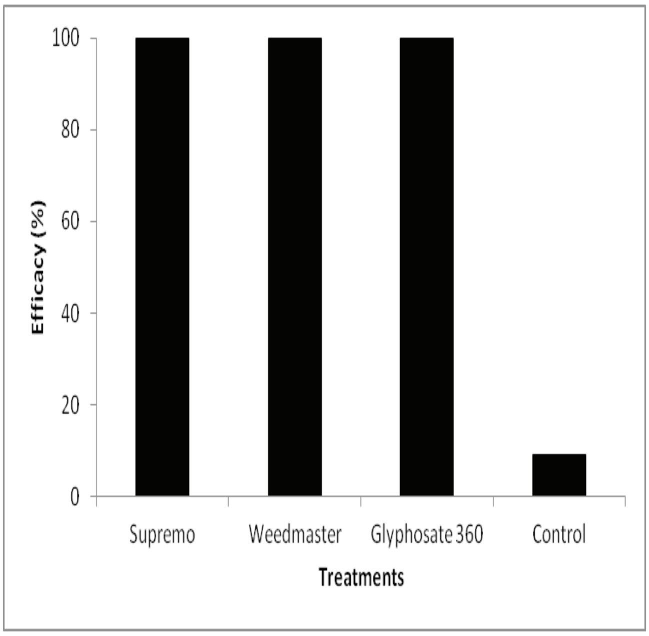

Figure 2. Mean herbicide efficacy (%) at three months after application of treatments at Wainivesi, Tailevu Province.

The management of Merremia vine using chemical application with integrated methods can reduce populations size of Merremia veins by 10% in long run population (Daigneault et al. 2013). A study conducted in the Solomon Islands showed that glyphosate (1.5kg a.i./ha) controlled Merremia vine (Miller 1982). In another study conducted in Vanuatu, Weedmaster (active ingredient 360g/L glyphosate) was also proven to be effective in controlling Merremia vine. However, in this study the herbicide was injected in the main veins relative to diameter at breast height at different levels of dosage instead of spraying (Maturin 2014). The 10ml injection (50:50water) of Weedmaster was most efficient for it was cheaper and less harmful to the environment (Maturin 2014).

Therefore, the current study has demonstrated that Merremia vine in Fiji is effectively controlled by slashing and immediately apply glyphosate 36% at the rate of 10ml/L water.

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RESEARCH PAPERS

Production and Marketing Constraints of Sugarcane (*Saccharum officinarum* L.) in Fiji Islands

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ABSTRACT

Sugarcane is one of Fiji's leading crops in generating foreign revenue and a major source of income for the farmers in western and northern half of the country. Topping the country's export market list for years, sugarcane has displayed some major downfalls at certain years of its production. Currently all the sugarcane operations from supplying farmers planting materials, harvesting aids to local distribution of sugar and export is managed by The Fiji Sugar Corporation Ltd. This Sugarcane Industry plays a vital role towards Fiji's economy and contributes 2.9 percent of GDP and generates about 16 percent of total exports with foreign earnings totaling at $187 million in 2009. Climate change stands as a major threat, which increases the biodiversity of pests and diseases through which the country loses millions of dollars every year and hence the local and international markets are affected. This paper will discuss some of the important constraints apart from climate change, which are the major factors leading to downfall of the Sugar Industry in Fiji.

Key words: Fiji, Sugarcane, South Pacific, Climate, Constraints

1. Introduction

Sugarcane has been the backbone of Fiji, and is part of various historic events for generations. Sugarcane is thought to be indigenous to the country and the South Pacific, and it is certain that several varieties of sugarcane were obtained from this origin. Early European settlers were the first to discover sugarcane, upon which they encountered that Fijians only consumed sugarcane through mastication for juice and sweetening food. First crystallized sugar production in Fiji was made in 1862, on the Island of Wakaya by Mr. David Whippy. Upon its emergence since then, in 1870 sugar displaced copra and took over as the country's main export commodity and has held the position to this day.

During the development of the industry around 35 sugar factories were established, out of which only four remain today. It was certain that early planters mistook the general prospect of wet zones for fertility and due to which all the early development took place in wet zones of Fiji, spreading outwards from Suva to Levuka. Due to unfamiliarity, the importance of sunlight and lack of knowledge, these established industries faced poor drainage issues and hence were unable to produce the required sugar content. It was for these reasons that many of the earlier sugar enterprises were short- lived.
In and before the mid-1980s Fiji was regarded internationally as an efficient producer and reliable supplier of high quality sugar. Later report submitted in 1991 by Landell Mills Commodities Studies displaced the early statement by tagging Fiji amongst the lowest in terms of key performance indicators such as cane yield per hectare, sugar yield per hectare, tonnes of cane to tonnes of sugar ratio, and sugar produced per tonne of milling capacity as highlighted by (Reddy, 2009).

Currently, the Sugar Industry and Farming sector of Fiji needs greater attention as it is experiencing different forms of survival pressure. These obstacles are encountered in form of growth and production deterioration factors, fluctuating cane repayments and information of other constraints, which will be discussed in this paper.

2. Production

Fiji comprises two major Islands Viti Levu and Vanua Levu on which sugarcane farming is mostly practiced. Sugarcane is currently grown in the Northern and Western dry zones of Fiji. Comprising a total of 4 cane crushing mills, out of which 3 in Viti Levu (Western) and 1 in Vanua Levu (Northern). About 22,000 farmers currently produce around 4 million tonnes of cane on just under 100,000 ha (74,000 ha harvested annually over past 4 years). Initially sugarcane was grown only on estates, but since the early twenties all growers land leases were returned to Colonial Sugar Refining Company (CSR) and developed into a successful (10 acre) tenant farm system still functioning today.

Cane production is almost entirely rainfed, and yields are subject to wide annual fluctuations depending on weather conditions. Average national cane yield as per the latest Sugarcane production statistics for years 2007- 2016 (FSC Annual Report.,2017), indicates that the country's sugarcane industry stands at a collapsing stage.

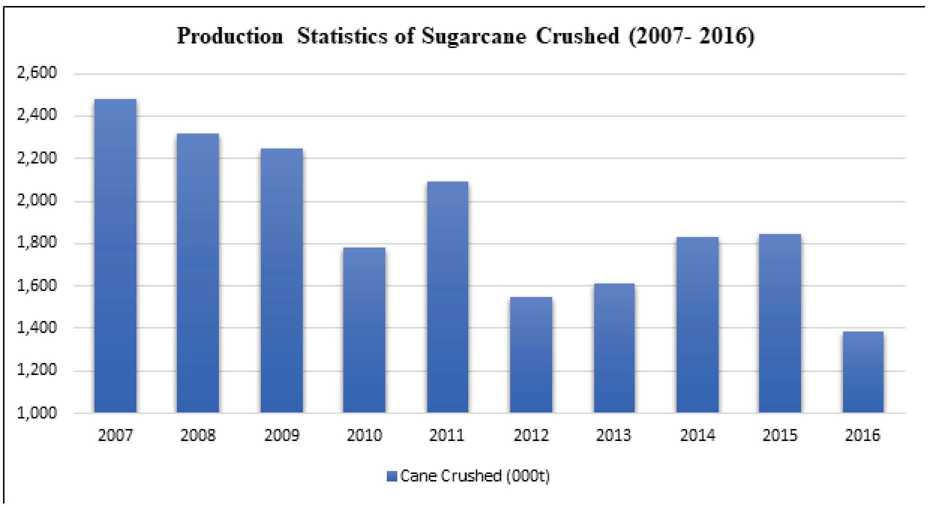

Figure.1: Graph representing total tonnes of Sugarcane crushed from years 2007- 2016. **Source:** FSC Annual Report, 2017

3. Constraints

3.1 Natural Disasters

Fiji is a tropical country and has been experiencing very devastating natural disasters over the past 10 years. Disasters are encountered in forms of cyclones, flooding and drought. It has been continuing suffering for both farmers, and the sugar industry. One of the major downfalls of sugarcane crushing in 2010, 2011, 2013 and 2016 were due to some very devastating disaster seasons. These recent climatic conditions have not only affected the sugarcane industries, but has also downgraded Fiji's agricultural advancement in the international markets. Sugarcane harvesting season starts from late May and continues till early December. In the process of reaching towards completion of its harvesting season, sugarcane starts to experience the early effects of Fiji's cyclone season, as the cyclone season in Fiji starts from November and continues till April.

Tropical Cyclone Winston in 2016 completely ruined the agricultural sector of Fiji. According to local media sources it cost the Industry a total of $167 million (US$80 million) loss (Fiji Times, 2017). Losses to crops, infrastructure and mills were recorded in the aftermath of Severe Tropical Cyclone Winston and flooding associated with tropical depression 04F. Damages were caused to mills, research facilities, houses, farms, transportation infrastructure and over 45% (19,000 ha) of crop damages in all the sectors of Rarawai, Penang and two sectors in Lautoka. Heavy flooding also resulted from TD04 and caused a total of $3.5m (US$1.7 million) damage in Tavua and Rakiraki cane farming areas of the country.

3.2 Insect Pests and Diseases

Insect pests and diseases are considered to have been one of the major problems associated with destruction of cane fields and hence been a major threat resulting declined production of sugarcane not only in Fiji, but throughout the world in leading sugar producing countries. Major insect pest affecting growth of sugarcane in Fiji are Asian Subterranean Termites (AST). Fiji has a total of 14 termite species out of which thirteen has been regarded as endemic to Fiji and one species, Asian Subterranean Termite *(Coptotermes gestroi*) has been causing major distress to the western half of Viti levu and isbelieved to be entered the country through shipping vessels travelling in from Asian countries (Chand et.al., 2018). Fiji experienced termite outbreak in late 2009 to early 2010 (Biosecurity Fiji, 2014). Termites have been continuously affecting growth and production of sugarcane in western region of Fiji and has significantly contributing towards collapsing of Fijian sugar industry. According to Fiji Sun news source farmers in Lautoka experienced huge downfall in sugarcane production in year 2014 with a particular farmer experiencing a loss of close to 100 tons (Nasilasila, 2014). In 2018, 15 farmers in Buabua-Qalitu area of Lautoka were affected due to increasing termite infestations and alongside the cane fields the termites have also been damaging the housing infrastructure of this farmers (Chambers and Gopal, 2019).

Another insect pests affecting sugarcane production are cane grubs. Cane grubs are larvae of sugarcane beetle borer (*Rhabdocnemis obscura*) (Veitch, 2009). This weevil is associated with effects of damaging cane roots and generally destroying whole vegetation. Infested stalks result in extensive sugar content lose and fall down to the ground, where they root again and disturb row sequencing and growth of other sugarcane plants (Veitch, 2009). Among the diseases, the most harmful disease is Fiji Disease Virus (FDV). FDV causes a disease of considerable economic importance which has been responsible for major losses of sugarcane in both Fiji and Australia. Major symptoms included abnormal leaf color and forms, stem galls, witches' broom, and eventually whole plant dwarfing. Red rot is one of the other diseases found in the cane field of Fiji. Major symptoms include stalks becoming discolored and hollow, development of acervuli (black fruiting bodies) on rind and nodes, reddening of the internal tissues with intermingled transverse white spots. During rainy seasons, these diseases exceed its economic threshold and have the ability to spread faster and dry the crop, out of which not a single malleable cane can be obtained.

Poor Management and Infrastructure Development for Cane Field

Poor farm management practices are one of the other issues that spoils the quality of cane supplied to the mills. Due to lack of laborer's farmers are unable to control excessive weed growths, fertilizer application, other cultural practices and hence plant growth gets affected. Farmers in western parts of Viti Levu tend to get in laborers from outer islands of the South Pacific. Upon their arrival, the farmers are to provide them with food, shelter and give them wages. Eventually the cost of farm maintenance increases and despite all demands of the laborers farmer's expectations are not met. Over the last 10 years the number of cane cutter total has declined rapidly. The major reason for this change is due to introduction of cane harvesting machines which creates a form of uncertainty amongst gang members and hence increases cost of production. The plotted graph represents a decreasing shift of cane cutters from years 2007 – 2016.

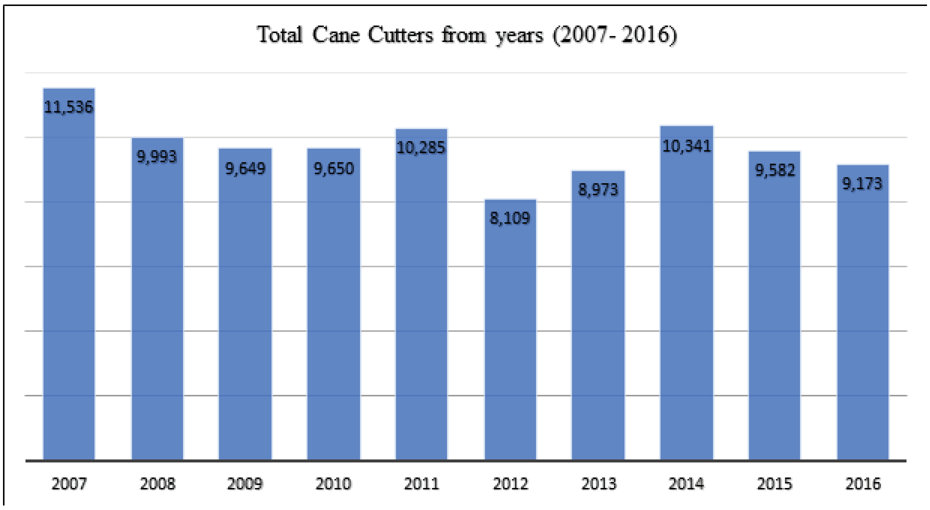

Figure: 2. Graph Representing Total Number of Cane Cutters for years 2007-2016.
Source: FSC Annual Report, 2017.

Sugarcane farms located in Rakiraki are at higher elevations and require better road access to transport cane to the mills. Due to poor infrastructure development farmers find it very challenging to hire sugarcane trucks for transporting sugarcane and getting the advantage of sugarcane researchers access to the fields to improve productivity. Project launched by the Secretariat of Pacific Community - European Union (SPC-EU)) June, 2017. Titled: Rural Access Roads and Associated Infrastructure (RARAI), benefited a minimum of 1000 people in the three sugarcane sectors of Viti Levu (Malolo, Drasa and Koronubu). Major aim of this EUR13 million project was to improve watershed management, drainage rehabilitation and road condition of these three main sugarcane farming sectors of Viti Levu. Introduction of projects as such allows the farmers to become more confident and expand their farm as major huddles preventing the production of sugarcane have been improved.

Cane Burning

Cane burning has been regarded as a disaster by the industry today. Main concern identified in this strategic plan relates to the practice of burning cane prior to its harvesting. This practice has been increasing rapidly through centuries of cane production in Fiji.
The combined effect of coordination problems, failure to abide strictly by the terms of the harvesting plan, transportation and milling disruptions and the fact that maximum cane is cut manually rather than mechanically is that the elapsed time from cutting to crushing is high and burnt can is unloaded to mills (Davis,1998).

In the context of sugar production in Fiji, burning is undoubtedly a major source of avoidable inefficiency, affecting both the costs of production and the potential incomes of all those stakeholders whose livelihood comes directly from sugar earnings or indirectly from economic activities sustained by the spending of sugar revenues.

In Fiji the burning of cane may be deliberate or accidental. Estimated burning of over 95% was deemed to be deliberately during the years of 1900's, the residual 5% being attributable to lighting, carelessness or neighborly sabotage (which is, of course, also deliberate). Some of the deliberate burnings are initiated by the harvesting gangs belonging to a particular sector. Given the very low incidence of accidental burning, no grave sin would be committed by assuming the analytical convenience, that all burning is deliberate.

In the past 10 years starting from 2007, the sugarcane industry has seen some major oscillations on cane burning. In 2016 cane burning exploited the market, where the cane burning percentage increased up to 57%. Graph illustrated below shows the total percentage of cane burnt from 2007-2016.

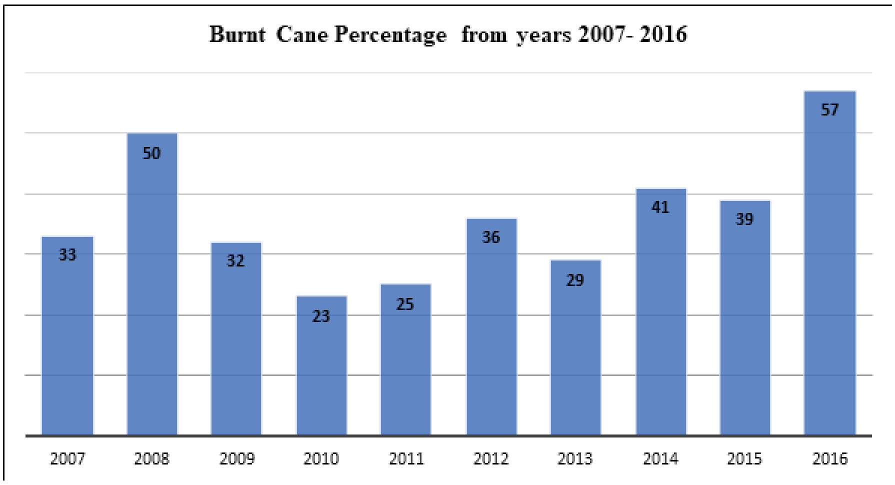

Figure: 3. Graph representing Total Burnt Cane Percentage from years 2007- 2016.
Source: FSC Annual Report, 2017.

Mill Breakdown

Mill breakdowns are thus regarded as one of the normal situations in the sugarcane industry. This breakdown accounts for major delay in cane crushing and creates frustration amongst farmers and lorry drivers. It not only contributes toward decreasing cane production status of the country, but also plays a major role in decreased revenue of a farmer. Most often it is seen that delay in cane crushing due to mill breakdowns leads to left over sugarcane in fields as the mill reaches towards its closing stage.

Mill breakdowns proved to be a major problem for lorry drivers. During mill breakdowns lorry drivers face poor sanitation issues, insufficient meals, and exposure to mosquitoes. This year's crushing season experienced some major mill breakdown issues, according to local media sources (Fiji Times dated 28th July, 2018). More than 260 lorry drivers queued up at the Lautoka mill yard, some waiting for 3 days. Frustration vented after the factory suffered its fourth mechanical breakdown within just over two weeks. These kinds of breakdowns affect the total turnover of lorry's and hence affects the wages of the drivers. All these issues turn to raise different sorts of conclusions, which creates conflicts between FSC staff, cane lorry drivers and farmers.

Consequently, a new penalty was announced later by the government to accommodate the loss of time and revenue, where the farmers could now claim a penalty of $5 a ton of affected cane in an event of mill breakdowns. While announcing the new penalty to aid farmers, Fiji Sugar Corporation (FSC) Chief Executive Officer, Graham Clark concluded the amount would be determined and paid after a thorough assessment of the breakdown.

Land Lease Issues

After years of hard work and determination some farmers tend to switch their farming career or immigrate. Farmers are getting crippled due to non-renewal of land leases. As expiration of land lease nears it creates fear amongst every farmer on whether their lease will be renewed or they have to find other alternatives. The sugar industry has experienced a lot of farmers leaving and looking for other sources to cater their livelihood over past years. Since the expiration of the very first leases in year 1997 thousands of Indo- Fijian tenants have lost their land and livelihood. In year 2000, Fiji saw hundreds of farmers being evicted from their lands on which they had regarded as their home for more than half a century. The farmers saw no hope for their families in the sugar industry and the government could not help them as it was the landowner's decision not to renew the leases.

The resulting insecurity surrounding land tenure has led to falling investor confidence in the industry as a whole. Given the FSC's status as technically insolvent, the lack of investment is an important issue. Another effect is that the younger generation see little incentive to enter the industry. The lack of commitment to cane farming is seen by some as a result of longer- term insecurity (Deverall, E. and Lennon, S. *et al., 2005*).

Lease tenure insecurity has a significant negative impact on productivity and investment in newly planted cane when leases are near expiry. On average, iTaukei tenants with leases expiring in 0–5 years achieve lower productivity, by 6.5-11 tonnes per hectare and make less investment in newly planted cane, by 0.14–0.25 hectares, compared to Freehold and State cultivators.

There are numerous reasons why many leases are not renewed after they have expired. In some cases, it might be that the landowners want to use the land themselves and benefit from the incentives brought in by foreign aids, for example European Union and new government formations after general elections. Other reasons include that landowners are no longer happier with what they receive as a rent for their land. Depending on the quality of the land, annual lease payment usually fluctuates between F$45 – F$480 a hectare. Though it is noticed, to improve the income from their land, the landowners often ask for "good- will payments", a contribution from the farmers to facilitate the renewal of leases, but situations on such a demand is illegal, not rare as it provides an ultimate chance to get the lease renewed at a cost of few thousand dollars extra. In many cases it is concluded as political reasons, mostly during years of general election that causes non-renewal of land leases.

4. Recommendations

Based on research and analysis completed in compilation of this paper, following concerns can be recommended on improving the industry and production status of sugarcane in Fiji:

Have a smart strategic plan to overcome post natural disasters farm problems, where both industry and farmers can benefit in a short time. This can be achieved by proper coordination among government, non-governmental organizations, private sector and sugarcane farmers after natural disaster.

Initiating research on flood tolerant sugarcane varieties and introducing them in flood prone sugarcane belt of the country which may help in sustained sugarcane production.

Standardize mill equipment in accordance to other leading sugar producing countries and initiate staff exchange programs, where staff can develop a better understanding on how to operate and safe guard advanced equipment.

Improve facility developments for lorry drivers outside sugar mills, to accommodate them during heavy que and mill breakdowns. This can be achieved by timely maintenance of sugar mills prior to start of cane crushing season which will improve crushing efficiency of mills and reduce waiting time to unload the cane.

Educating sugarcane farmers on the benefits of green cane harvesting and offering higher payments to such canes. Use of mechanical harvesters provides an opportunity for more green cane harvesting in Fiji with cane trash removed as blanket over roots allowing moisture conservation and weed control in the sugarcane field. Introduce deterrent penalties on intentional cane burning, since it is one of the major issues in decreasing cane purity and has increased in past few years specifying about 50 percent burnt cane crushing in Lautoka mill and around 39.3 percent in the Rarawai and Penang Mill areas in year 2019.

Focus more on improving road access to cane farms in remote areas to encourage more farmers on practicing cane farming and reduce cane wastage and delivery time of cane to mills. All weather cane access roads through rehabilitation works, notably improvement of drainage systems will reduce time and costs to transport cane between their farms and the mill

Solve land lease issues to increase the number of cane farmers and hence improving the production status of sugarcane in Fiji because insecurity arises because of a lack of protection for tenants against the threat of eviction as leases expire. However, tenure security may be strengthened through alternative measures such as providing legal protection to long-term occupants and offering lease extensions; these practices will enhance investments and improve the production efficiency of the sugarcane industry in Fiji.

5. **Conclusion**

Indeed, sugarcane is regarded as the backbone of Fiji's economy and is the major target during natural disasters. Past 10 years of growth and production fluctuation statistics shown according to the latest FSC Annual Report 2017, defined the drifting status of sugarcane production in Fiji. Major issues highlighted have confirmed the reasons behind this struggling journey. Fiji Sugar Corporation with the help of Government has gone out to its very extent in helping farmers and other sugarcane sectors of the country in solving problems faced in regards to cane farming. Though farmers have benefited from government relief funds and foreign aids, major constraints discussed in this paper have really affected the farmers beyond their reach. All this contributes heavily towards decreasing sugar production and increases sugar price locally. Major threat arising is the renewal of land leases, which upon identifying a proper solution can improve the decreasing sugar production status of the country.

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