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A descriptor list for giant swamp taro (*Cyrtosperma merkusii)* and its cultivars in the Federated States of Micronesia

Shiwangni Rao[1], Mary Taylor[2] and Anjeela Jokhan[3]

ABSTRACT

Atoll islands are the diversity hot spots for *Cyrtosperma merkusii* (giant swamp taro) and its traditional knowledge, especially in the Federated States of Micronesia (FSM). In these atoll islands the giant aroid is given high importance in the food, cultural and traditional systems. Despite this, a significant lack of knowledge and threat of salt water intrusion in the face of climate change exists for the aroid. To curb the issue, a classification descriptor list using the taro descriptors IPGRI (1999) and traditional knowledge of the FSM farmers was developed. The descriptor list was then employed to classify the many cultivars present in FSM. The list consisted of 37 morphological traits divided into plant habitat, leaves, petiole, inflorescence, root, corm, taste and special characteristics. Using this descriptor list, 40 distinct FSM cultivars were classified, three of which were unknown to the locals namely: 'PF1', 'Semes rao' and 'Nah'. The results of the classification provided some knowledge of the various cultivars and also showed that diversity did exist within the gene pool of the aroid. With further research and documentation, the diversity that exist within the gene pool of the aroid can be explored and utilized to buffer the impacts of salt water intrusion, while conserving the aroid and building its knowledge base.

Key words: Giant swamp taro, diversity, descriptor, atoll, *Cyrtosperma merkusii*.

INTRODUCTION

There are four types of taro which are normally found in the Pacific, these include the common taro *Colocssia esculenta, Xanthosoma sagittifolium*, *Alocasia macrorrhiza* and the giant swamp taro *Cyrtosperma merkusii (syn. Cyrtosperma chamissonis)*. Of these four types of taro, *Cyrtosperma* is the largest reaching up to 5 meters in height (Dunn, 1976; Iese, 2005; Webb, 2007). It also takes the longest to reach maturity, and is known for its hardy qualities of surviving in atoll environments (Thaman, 2002; Manner, 2009). Giant swamp taro is one of the root crops that have spread across the Pacific reaching as far as the Makatea Island on the northwest of Henderson Island in the Tuamotu Archipelago (Hather, 2000).

Hay (1990) and Lebot (1992) state the origin of the giant aroid to be the high lands of Papua New Guinea, while on the other hand, some have concluded it to be of Indonesian or Indo-Malayan origin (Bradbury, 1988). While it has been perceived that giant swamp taro was domesticated in Indonesia, the Indo-Malayan region is the region which holds the greatest diversity of the root crop (Bradbury, 1988; Iese, 2005). However, employing techniques of archaeobotanical analysis, Hather (2000) found that "…*Cyrtosperma* was an aboriginal introduction across Polynesia except for New Zealand and Easter Island where climate plus cultural preferences may have discouraged its growth...". He also found that *Cyrtosperma merkusii* was present as far back as 1451 A.D.

The production levels of this giant aroid in the atolls are now under threat from the effects of climate change related sea level rise. The increased frequency and intensity of king tides and sea swell bring huge waves inundating the low lying atoll islands (Liz,

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2007; White & Falkland, 2010). This inundated sea water percolates into the groundwater lens increasing the fresh groundwater lens salinity (Woodraffe, 1989; Mimura, 1999; Gerald, 2007). Along with this, the disturbance caused by rise in sea level to the sensitive balance of the groundwater lens results in seawater intrusion which adds to the increasing salinity levels (White & Falkland, 2010).

In addition, modernization has played a pivotal role in shaping the present trends in lifestyle preferences with nutritional Pacific staple crops being replaced by nutritionally poor imported foods. Giant swamp taro is no exception and has also fallen victim to modernization, as where in the Indo-Pacific region it once was a major food source, but is now being replaced by western food at an accelerating pace. Foods such as instant noodles, rice, flour, and biscuits are not only replacing giant swamp taro but other local food crops such as pandanus, taro, yams, breadfruit and many others.

Therefore, the objective of this paper is to present a detailed descriptor list for classification, conservation and documentation of FSM giant swamp taro cultivars.

METHODOLOGY

The descriptor list was developed during a two day workshop conducted in Pohnpei, FSM with the help of the locals. The workshop consisted of 37 participants, 27 framers and 10 agriculture field technicians of Pohnpei Agriculture Department. There was an equal distribution of age ranging from young to old framers, while a 3:1 gender ration for men to women was present in the workshop. Using a giant swamp taro descriptor list composed by Iese (2005) consisting of 27 descriptors, along with IPGRI (2007) full descriptor list for Taro *Colocasia esculenta* (taro) a detailed draft descriptor was prepared. This was then presented on a PowerPoint presentation and explained to the participants with translations in Pohnpeian from the Pohnpei Chief Agriculture Officer Mr. Adelino Lorens. Through an open discussion the participants at the workshop, worked through the various descriptors to select the most pertinent descriptors to swamp taro. There was common agreement among the participants for all the selected descriptors across both age range and gender. Mr. Adelino Lorens from his previous trips to the outer islands of FSM had collected approximately 50 proposed cultivars and had planted these in the Pilot farm. The Pilot farm presented a fair collection of all FSM cultivars, hence it was used for characterization of the aroid cultivars using the developed descriptor list with the help of four agriculture field technicians.

RESULTS AND DISCUSSION

Descriptor

Divided into eight sections namely plant habitat, leaves, petiole, flower, root, corm, taste, and special characteristics, 37 key morphological traits where identified. Plant habitat had three traits, namely plant span, height at maturity and number of suckers (Table 1). Leaves had 10 traits, leaf base shape, spread of leaf lobes, blade colour, main vein colour, presence of appendages/ cataphylls (small leaf like structures emerging on the underside of leaves), arrangement, number of leaves, lamina length: width ration and petiole junction pattern (Tables 2a and 2b). Petiole had nine traits, colour of top, middle and bottom thirds of petiole, presence of stripes, shape of petiole, presence of spines, number of spines, spine colour and size (Tables 3a and 3b). Inflorescence or flower had eight traits, formation, stalk colour, spathe colour, spadix colour, berries colour, seeds viability, exposure of flower male portion, degree of fertility (Table 4). Corm had four traits, corm size, cortex colour, central corm colour, and fiber colour (Table 5). General descriptions were given for root, taste and special characteristics as it is difficult to pose closed more structured questions for these traits (Table 6).

While all the 37 descriptor traits were useful in characterizing the cultivars, there were a few outstanding ones that were key to effective characterization. These included number of suckers, presence of cataphylls, spread of lobes, leaf arrangement, traits related to spines on petiole and color of spathe.

Table 1. Plant habitat descriptors.

Trait	Variability
Plant span/ spread	Narrow (<50cm) Medium (50-100cm) Large (>100cm)
Plant height at maturity	1.Short (3-4ft) 2.Medium (5-10ft) 3.Long (>10ft)
Number of suckers (direct shoots)	1.Many (<10) 2.Few (5-10) 3.Less (>5)

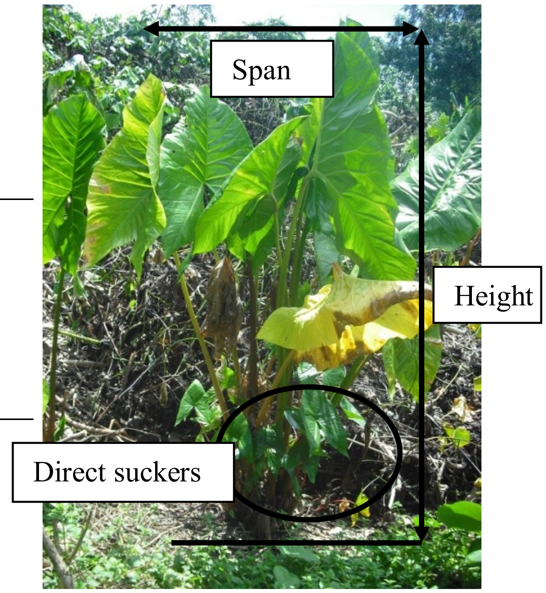
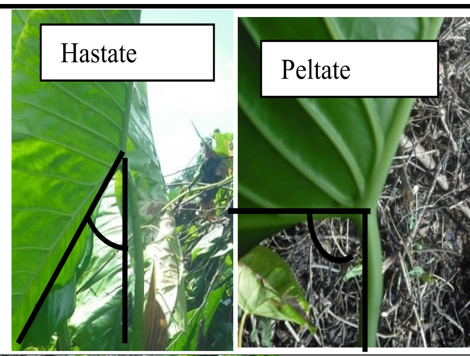


Table 2a. Leaf descriptors.

Trait	Variability
Leaf base shape (petiole attachment)	1. Hastate (Having the shape of an arrowhead but with the basal lobes pointing outward at right angles.) 2. Peltate (Having a flat circular structure attached to a stalk near the center, rather than at or near the margin; shield-shaped.)
Spread of leaf lobes	1. Overlapping 2. Acute angles (<45°) 3. Right angles (90°)
Leaf blade margin	1. Entire (not wavy) 2. Undulate (wavy) 3. Sinuate (very wavy)
Leaf blade colour	1. Whitish 2. Yellow/Yellow green 3. Light green 4. Dark green 5. Pinkish green 6. Reddish green 7. Purplish 8. Blackish



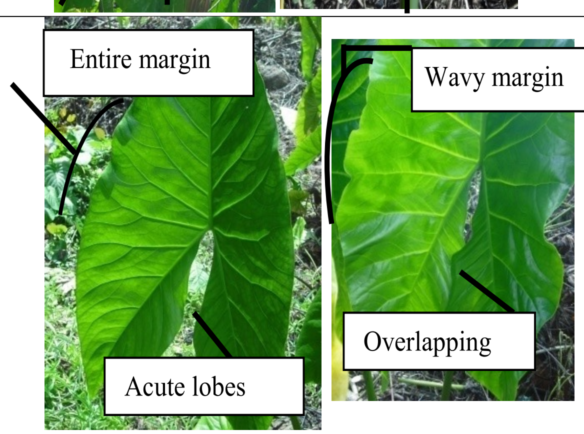
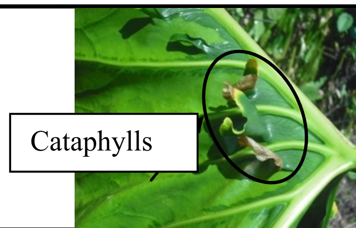
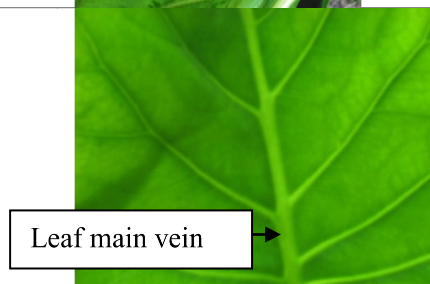
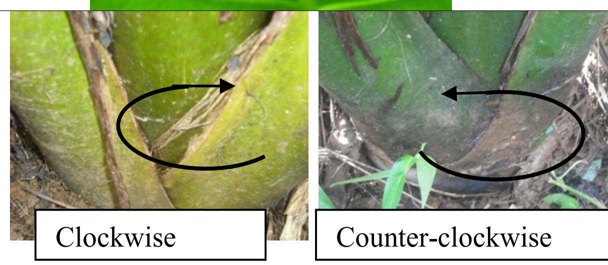
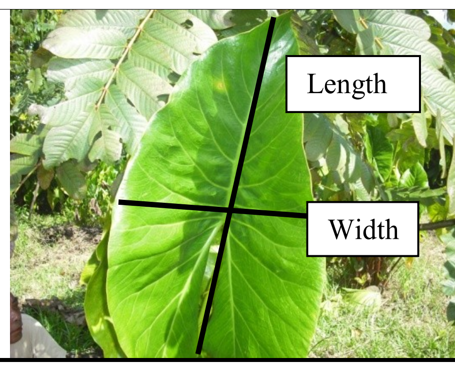


Table 2b. Leaf descriptors.

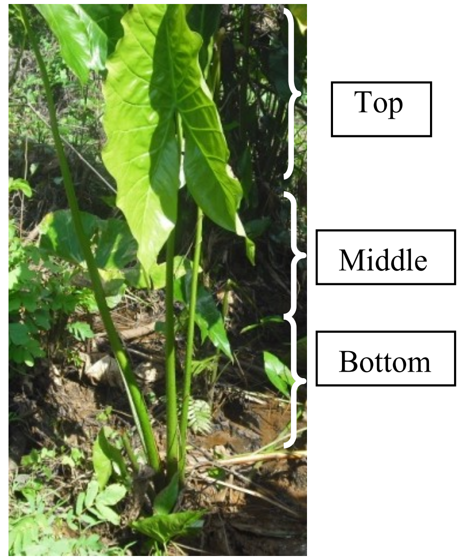
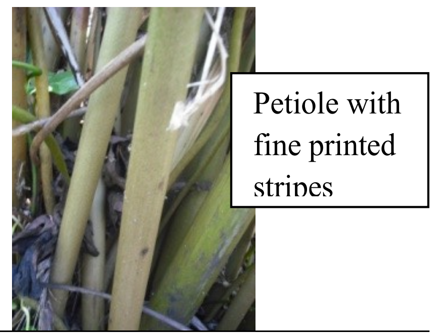
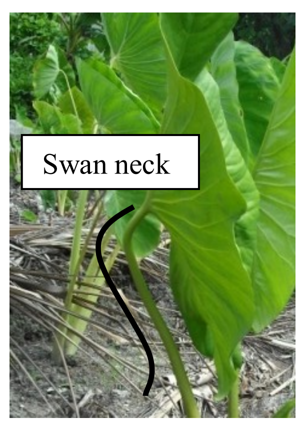
Trait	Variability	
Leaf lamina appendages/ cataphylls	1. Absent 2. Present	
Leaf main vein color	1. Whitish 2. Yellow/ Yellow green 3. Light green 4. Dark green 5. Pinkish green 6. Reddish green 7. Purplish 8. Blackish	
Leaf arrangement (la)	1. Counter-clockwise 2. Clockwise	
Number of leaves (nol)	1. Few (<5) 2. Normal (5-10) 3. Many (>10)	
Leaf lamina length : width ratio	Describe	
Petiole junction pattern	Describe	

Characterization

Using the developed descriptor list for giant swamp taro, 40 distinctive cultivars were characterized of the 50 cultivars present in FSM Pilot farm. These were: Mwahng pwiliet, Nah, Liha mwahu, Semes rao, Pah weitata, Mwahng wel/nihn danis, nihn dihjon/saimon, Mwahng sehm, PF1 Nihn Doahm, Nihn Eneri, Mwahng wiklale, Omp 1, Omp 2, Loahr, Smihden 1, Smihden 2, Smihden 3, Smihden 4, Inpahrau, Nein serin, Mwahng Palau, Mwahng Meir, Mwahng Nukuwer, Mwahng so kalewe, Mwahng weitahta takateki, Pah rotorot, Nein Aidai, Anetchimo 1, Anetchimo 2, Smihden en nukuro, Mwahng seri, Mohotuwa, Neni sehm 2, Neni sehm 3, Neni sehm 4, Fanal en nukuro, Weito, Pula fabul, and Pularis. Of the 50 proposed cultivars present in the pilot farm, only 40 were characterized as some cultivars had been severely damaged (hence inadequate for characterization), lost, or were a duplicate.

During the characterization it was found that four of the 40 cultivars found in FSM were not distinguished by locals hence these were named Nah, Liha mwahu, Semes rao and PF1. The first unknown cultivar was named Nah, as the cultivar originated from the

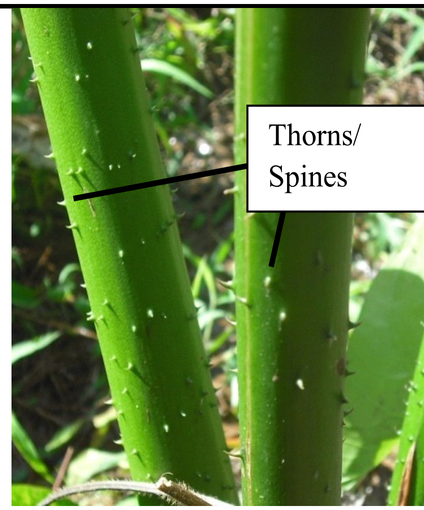
Table 3a. Petiole descriptors.

Trait	Variability	
Color of top third (P/c/t/third)	1. Whitish 2. Yellow/ Yellow green 3. Light green 4. Dark green 5. Pink-Pinkish green 6. Red-Reddish green 7. Purple 8. Black	
Color of middle third (P/c/m/third)	Same as above	
Color of lower third (P/c/l/third)	Same as above	
Petiole stripes	1. Absent 2. Present	
Petiole shape (top) (ps top)	1. Straight 2. Curved 3. Swan's neck	  

island of Nah. Liha mwahu, meaning 'nice lady', was the name given to the second unknown cultivar as a form of appreciation for the author's contribution to towards the farmers crop. Semes rao was the name given to the third unknown cultivar as this cultivar was identified by the field technician Semes and the author Rao. PF1 was the name given to the fourth unknown cultivar to acknowledge the Pilot Farm (PF) the cultivars was identified on. These names were given by the participants of the workshop and were in

Table 3b. Petiole descriptors.

Trait	Variability
Petiole thorns/spine/(pthorns)	1. Absent 2. Present
Number of spines	1. Very little 2. Few 3. Plenty
Petiole spine color(p/t/(col)	1. Green 2. Dark green 3. Yellow 4. Red 5. Pink 6. Purple
Spine size(p/t/size)	1. Short (<2mm) 2. Medium (2-3mm) 3. Long (3-4mm) 4. Very long (>4mm)



agreement with everyone.

While generally flowers of the giant swamp taro are not known to have fragrance it was found that the cultivar Semes rao had a frangipani like fragrance, therefore similar to the flowers of *Colocasia esculenta*. The flower of Semes rao has a light yellow Spathe and a white spadix, unfortunately specific use of the flower is unknown but can be used as floral decoration. Another outstanding cultivar which is easily distinguished is the Mwahng nukuwer due to the presence of cataphylls, it is the only cultivar that had these appendages and similar to the Paipaitalinga found in Tuvalu.

CONCLUSION

From the Workshop in Pohnpei, Federated States of Micronesia a descriptor list for *Cyrtosperma merkusii* (swamp taro) was prepared and many of the FSM cultivars in the collection characterized. While the descriptor list has many of the morphological and some physiological descriptors present. It can be improved through further use, by either or addition of traits to make it more effective. The use of molecular markers would also add another dimension to the characterization process. For effective conservation, collections have to be described and therefore descriptors list are essential. They help to rationalize an existing collection, thereby saving resources and they can assist in identifying unique accessions for safe conservation and duplication. The existing threats of climate change and modernization means that it is vital to conserve the diversity of this important and unique crop. The Secretariat of the Pacific Community, Centre for Pacific Crops and Trees (SPC CePaCT) based in Fiji is working towards conserving and documenting the Pacific aroids which includes the species of the atolls, giant swamp taro.

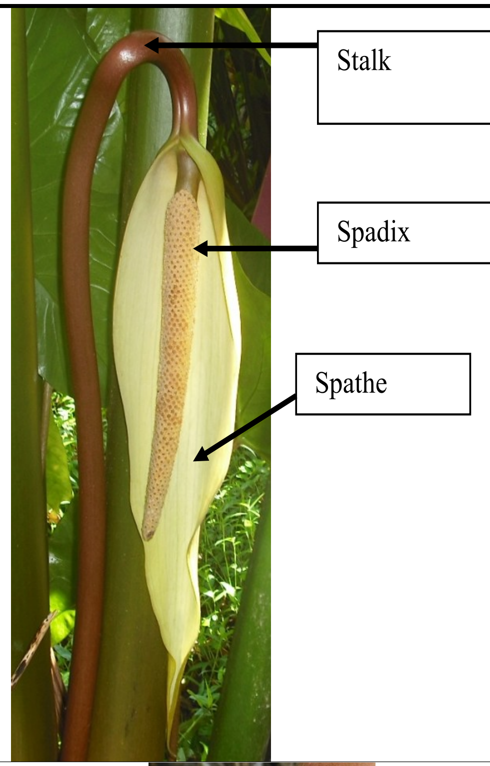
In addition, not all the varieties are cultivated as preference varies according to taste use, ease of cultivation and so on (Iese, 2005). So apart from the effects of climate change and modernization current-day preferences may also contribute to the extinction of some of the varieties.

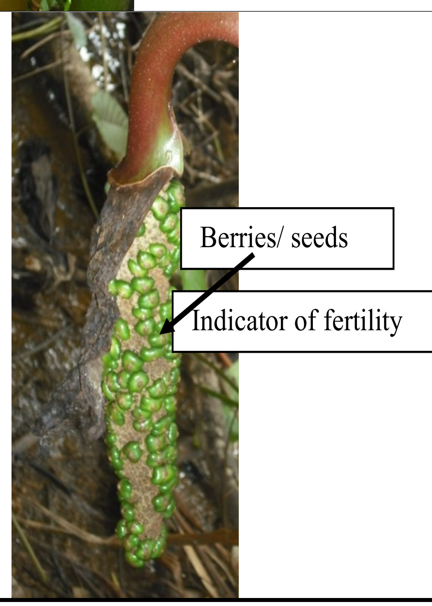
It is essential not only to conserve these varieties but also to document it, so that the valuable information about these varieties is not lost. Currently a handful of the varieties are threatened as many of these have evolved in isolation on the islands, such as the four cultivars that were unknown to the locals.

Apart from being a food crop giant swamp taro is also woven into the island culture and traditions, which makes this a

Table 4. Inflorescence or flower descriptors.

Trait	Variability
Flower formation	1. Absent 2. Present
Flower stalk colour	1. Whitish 2. Yellow/ Yellow green 3. Light green 4. Dark green 5. Pink-Pinkish green 6. Red-Reddish green 7. Purple 8. Black
Spathe (flower cover) color top/ bottom and young/old	Describe
Spadix/ pollen colour	Same as for flower stalk colour
Berry color	Same as for flower stalk colour
Seeds Viability (sv)	1. Viable (grow) 2. Non-viable (don't grow)
Male portion of flower	1. Enclosed 2. Exposed
Fertility of the female part of the inflorescence	1. None 2. Low (<40% fertile flowers) 3. Intermediate (<80%) 4. High (almost 100%)





particular crop of major significance for these island nations. Loss of this species will not only have implications for food security but also for culture, traditions and to some extent identity.

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Table 5. Corm descriptor.

Trait	Variability
Corm Size	1. Small 2. Medium 3. Large
Corm Cortex Color	1. White 2. Yellow3. Orange 4. Pink 5. Red 6. Purple 7. Other
Corm flesh color central part	Same as above
Corm flesh Fiber color	Same as above

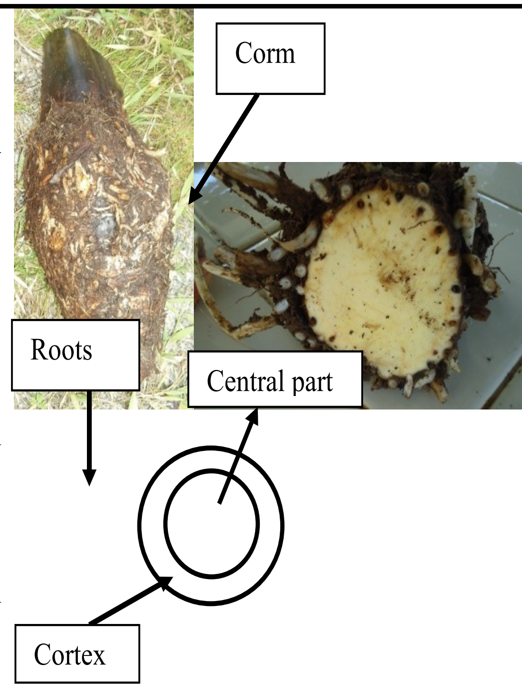

Table 6. Descriptors of root, taste and special characteristics.

Trait	Variability
Roots	Describe
Taste	1. Very Hard 2. Itchy/irritating 3. Good 4. Very good
Special characteristics e.g. drought or salinity tolerance	Describe

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Value of *Leucaena leucocephala*, *Gliricidia sepium* and *Ipomea batatas* supplements for apparent nutritional adequacy and maintenance of adult Anglo -Nubian x Fiji local goats on a basal diet of Elephant grass (*Pennisetum purpureum*) in the dry season

Simon Baete[1] and Eroarome Martin Aregheore[2]

ABSTRACT

Four adult Anglo-Nubian x Fiji local goats; 2-3 years old, pre-trial body weight of 25.6 kg were used in a 4 x 4 Latin Square design to investigate the value of *Gliricidia sepium* (GS), *Ipomea batatas* (IB) and *Leucaena leucocephala* (LL) to a basal diet of Elephant grass (EG) (*Pennisetum purpureum*). Treatments were EG-sole diet; EG + GS; EG + IB and EG +LL. Dry matter intake (DMI) of EG-sole diet was 1008 g/d/goat, while EG + GS; EG + IB and EG +LL was 766; 898 and 902 g/d/goat. Total voluntary feed intake (TVFI) (grass + browse) EG + GS; EG + IB and EG +LL was 1158 1332 and 1375 g/d/goat, respectively. There was an initial rejection of EG + GS by the goats. Intake of EG and EG + GS were lower than EG + IB and EG +LL ($P<0.05$). DMI of EG was 350.8 g while EG + GS; EG + IB and EG +LL was 367.0; 430.9 and 490.3 g/d/goat. Daily protein intake was 7.04; 9.76; 10.42 and 11.37 g/kg$^{0.75}$/day in EG; EG + GS; EG + IB and EG +LL, respectively. DM, CP, NDF, ADF, NFE, OM; ME (MJ/kg) digestibility and TDN was high in EG + GS, EG + IB and EG +LL than in EG ($P<0.05$). Digestible energy (MJ/kg DM) and NVI (KJ/kg$^{0.75}$/d) were low in EG + IB and EG + GS, respectively. The treatments can be ranked as: EG + LL> EG+ IB > GE+ GS > GE-sole diet in meeting apparent nutritional adequacy of adult goats .

Key words: Adult goats, elephant grass, voluntary feed, dry matter intake, daily protein intake, nutritive value index.

INTRODUCTION

The productivity of ruminants' livestock during adverse weather conditions (drought or dry season) is dependent upon the use of available pasture resources for maintenance, growth and reproduction. The goat is an indispensable ruminant livestock in the Pacific Island countries region due to its effective utilization of fibrous feeds, and the ability to adapt to different climatic conditions under varying management systems. The goat can also survive in areas, where cattle and sheep cannot because of their digestive efficiency. These attributes have contributed to make the goat appreciated by smallholder farmers in the Pacific island countries (PICs) where available land mass permits.

Elephant or Napier grass (*Pennisetum purpurem*) is one of the natural pasture grasses in PICs that withstand heavy grazing and yet provide a substantial bulk feed to large and small ruminants. It is the main fodder grown by over 70 % of livestock farmers in PICs, and usually provides over 40 % of feed requirements in silage or cut-and carry system, in the dry season (Aregheore, 2005). It makes excellent hay if cut when young but get too coarse if cut late. In comparison with other grass species, it is the most promising and high yielding fodder giving dry matter yields that surpass most tropical grasses (Skerman & Riveros, 1990; Humpreys, 1994), however, its digestibility and palatability decrease rapidly after the heads appear. Small ruminants reared on elephant grass only have problems meeting their maintenance need or maintain body weight gained in the rainy season during the dry season. Elephant grass, despite its availability, has high-lignin content in the dry season.

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Productivity of small ruminants in PICs is less than their genetic potential due to large fluctuations in quantity and quality of available forage. Supplementation with available, cheap, feed resources is necessary to overcome the nutritional constraint. Poor-quality diets from forage in terms of protein; vitamins and minerals can be improved with leaves, shoots and twigs of browses, legumes and multipurpose trees of indigenous and introduced browse species that abounds in PICs. *Leucaena leucocephala, Gliricidia sepium, Calliandra calothyrus* and *Moringa oleifera* to mention but four extensively studied as supplements to poor quality roughage. Aregheore (2004, 2005), however, limited data exist on the potentials of vines of sweet potatoes (*Ipomea batatas* [L] Lam) as a source of nutrients for small ruminant livestock in the PICs. Sweet potatoes (*I. batatas)* widely grown in Fiji Islands, Vanuatu, Solomon Islands, Papua New Guinea, the Cook islands and a host of other PICs as "a store of goodness" (SPC, 1983), but after the harvest of the tubers, the vines considered a waste and, therefore, underutilized (Moat & McL Drylen, 1993; Aregheore, 2004, 2005).

The leaves, twigs, and seeds of browses, legumes and multipurpose trees have become an integral part of ruminant feeding systems, and their importance stressed in ruminant nutrition in the tropics and sub-tropics in the dry season (Orden *et al.*, 2000; Aregheore *et al.,* 2004; Bamikole & Ikhatua, 2010). While these legumes do exist, most small holder farmers, the crank handler of ruminant production in PICs seems to have little or no knowledge of them as cheap protein supplements for the growth, reproduction, production and maintenance of meat goats. The objective of this study, therefore, was to investigate the importance of *L. leucocephala*, *G. sepium* and *I. batatas* supplementation on apparent nutritional adequacy and maintenance of adult Anglo-Nubian x Fiji local goats on a basal diet of elephant grass (*P. purpureum*) in the dry season.

MATERIALS AND METHODS

Location of Study

The study was carried out during the dry season at the goat unit of the University of the South Pacific, School of Agriculture, Alafua Campus, Apia, Samoa (Latitude 13.5^0S, longitude 172.5^0W). Dry season in Samoa lasts from April to September with temperature of $27\text{-}30^0$C.

Feeds preparation

L. leucocephala, G. sepium and elephant grass (the basal diet) were harvested from re-growth. Sweet potato foliage (leaves, petioles including stems (vines) were harvested from the student's plot within Alafua Campus. Leaves of *Leucaena; Gliricidia* and sweet potato were harvested fresh daily. The elephant grass component was harvested fresh daily from a re-growth and chopped with a manual chaff cutter into pieces of 3-5 cm, length. Stems were removed from the leaves to ensure that the fodder composition was uniform. The reduction in length was necessary to minimize its wastage by the goats.

The four dietary treatments consisted of the following:

- 100 % Elephant grass only (Control) (EG-sole diet)
- 72 % Elephant grass + 28 % *Gliricidia sepium* (EG+GS)
- 70 % Elephant grass + 30 % *Ipomea batatas* vines (EG+IB)
- 75 % Elephant grass + 25 % *Leucaena leucocephala* (EG+LL)

The above proportions were mixed thoroughly to reduce selection and offered as a whole diet in the trough (Theng Kouch *et al.*, 2003). The levels of supplementation were calculated as percentage of *ad libitum* daily forage allowance of adult goats. The ratios were mixed to contain between 13.4 – 14.6 % CP levels.

Animals, experimental design and procedure

Four adult Anglo-Nubian x Fiji local goats, 2 bucks and 2 does; 2-3 years with mean pre-trial body weights of 25.6kg were allotted in a randomized 4 x 4 Latin square design and individually housed in metabolic crates under a common roof, fed and watered. The goats were fed on each dietary treatment for 21 days before the treatment was changed. The first 10 days were dietary adaptation period and adjustment, while the final 11 days were for intake measurement and faecal collection prior to been allocated to new dietary treatment. The assigned dietary treatment was offered daily beginning at 0900hr, and additional feed was offered to ensure *ad libitum* access to forage while minimizing wastage.

However, the feed offered were adjusted daily based on increased and decreased intake by keeping the refusal rate at 10-20%. Feed refusals were collected each day and weighed to assess intake before any new feed was offered (Aregheore, 2007). Grab samples of browses, elephant grass and dietary treatments were taken on a daily basis each time mixture was weighed for each goat. These samples were placed in paper bags and dried to a constant weight at 50°C for DM determination.

Record of daily intake and refusals were recorded and kept. The goats also had access to ample drinking water and mineral lick salt (Summit multi-mineral, Auckland, New Zealand). The quantity of leaf materials eaten by an individual animal was calculated by the difference between weight of leaves given (gDM) and the weight of leaves refused (gDM) (Mtenga *et al*., 1999).

Digestibility studies

During each phase, faeces voided were collected for 5 days and weighed to know total, faecal output for each goat before a 25 % sample was collected for dry matter determination. Samples of collected feeds and faeces were dried in forced draught oven at 70^0C for 48 hours, until constant weight was achieved. These were sampled and bulked for each goat, milled with a simple laboratory mill and stored in air-tight bottles until required for analysis.

Analytical Procedures

AOAC (1995) method was used for proximate analysis of samples. All analysis was done in triplicate. Dry matter was determined by drying at 102˚C for 24 hours, ash by placing samples in a muffle furnace and firing at 600˚c for 24 hours and protein by the micro-kjeldah procedure (N x 6.25). Fibre fractions were determined using the procedure of Van Soest *et al*. (1991). Hemicellulose was calculated as the difference between neutral detergent fibre (NDF) and acid detergent fibre (ADF). Gross energy (MJ/kg) values of forages and faecal samples were determined by a Bomb calorimeter (Adiabatic bomb, Parr Instrument Co. Moline, IL) using chemical benzoic acid as standard. All samples were done in triplicate.

Statistical Analysis

Data on voluntary feed intake, dry matter intake, and nutrient digestibility were statistically evaluated using analysis of variance (ANOVA) with goats, period and dietary treatment included as main effects and significant differences between means were compared using least significant difference (LSD).

RESULTS

Table 1 presents proximate chemical composition of individual feedstuffs used in the study. Elephant grass had higher fibre contents than the browses. Among the browses, sweet potato (*Ipomea batatas*) had lowest dry matter (DM), CF, NDF, ADF, ash and ME contents. LL had higher CP and M E (MJ/kg) followed by GS; and IB the lowest. OM of EG-sole diet was close to IB while GS and LL were similar in OM value.

Table 2 presents the proximate chemical composition of the dietary treatments fed to the goats. The CP of EG-sole diet was lower than the CP value of EG+GS; EG+IB and EG+LL. The CP of EG+GS; EG + IB and EG+LL ranged from 11.4-14.6%. All the dietary treatments including EG- sole diet had high organic matter content. Except for the high ADF in EG- sole diet, other fibre fractions (CF, NDF and hemicelluloses) were numerically similar in EG-sole diet; EG+GS; EG+IB and EG+LL.

Data on feed intake and apparent nutrient digestibility of the goats are presented in Table 3. Voluntary dry matter intake of the basal diet was 1008; 766; 898 and 902 g/d/ goat, for EG- sole diet; EG + GS; EG + IB and EG +LL, respectively. Goats on EG-sole diet had higher forage intake ($P<0.05$) and followed by EG +LL and EG + IB while EG + GS was the least in the intake of the basal diet. The percentage (%) of browse in total voluntary feed intake was similar however, total voluntary forage intake (grass + browse) was 1158, 1332 and 1375 g/d/goat for EG+GS; EG+IB and EG+LL respectively (P<0.05). Browse supplementation ranged from 25-30% increasing daily DMI with statistical significant difference (P<0.05).

There was an initial rejection of EG + GS by goats and this affected intake. However, its intake was close to EG-sole diet but lower than EG+IB and EG+LL. DMI of goats on EG -sole diet was 562.5 while the total DMI of goats on EG+GS; EG+IB and EG+LL was 527.8; 655.8 and 632.4 g/d/goat, respectively. DMI of EG-sole diet was higher than EG+GS while EG+IB and EG+LL were similar but statistically different from EG-sole diet and EG+GS (P<0.05).

Except for the goats on EG+GS, total DMI was higher in EG+IB and EG+LL (browse supplemented diets) than in EG-sole diet. The intake of D3 (EG+IB) was followed by EG+LL and the least in EG+GS.

Table 1. Proximate chemical composition of Elephant grass and the browses.

	Forage/browses*			
Nutrients	**Elephant grass**	***Gliricidia sepium***	***Leucaena leucocephala***	**Sweet potato (*Ipomea batatas*)**
DM	55.8	58.7	50.8	37.3
CP	11.4	19.5	24.2	18.3
OM	85.0	90.5	90.5	88.5
CF	26.5	9.2	12.2	8.6
Ash	14.9	9.5	12.	11.5
NDF	54.4	47.7	48.1	39.6
ADF	41.5	25.3	32.2	20.3
HEM	22.9	22.4	15.9	6.8
ME (MJ/kg)	13.1	14.0	16.4	9.5

*DM, dry matter; CP, crude protein; OM, Organic matter; NDF, Neutral detergent fibre; ADF, Acid detergent fibre; HEM, hemicellulose; ME, Metabolizable energy

Table 2. Proximate chemical composition of dietary treatments.

	Diets*			
	EG-sole diet	EG+GS	EG+IB	EG+LL
Proportion of Grass: Browse	100:0	72:28	70:30	75:25
	Nutrients as percentage (%) of DM			
Dry matter (DM)	55.8	56.6	50.3	54.6
Crude protein (CP)	11.4	13.6	13.3	14.6
Organic matter (OM)	85.0	86.5	86.1	88.4
Crude fibre (CF)	26.5	24.1	20.3	24.1
Ash	14.9	13.4	13.9	12.9
Neutral detergent fibre (NDF)	54.4	52.5	45.3	52.8
Acid detergent fibre (ADF)	41.5	37.6	35.1	39.1
Hemicellulose	12.9	14.9	10.2	13.7
Nitrogen free extract (NFE)	45.1	46.2	49.0	49.9
Metabolizable energy (MJ/kg DM)	13.1	13.4	12.0	13.9

* EG-sole = Elephant grass–sole diet; EG+GS = EG+ *Gliricidia sepium*; EG+IB = EG+ *Ipomea batatas;*
EG+LL = EG+ *Leucaena leucocephala*

Table 3. Voluntary feed intake, total dry matter intake, daily protein intake and apparent nutrient digestibility of goats.

	Diets*				
Proportion of Grass: Legumes	EG	EG+GS	EG+IB	EG+LL	SEM+
	100:0	72:28	70:30	75:25	
Parameters					
Forage (grass) intake (g/d/goat)	1008	766	898	902	51.0
Browse intake (g/d/goat)	-	392	434	473	10.0
Total voluntary feed intake (grass + browse) (g/d/goat)	1008[b]	1158[b]	1332[a]	1375[a]	108.2
% of elephant grass in total intake	100	66.0	67.4	65.6	10.1
% of browse in total voluntary feed intake	-	34.0	32.6	34.4	0.5
Total grass dry matter intake (g)	562.5	427.4	493.9	503.3	28.9
Total browse dry matter intake (g)	-	100.4[b]	161.9[a]	129.1[b]	15.7
Total dry matter intake (grass + browse) (g)	562.5[b]	527.8[c]	655.8[a]	632.4[a]	39.7
Apparent nutrient digestibility (%)					
Dry matter	47.5[b]	58.6[a]	59.6[a]	63.1[a]	3.9
Crude protein	61.8[b]	72.9[a]	75.5[a]	77.9[a]	4.1
Crude fibre	50.3	55.2	57.4	51.2	2.2
Nitrogen free extract	47.8[b]	60.2[a]	65.0[a]	68.2[a]	5.0
Organic matter	52.9[b]	60.3[a]	64.2[a]	65.5[a]	3.3
Total digestible nutrient (TDN)	46.5[b]	53.5[b]	53.6[b]	64.4[a]	3.9
Energy	73.7[b]	70.7[b]	73.7[b]	87.9[a]	4.6
Digestible dry matter intake (g/kg$^{0.75}$/day)	26.4	30.9	39.0	39.9	4.3
Daily protein (N x 6.25) intake (g/kg$^{0.75}$/day)	7.0	9.8	10.4	11.4	1.1
Daily organic matter intake (g/kg$^{0.75}$/day)	45.0[b]	52.0[a]	56.7a	57.4a	3.4
Digestible energy (MJ/kg DM)	9.65	9.47	8.84	12.22	0.87
Nutritive value index (KJ/kg$^{0.75}$/d)**	543[bc]	500[c]	588[b]	773[a]	68.8

* EG- Elephant grass –sole die; EG+ *G. sepium*; EG+ *Ipomea batatas* and EG + *L. leucocephala*
** Nutritive value index: relative intake x percent energy digestibility (Crampton *et al.,* 1960)
+SEM – Standard error of mean
[a, b, c]Means for each response variable followed by the same letter are not different at P>0.05 using LSD.

Apparent digestibility coefficients in the grass+ browse mixtures were higher compared to the sole diet. Digestible DMI was 26.4, 30.9, 39.0 and 39.9 (g/kg$^{0.75}$/day). Daily protein (N x 6.25) intake was 7.0, 9.8; 10.4 and 11.4 (g/kg0.75/day) for EG-sole diets; EG + GS; EG + IB and EG +LL respectively. Digestible energy (MJ/kg DM) was lowest in GE+IB at 8.84 MJ/kg DM compared to GE-sole diet, GE+GS and GE+LL. Nutritive value index (KJ/kg0.75/d) of GE+LL at 773 KJ/ kg0.75/d was the highest (P<0.05).

DISCUSSION

Chemical composition of feed stuffs and dietary treatment

The chemical composition of EG (*Pennisetum purpureum*), GS, IB and LL are similar in values to those reported in the literature by Ash (1990), Moat & McL Drylen (1993), and Aregheore (2004). Crude protein of GE-sole diet and dietary treatments ranged from 11.4-14.6% above the level that was suggested by NRC (1981) to meet the maintenance and fattening requirement of adult goats stall fed with minimal activity. Metabolizable energy contents of EG-sole diet and EG+GS; EG+IB and EG+LL are consistent with published estimates for forages fed in the tropics and sub-tropical countries (Butterworth, 1964).

Voluntary feed intake

Feed supplements did not adversely affect the intake of basal diet. Voluntary DMI of the goats on EG-sole diet was comparatively higher. The differences between the goats EG-sole diet and those on EG+GS; EG+IB and EG+LL seems to implicate substitution effects of the basal diet by the supplements. The EG+GS; EG+IB and EG+LL diets were consumed better than the single component diet (EG-sole diet) and this is consistent with the utilization of mixed diets (Aregheore *et al.*, 2002). Total dry matter intake of goats on EG+IB was comparatively higher, and the low DMI of EG+GS was due to an initial rejection of *Gliricidia* by goats. The presence of inhibiting allelochemicals such as coumarins (Griffiths, 1962; Aregheore, 2005), flavanols (Manner & Jurd, 1979; Aregheore, 2005; Jose & Reddy, 2010; Reddy & Jose, 2010) and strong odour (Nochebuena & O'Donovan, 1986) are implicated to cause palatability problems and low intake of fresh GS foliage (Smith & van Houtert, 1987) even when mixed with other palatable forage. The initial reluctance of goats for EG+GS concurs with earlier reports that both anti-nutritive factors mask and depress intake of GS based diets (Chadhokar, 1982; Carew, 1983; Brewbaker, 1986; Aregheore, 2005).

After the adaptation period of about 5 days, the goats freely consumed and utilized the EG+GS mixture without detrimental effects, and thereafter no rejection. Aregheore *et al.* (2004) reported about 4-6 days for goats to adapt to *Gliricidia* leaves. The intake of EG+LL concurs with Abdulrazak *et al*. (1996) who reported higher intakes of LL than GS in sheep and cattle when both browses were used as supplements to Napier grass in Kenya. Behavioural and intake studies showed that Leucaena is the most preferred among browse and GS least preferred (Mtenga *et al.,* 1993). The presence of secondary plant metabolites such as beta-carotene and xanthophyll in LL makes it most preferred among browses (Meulen *et al.*, 1979), however in our study, GS had no adverse effect on adult goats.

Goats were observed to spend more time in eating, selecting the feed and ruminating. However, more feed was consumed to compensate for the energy lost due to some feeding behavioural activities. We also observed that DMI was influenced by standard of tastiness (preference and palatability) and level of protein in the browse + grass mixtures, and this agreed with earlier studies on forage preference and palatability phenomena of goats (Marten, 1978; Real *et al.*, 2001; Theng Kouch *et al.*, 2003; Aregheore *et al.*, 2006).

Daily protein intake (DPI) ranged from 7.0 to 11.4 (g/kg $^{0.75}$/day), value higher than that suggested by NRC (1981) to meet maintenance requirement of goats in the tropics and sub-tropics. The goats maintained their live-weight throughout the experimental period.

Apparent digestibility coefficient

Goats on EG-sole diet had the lowest digestibility (Table 3). The high apparent digestibility coefficients in the mixed diets (EG+GS; EG+IB and EG+LL) is consistent with (Norton, 1994; Aregheore, 2004) that the inclusion of legumes in grass based diets improves digestibility, nutrients utilization and performance of goats. Foliage of legumes, browses and multipurpose trees (Topps, 1992) and *Ipomea batatas* vines (Scott, 1992; Aregheore, 2004) are richer in CP, minerals and digestible nutrients than grass alone. Supplementation of grass based diets increased voluntary intake, improved apparent digestibility coefficient and nutrient utilization for maintenance of adult goats in the dry season period.

Data on DMI, DM digestibility and nutritive value index (KJ/kg $^{0.75}$/d) (Table 3) are consistent with the three qualitative effects of stimulative, additive and substitutive reported by Huston (1993). Goats on EG-sole diet, and EG+GS, EG+LL and EG+IB exhibited all three qualitative effects in each of phase of our trial.

Organic matter digestibility (OMD) is used to predict the value of metabolizable energy. Organic matter digestibility (OMD) in all the dietary treatments was above 50 % but lower than values reported by Theng Kouch *et al.* (2003) when the foliage was offered hanging compared to feeding troughs used in our study. OMD, digestible energy (MJ/kg DM) and daily protein (N x 6.25) intake (g/ kg0.75/day) values demonstrated that the diets had enough energy and protein that were efficiently utilized to sustain nutritional adequacy of adult goats during each phase. A biological/nutritional explanation for the difference observed in digestible energy (MJ/ kg DM) of the dietary treatments may be due to the metabolizable content of diets. Although, the EG-sole diet had higher nutritive value index (KJ/kg$^{0.75}$/d), the addition of LL, GS and IB leaves improved the intake and utilization of EG. This subsequently helped to overcome the problem of weight loss and low productivity; the usual characteristics experienced in grazing ruminants during the dry season period (Aregheore, 2001).

CONCLUSION

Available data suggest that leaves of LL, GS, and IB are potential supplements to elephant grass in meeting nutritional requirements of adult goats' in PICs. Leaves of *Ipomea batatas* (IB) provided cheap nitrogen source in adult goat's diet (Nambi *et al.*, 2001; Katongole *et al*., 2009). *Ipomea batatas* high foliage yield and CP content; and palatability implicate it as a suitable protein supplement for animals on low quality forage in the dry season. The leaves of IB are underutilized protein supplement in the nutrition of small ruminants.

Among the dietary treatments the vines of IB were more acceptable than GS. EG+IB compared favourably with EG+LL in daily forage intake of adult goats. Based on apparent digestibility coefficients and potential utilization, the dietary treatments can be ranked in the following order: EG+LL> EG+IB > EG+GS > EG-sole diet in meeting maintenance requirements of adult goats. Leaves of the browses and vines of sweet potato can be incorporated in the daily forage allowance of adult goats without deleterious effects on apparent nutritional adequacy during the dry season in PICs.

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Forging Fijian Camaraderie: The cultural significance and social uses of kava *(yaqona)* (Piper methysticum Forst. f) in three upper watershed communities in north western Viti Levu (Fiji Islands)

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ABSTRACT

Kava (*yaqona)* (*Piper methysticum* Forst. f) is an important non-timber forest product for many Pacific Island cultures. Three villages (Navala, Nadrugu and Nakoroboya) in north-western Viti Levu (Fiji Islands) were part of a FORENET/USP/PACE-SD (International Forestry and Environmental Network/University of the South Pacific/ Pacific Centre for Environment and Sustainable Development) sponsored, socio-economic and bio-cultural study (April to June 2011). Part of this field work focused on the anthropology of kava, using participant observation and ethnographic analysis in traditional *bure* settings. Results revealed that Navala villagers had a more intense and profound symbolic meaning and cultural understanding of kava and elders upheld and safeguarded kava protocols, stories and traditions. Nadrugu and Nakoroboya however exhibited a less cultural understanding of kava based on varying degrees of acculturation and changing traditional mores and customs. The cultural significance and social uses of kava (*yaqona*) were important in all three villages studied and contributed to forging strong social and cultural relationships.

Key words: Kava, cultural significance, social issues, biocultural diversity, traditional ecological knowledge, *sevusevu* and *ni tautau*.

INTRODUCTION

Kava and its importance in the Pacific

Kava (*yaqona)* (*Piper methysticum* Forst. f) has long been at the social, cultural and economic centre of many Pacific island cultures (Lebot *et al.,* 2007), and often characterised as a valuable non-timber forest product. Kava is profoundly important as a way of bringing people together, along with its ethno-botanical and ethno-pharmacological properties. *Yaqona* in the Fijian vernacular is also "*grog dope"* or "*yaqona ke nasha".* According to legend (Go-Fiji, 2012):

> "the word "yaqona" (pronounced yang-GO-na) was derived from the Fijian god Degei, whose name means "from heaven to the soil and through the Earth." He had three sons, all of whom he had given two sacred crops, vuga (a type of tree) and yaqona, so that they could receive wisdom from them. In turn, the sons gave them to their other people, and the legend states that to this day, the crops grow wherever Fijian descendents" (p.1).

Kava carries with it symbolic and ritualistic traditional ecological knowledge (TEK), that has been passed down through the generations. Depending on the culture and specific local socio-cultural milieu's, kava occupies an important place in forging spiritual sources of wisdom to seek ancestral favour (Lebot *et al*., 1997:121) that encompasses the use of this

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[2]Which included its symbolic meaning and cultural understanding that sustains its central place within Pacific Islander social life, and highlighted the uses of kava (*yaqona*) as a valuable exchange item within social relationships?

[3]A series of three community sevusevu's and departure i tautau ceremonies were conducted as well as 10 in-depth kava-sessions were completed in all three communities. The author combined visualism and collaborative ethnographic methods to be socio-cultural determinants (departure points) from which observations and conclusions were made. Prior and informed consent was agreed upon involving the village headman (Turaga ni Koro) and other men and women participants.

mildly psychotropic drug[4].

Pre-historical memoirs of the discovery and settlement of the remote Pacific Islands, has been characterised by historians as speculative and dubious since the 1700's (Lebot *et al*., 1997). The same author reiterates that it "seems clear that Pacific Island peoples, along with most of their domesticated plant and animal assemblages, originated in Southeast Asia" (p.5). Human populations first colonized Sahul; a large land area of New Guinea and Australia (then connected by land bridge), at least 40,000 years ago (Bellwood, 1978). This affirmation is also substantiated by Nunn (1994; 1998). The nearby islands of Western Melanesia were reached later in history (e.g. New Ireland circa 32,000 B.P), and the western Solomon Islands *circa* 29,000 B.P; (Allan *et al*., 1989). Until about 4000 years B.P, human settlements in the Pacific were restricted to these Western most Islands of Melanesia. Since then, migrants and sailing canoes have located and populated all of the remaining inhabitable tropical and subtropical islands of the central and eastern Pacific. When European explorers first arrived on the remote Pacific Islands, kava was used in many societies an integral part of religious, political and economic life (Figure 1), which transcended into its habitual and ritualistic uses in ceremonies.

As far as its origin, Kava is a Pacific plant domesticate (Yen, 1985), and suggests that "the Oceanian's[5] retained (or reinvented) the ethno botanical concepts of domestication throughout their geographical spread and individual paths of development (p.5)". The plant itself is a Pacific domesticate that originated outside of Southeast Asia and New Guinea. Some suggestions by Yen (1985) highlight that in the northern Islands of Vanuatu is a species and as vegetatively

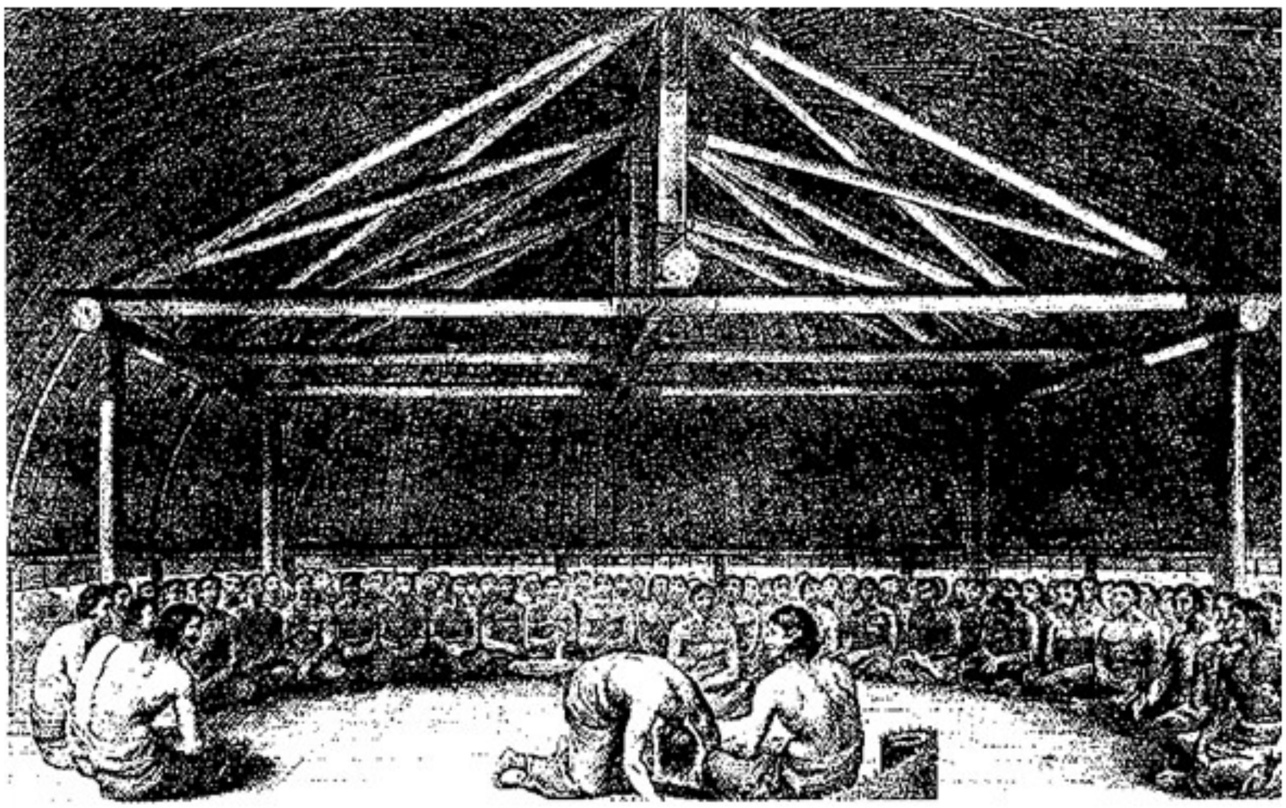

Figure 1. Paulaho King of the Friendly Islands (Tonga) Drinking Kava. (Source : J, Webber artist on James Cook's third voyage to the Pacific (Courtesy of Hawaii State Archives, Honolulu).

[4]Its active principle, are a series of kavalactones that are concentrated in the rootstock and roots. Islanders in just these psychoactive chemicals I drinking cold water infusions of chewed, ground, pounded, or otherwise macerated kava stumps and roots (Lebot *et al*., 1997, p.1).

[5]The islands of the southern, western, and central Pacific Ocean, including Melanesia, Micronesia, and Polynesia. The term is sometimes extended to encompass Australia, New Zealand, and the Malay Archipelago. (Free Dictionary, 2012. Retrieved from: http://www.thefreedictionary.com/Oceanians).

propagated root crop. The same author suggests that kava is very young domesticate- perhaps less than 3000 years old, and that it originated from Vanuatu; carried eastward into Fiji and Polynesia and then westerward into scattered areas of New Guinea and into two islands of central Micronesia (Lebot *et al*., 1997).

From a linguistic anthropological perspective, affinity exists between the name *malohu* in the reconstructed term *maloku* (kava) from Portal-North Central Vanuatu (Lebot *et al*., 1997). According to Crowley (1990), "is the language ancestral to probably all of the languages spoken between Efate and the Torres in Vanuatu" (Crowley, 1990;1991). The same author reports that *maloku* also has Fijian reflexes that mean "quiet" or "subdued" (Lebot *et al*., 1997). This brief linguistic history or heritage could date kava's domestication to before the breakup of Proto-North Central Vanuatu language some 3000 years ago. Recent speculation from a socio-cultural perspective that a large number of present-day kava cultivars supports linguistic clues to partially explain its antiquity in Vanuatu (Lebot *et al*., 1997; Allan *et al*., 1989).

Kavettes[6]

The way in which kava is prepared and consumed various greatly between Pacific islands such as Vanuatu, Papua New Guinea and American Samoa. In Vanuatu for example, during a circumcision ceremony, kava is prepared with the roots and root stocks and the stump is cut to smaller pieces and cleaned, then "chewers" masticate the kava and drank from three chewed mouthfuls of honoured guests. In the Western Province of Papua New Guinea, men move indoors and prepare kava (Lebot, 1997). Hosts harvest the kava plants earlier that day and "empower" the roots by yelling "*yikay"*. In an act of whooping and stomping, the men carry them to their longhouse[7], in which all members of the community reside. Men burn the leaves of a forest palm to sweeten the kava. Others chew, spitting mouthfuls of pulp into a bowl made from the spathe of palm inflorescence. Both hosts and guests contribute multiples to the growing communal pile of chewed kava. Leaf ashes mixed into the masticated kava which is then divided into servings, each in a coconut spathe bowl. Water is added and, is squeezed by hand to infuse the drug (Lebot, 1997:162). According to Holmes (1967, 1974) and Malauulu *et al*. (1974), kava preparation and consumption in American Samoa, starts with the presiding chief, who selects a kava root and hands it to one of the younger members of the *aumaga* (the younger untitled men of the village). This man cuts the kava into pieces and uses a hammer stone to pound them into pulp on the concave surface of the stone mortar. Other *aumaga* members are washing a large, multi-legged wooden kava bowl and fetching water in plastic buckets. Conversation is kept at a minimum and often workers smoke is the work of preparation proceeds. Three members of the *aumaga* carried a massive bowl to the back of the house and sit behind it. Patterns of kava consumption in American Samoa are based on strict protocol. The village *manaia,* the leader of the *aumaga*, who prepares the kava sits directly behind the bowl[8]. The *manaia* takes off his shirt and turns up his *lavalava* (waistcloth) not extend below his knees. He turned to his right to wash his hands for beginning to prepare the kava infusion. Kava pulp is then strained through the inner bark of *Hibiscus tiliaceus* ('*fau'*), and twists the *fau*, as to allow the strained kava to pour back into the bowl. The *manaia* inspects the color, cleanliness and the sound of splashing, and signifies its readiness. In response, the collective chiefs clap their hands together several times. At this point, the *manaia* wipes the rim of the bowl with the fau and lays his hands upon the size of the container. The *tulafale* (orators or "talking chiefs"), begin kava service by conducting rollcall of drinkers (Lebot, 1997:166). In Samoa, as elsewhere in Polynesia and Fiji, drinking order is politically charged and

[6]Lebot refers to these *as "Kavettes*" (derived from the term *"vignettes*"), that describe kava use and consumption in various island communities (adopted from Labot, 1997:155).

[7]Single building about 23 m long in which all members of the community reside (Lebot, 1997:162).

[8]In other Pacific island contexts, this place is taken by the *taupau*, the ceremonial village virgin.

culturally significant. The most prestigious positions in the roll calls differ from place to place, but are usually at the beginning and the end of the drinking order.

Cultural importance of the kava ceremony in Fiji

Historically and according to Singh (1986:1992) and Anon. 2012b, "Kava was used as a social drink for high-ranking chiefs and elders, and drank as a form of welcome for honoured guests, consumed for preparation and completion of an event or of work, to validate status, observe births, marriages and deaths, to relieve stress, remedy illnesses etc (p.2). Kava was also drank in kinship and chiefship rituals, for public atonement of misdeeds. Many people were pardoned for their crimes after a kava ceremony" (p. 1). Kava's historical significance continues in the Pacific (and more specifically in Fiji) *yaqona* is also referred to locally as *wai ni vanua* (water of the land, people and culture). Work by Aporosa (2011) suggests that many Fijians refer to this as a ingestible manifestation of their *vanua;* a drinkable representation of the people, the land, culture and cultural practice (Tomlinson, 2009:111-112). The drinking of yaqona is encouraged as it demonstrates, externalizes and personifies "*Fijian-ness*" and the Fijian way, therefore further enhancing cultural identity (Ratuva, 2007:92-6, 98-9; Vakabua, 2007:103). Former Fijian Methodist Church President Talatala Ilaitia Tuwere stated yaqona importance in "hold[ing] the people and land together [to] save them from alienation like overseas countries" (1999:16). Tuwere (1999) comments that Fijian custom considers the drinking of yaqona a moral obligation (p.16) with consumption guided, informed, and founded upon the central ethos of vakaturaga (Ravuvu, 1987:26, 235). In essence, Vakaturaga (and its parallel *vakamarama;* womanly character traits) encapsulates the Fijian ideal, comprising "Chiefly" values irrespective of one's status such as *veidokai* (respect), *vakarokoroko* (humility), *kila na i yatu* (knowing ones place in the community), *qaravi tavi* (fulfilling obligations), *veiwasei kei na veikauwaitaki* (sharing and caring), *veivosoti* (forgiveness), *veivukei* (helpfulness) and *yalo malua* (a quiet demeanour) and *ideals*. Ravuvu (1987:18-19, 235) argues that this reinforces cultural identity and strengthens. Turner (1986) describes the kava ritual is a form of sacrifice, allowing the participants to communicate directly with supernatural (p. 203).

Aporosa (2011:230) further describes yaqona's significance within ritual practice as "deemed to be beyond measure and quantity, therefore 100 grams has the same value and importance as 1 kilogram, and *visa-versa* (Arno, 1993:79). This author further describes that "once prepared in its aqueous beverage form, yaqona becomes a sacred and living entity; one that both embodies *mana* and has the ability to enhance a person's *mana* " (Turner, 1986:209; Tomlinson, 2004:669). It was also noted in Ravuvu (1983:41), that certain aspects of kava ritualistic drinking formalities are observed as an automatic response by drinkers in less formal social drinking occasions. These traditional purposes for Kava use in ceremonies still hold true today, but vary in terms of the intensity and overall significance, depending on the type of ceremony/ritual or cultural activity being performed.

METHODOLOGY

Three upper watershed communities (Navala, Nadrugo and Nakoroboya) in northwestern Viti Levu (Fiji Islands), were part of a FORENET/USP/PACE-SD sponsored in-depth socio-economic and biocultural study from April to June 2011. One of the study's socio-cultural objectives was to focus on the anthropology of kava; which includes its symbolic meaning and cultural understanding that sustains its central place within Fijian social life. This study also highlighted the uses of kava (*yaqona*) as a valuable exchange item within social relationships and the spiritual and religious significance of kava consumption (Lebot *et al*., 2007). Participant observation and ethnographic analysis were used within an informal village settings in traditional *bure's* (Photo 2). A series of three community traditional *sevusevu's* and departure *ni tautau* sessions were conducted as well as 10 kava sessions in all three communities. Anon.

(2012a) and Lester (1941) reported that *Sevusevu* ceremonies are based similar activities and protocols and that most Fiji communities follow these rituals. Further explanation of the actual ceremony can be found in Appendix 1. *Sevusevu* sessions were used as ethnographic determinants (socio-cultural departure points) from which overall observations and conclusions were made.

Figure 2. Kava drinking in Nakoroboya village in traditional *bure* setting. (*With permission from participants.*) Photo by Sainimere Veitata, Research Assistant with FORENET Project.

Free, Prior and Informed Consent (FPIC)

There was the needed to incorporate free, prior and informed consent as an ethical and rights-based approach to research, especially dealing with human subjects and the analysis of livelihood strategies (IFAD, 2005). Essentially, "Free, prior and informed consent recognizes indigenous peoples' inherent and prior rights to their lands and resources and respects their legitimate authority to require that third parties enter into an equal and respectful relationship with them, based on the principle of informed consent" (IFAD, 2005). This approach was adopted in the introduction phase of the PACE-SD methodology (Appendix 2).

RESULTS AND DISCUSSIONS

Brief socio-cultural characterisation of three upper watershed communities

Table 1 and Table 2 show summaries of socioeconomic services and livelihood activities, respectively, in three villages in Upper Ba watershed.

Kava (*Piper methysticum* Forst.f), a member of the pepper family (Piperaceae), sustains a central place within upland Fijian culture and social life, based on its profound

Table 1. Summary of some generalized baseline socioeconomic (and other services) in three (3) villages in Upper Ba watershed (Ba Province).

Village	Number of households	Government services
Nakoroboya	57	- School - Village nurse - Tavua/Ba health centre's - Water supply
Navala	128	- Namau Government Station:- Health Centre - Navala Catholic Primary School
Nadrugu	70	- Water supply - For school they go to Navala and Bukuya Primary and into town for secondary education - Health service are acquired at Bukuya/Namau or Ba town

Table 2. Summary of the livelihood activities of the three (3) villages.

Livelihood activities	Nakoroboya	Navala	Nadrugu
Agriculture	Dalo and yaqona	Taro, cassava, banana, yaqona, dalo ni tana (*Xanthosoma sagittifolium),* sweet potato and also native and exotic fruit trees	Taro, cassava, banana, yaqona, dalo ni tana (*Xanthosoma sagittifolium),* plantain, sweet potato and also native and introduced fruit trees
Forestry	Pine	Pine, **vesi** *(Intsia bijuga*), **koka/togotogo (***Bischofia javanica*), **yasi (***Santalum spp*), **yaka (***Dacrydium nidulum*), **bua ni viti (***Fagraea berteroana*), **amunu (***Dacrycarpus imbricarpus)*	Pine
Freshwater resources	Prawns, eels, *Kulia repestris* (freshwater fish)	Prawns, eels, *Kulia repestris* (freshwater fish)	Prawns, eels, *Kulia repestris* (freshwater fish)
Village remittances	Part time work at the farm, and working in Ba town	Work in resorts making bures for tourism purposes and also part time work in Ba town.	Some villagers have their children and relatives sending money from outside the village (in towns)

symbolic meaning and cultural understanding (Lebot *et al.,* 1997). The FORENET research team found that in all three communities studied, Kava *(yaqona*) plays an integral part of the villagers' daily lives; either as a complementary social activity (both culturally and spiritually), in ceremonies or rituals, or as an important economic commodity (source of income to improve livelihoods). In a similar study conducted by Reddy *et al*. (2003; In: Prasad & Raj, 2006, p.13), it was found that the third highest expenditure item of urban households was on kava (after food and transport cost). These results are coincidental with preliminary household and livelihood data from the three upper watershed communities; revealing that kava production in Navala village was close to 100 kg per season; Nadrugu, 87 kg and Nakoroboya, 76kg. Household incomes varied from village to village, but the average range was between $120 FJD to $500 FJD per month (Figure 3).

Figure 4 summarises the importance of *yaqona* in the three villages studied. From a sample size of 25 households in each village, about 60%, the villagers spoken to in the kava sessions considered kava (compared to other forms of social/cultural activities) to be very important (48%); about 38% said that *yaqona* was somewhat important, and a smaller majority (13%) said that it was not that important.

Some women and non-drinkers (comprising the other 40% of the same sample size from each village) said that kava was not important and commented of its detrimental effects, addictive properties and overall misuse, which in turn contributed to tardiness (related to completing household tasks), laziness, as well as family disruptions and breakups.

Kava and its social, cultural and economic importance

Most kava drinkers in the villages considered that its importance rests primarily

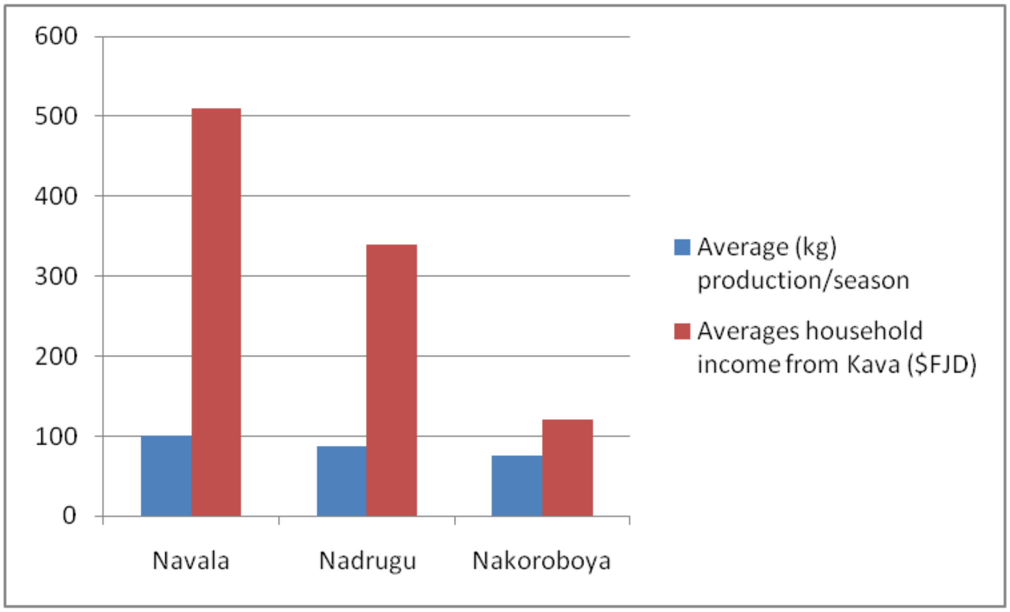

Figure 3. Average production (kg) and average household income ($FJD) derived from Kava (*Piper methysticum* Forst.f) in three villages in Upper Ba Watershed.

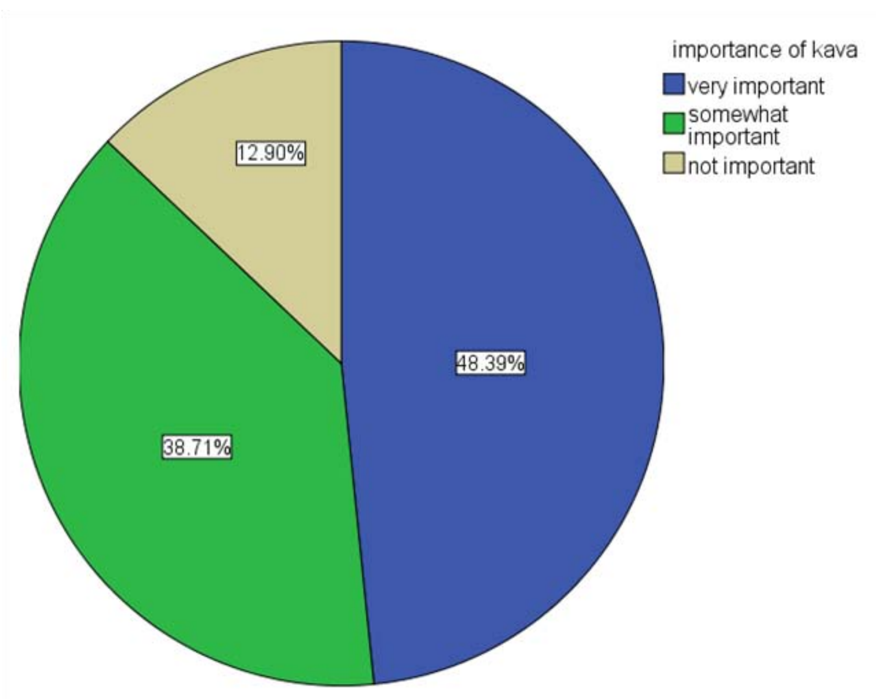

Figure 4. Importance of *yaqona* in all six villages in Upper Ba watershed. Results based on ethnographic analysis and participant observation.

on the fact that it is a source of income (mainly because of stable market prices, availability of local markets – Ba Town or Nadi). Local consumption of Kava in Navala village accounts for roughly 45%, and the remaining 55% is sold in markets (e.g. Ba town being the closest urban center where most of kava is marketed and sold). Smaller amounts are sold in markets in Tavua and Rakiraki, as well as Nadi. Similar results were obtained for Nadrugu village (30% local consumption; 70% local market mainly Ba) and Nakoroboya with a higher proportion of kava (85%) being consumed locally and the remaining 15% sold in markets; presumably because the opportunity costs of selling kava in markets (mostly Ba) was lower than consuming it locally. Respondents explained that it was more costly for them to transport to Ba market even with the high market prices for dry-kava roots. On almost all the farms in all three villages, Kava plants themselves maintain high rates of on-farm productivity. Most farmers commented on ease of accessibility to plants, cultivars and/or seed-plants (Figure 5), but complained that it was getting harder to find plants that can withstand drought or heavy rains, due to the effects of climate change. Respondents commented that due to unpredictable seasonal changes and intensity of extreme rainfall events, kava plants become stunted and necrotic (yellowing of leaves) due to excess water on poorly drained soils. Kava tends to grow slower than usual even with the same amount of care and maintenance.

Drought periods are becoming noticeably longer (particularly in "El Niño years") which affects the ability of the kava plant to produce strong, well-formed root systems. Slash-and-burn (or migratory agriculture) practices and deforestation causes upland forest degradation and soil erosion, which ultimately affects kava production. As an innovative adaptation strategy to the impacts of climate change, farmers in Bukuya (close to Nadrugu) for example are using an N^2 fixer *Leucaena leucocephala (Lam.) De Wit* (referred to as *vaivai)* as partial shade between young kava to supplement nitrogen and prevent soil erosion on slopes >20% (Figure 6).

Villagers also commented the spiritual and cultural significance of *yaqona* as a socialising tool to “break down barriers” and bestows upon them a feeling of “friendship and camaraderie”. Some villagers, however,

Figure 5. Washing kava in Nadrugu village, in preparation for drying. (*With permission from participant.*) Photo by D. Orcherton, 2011.

don't partake in the consumption of kava, which is considered an acceptable anomaly, depending on the circumstances or whether kava is used for ceremonies or other community events, or not. Other motives behind why Kava was not consumed in the villages, was considered to mildly 'neo-religious' (introduction of new forms of "religion' (e.g. Seventh-day Adventists, Jehovah's Witness, and Baptists), which discourage intoxicating beverages or other stimulants as part of their doctrine. This "missionary" rhetoric or influence particularly with respect to the cultivation and consumption of kava, has been at the center of its symbolic meaning and cultural understanding more than a millennium and has also shaped villagers' appreciations (or dislikes) of its many attributes.

The author considers "traditional" Fijian communities in this study as those that demonstrated a closer (tangible) association with historical, cultural, social and spiritual practices[9] for the past decade, through manifested oral histories, historical archives, anthropological and varied ethnographic research. The author also noted that more traditional communities like Navala village had a broader cultural respect for kava, and seem to not misuse it as much as other communities in the same watershed. This was primarily based on its deep-rooted cultural significance and symbolism with respect to the villagers' overall holistic understanding of the plant. Elders in Navala village, for example, keep a 'watchful eye' on the use of kava in the community. Nadrugu and Nakoroboya villagers (including the elders present in kava sessions) has less regard for misuse of kava, mainly because it was acceptable to drink kava for the "sake of drinking-it", or because it was easily available. In all three villages, special events such as funerals, births, or other festivals, were considered important, but seen as ways to indulge without too much concern for protocol; Navala village, however exhibited more rigor and rules that were adhered to in terms of kava use (or misuse). It was observed that women are permitted in the kava *sevusevu* ceremony in Navala village, and participated in the open-ended focus group discussion sessions. The presence of women in was also consistent with village protocol during *sevusevu* and *ni-tautau* sessions in Nadrugu and Nakoroboya villages (Figure 7).

Regardless of religious beliefs or new-

Figure 6. Community facilitator explaining the use of an "A-frame" for soil conservation on hillsides. Farmers are using *vaivai* (*Leucaena leucocephala* (Lam.) De Wit, as light-shade for their kava, and use an A-frame for planting on-contour to improve soil conservation on steep hillsides. *Photo by Matthew Kensen*.

[9]Mainly refers to the maintenance/practice of traditional agriculture, soil conservation, Fijian folklore, transmission of life-stories and oral narratives, maintenance of traditional folkways, use of medicinal plants , , care and maintenance of crops for food security, as well as maintenance of traditional livelihoods.

found devotions, *yaqona* was seen by Navala villagers' as an "acceptable and accepting beverage that is used to welcome outsiders and collaborators". Kava consumption promotes tranquility, sociability and enables peacefulness among villagers. Many commented on its abilities of kava to calm the nerves and promote negotiations were tensions are sometimes high. Some villagers commented that kava sessions are good for negotiating land tenure, work in *matagali's* and planning for crop or tree planting and harvesting.

Kava drinking practices have carried over to shape the ways that these villagers use alcohol (and more recently introduced drug): consumption is typically social rather than solitary; people drink quickly; men drink more than women; drinkers empty entire bottles at once, just as they drink the bottom of the comparable; and so on (Lebot *et al.,* 1997, p.140). Historically however drinkers normally sat silently, as noise and bright lights can spoil kava affects (Lebot *et al.,* 1997). In much of Vanuatu example, kava drinkers quietly listen to the effects of the drug and to the voices of their ancestors (Ashby,1984; Emerson 1903). Emerson (1903) also noted that "this idea which so prevails among Hawaiians that [kava] drunkenness is a goal of the drinker, has this tendency, when they give themselves to the use of alcohol stimulants, to make them hard drinkers" (p. 3). Expectations of social and peaceful kava drunkenness from villagers in Navala, Nadrugu and Nacoroboya, contrasts with what to expect from alcohol (Lindstrom, 1982). In many cases, Pacific Islanders understand that alcohol makes it drinkers unruly and violent whereas 'peaceful kava' invokes the coexistence of two psychoactive drugs in many Pacific societies are strengthened by these opposed expectations of their effects (Philibert, 1986). In other words, peaceful kava informs disorderly alcohol, and *vice versa* (Lebot *et al.,* 1997, p. 140). Very little influence of alcohol was present, even in habitual kava drinkers in all three villages studied.

Origin myths (Malinowski, 1948) have been at the centre of Pacific societies for a long time, and myths themselves often

Figure 7. Assistant *Turaga ni Koro* in Navala village mixing kava with women in traditional *bure*. (*With permission from participants.*) Photo by D. Orcherton, 2011.

serve as a kind of narrative deed or claim to land and other important resources; they also function as sacred constitutions for existing social groups (Malinowski, 1948). The underlying narrative structures and core symbols concerning origin myths encapsulated specific Fijian worldviews; *na Kalao* (God); *na Vanua* (including the land, people, ancestors, spirits, environment, landscape, seas, and water bodies); *Na Tamata* (human beings). Villagers commented as well on a spiritual dimension that *yaqona* helps to "bring to the surface", particularly in *Vugalei* (where there are places or spots that are known to be *tawa* (occupied/ filled with spirits). *Vugalei* believe that there is a power of darkness in their world that could be avoided if people were widely informed of one's *rai* (Baba, 2006, p.47). One of the things that were discovered in the kava sessions was this connectedness to their spirit-world, and that *Vugalei* Fijians believe in the force or spiritual power of *mana*- the power with which most things in the *vanua* are said to have life. Most ceremonial presentations in the three villages involved giving of *mana* to people, and it is spoken of in daily life (Baba, 2007, p.49).

Kava's origin myths are recounts of external provenience that centered on ancestral heroes and descended from heaven that bestowed kava to the people (Lebot *et al.,* 1997). For the villagers of Nadrugu and Nakaroboyo (Figure 8), and as described in the open-ended sessions, *yaqona* comes from and causes death, but for the villagers of Navala (Figure 9), origin myths are commonly associated with sugar-cane myths, due to the villages' close association with Fijian cane growing cultures, descendent from immigrant Indians. These origin myths coincide with findings from Malinowski (1948) where often these were interpreted as social charters, and as a kind of narrative deed or claim to land and other important resources. According to Lebot *et al.* (1997), origin myths also served as sacred constitutions for existing social groups (Malinowski, 1948, in Lebot *et al.,* 1997). In terms of kava's life giving properties, respondents also told of kava's apparent medical uses and are associated with garden fertility magic and first fruits ceremonies. This coincides with Sahlins' findings that kava resembles symbolizes life giving fluids (semen or mother's milk) (Sahlins, 1981). Within the Fijian culture, rules define social status and create and nurture relationships and social status, but these relationships also regularly access to the drug. Villagers in Nadrugu and Nakoroboya communities (though unintentionally) seem to misuse kava and undermine its legitimacy in a social or cultural context, which in turn destabilizes the communities public health and well-being. Some of the habitual drinkers have skin problems, breathing difficulties and other ailments that seem attributed to chronic substance abuse. There seems to a better response from Navala villagers in terms of gauging overuse, which was coincidental with more traditional uses of kava for medicinal and therapeutic purposes.

In terms of social consumption and exchange, all three communities exhibited similar characteristics; that kava ceremonies promoted tranquility, sociability and acceptance of the local political hierarchies. Many of the community-based land organizations and working relationships were divided into *matagalis*[10] and clan-based kinship relations are strengthened by kava preparation and consumption, which fortified farming tasks and responsibilities. Navala village exhibited stronger traditional ties held together by both utilitarian and ceremonial exchange however in all three villages kava was used to improve and sustain social relations among family members and among village residents. The most valuable exchange tokens were the *yaqona* wrapped in newspaper[11] (Figure 10) but more importantly, were people themselves. These observations coincide with results from Lebot *et al.*,1997, and Toren, 1988) where kava exchange is ritually formalised for important social occasions (Lebot *et al.*, 1997), and is a form of conflict resolution and building political alliances.

[10]*Matagalis* are land-based divisions based on clan or kinship relations in communities. Many of the *mataglis* that are known are based on historical and cultural understanding of their land–based resources.

[11]The kava presented in *sevusevu* has to be dried roots (not powder). The newspaper wrapping around the roots is less significant than the cultural/spiritual gestures during the ceremony itself.

Figure 8. Village Head man (left) and wives discuss the importance of Kava as part of their daily livelihood and family economy. (*With permission from respondents in Nanoko village.*) Photo by *D. Orcherton, 2011.*

Figure 9. Stories are often told by villagers during kava sessions. (*With permission from Navala Village Development Committee.*) Photo by Sainimere Veitata, 2011.

Figure 10. Jale Turaga (Forestry Department/FORENET volunteer researcher) presenting the kava root (wrapped in newspaper) at *sevusevu* ceremony (Navala Village). (*With permission from Navala Village Development Committee.*) Photo by D. Orcherton, 2011.

The traditional rites of passage (e.g. weddings, funerals, male and female initiations) of Fijian societies still exists, however in recent years there has been more influence of the Catholic Church and other religious denominations in these villages that has deterred people from more traditional/ ceremonies or traditional means of exchange (Lebot *et al*., 1997).

In all villages studied, the mixing of kava seemed ritualistic and according to protocol, however traditional roles and responsibilities were less defined in Nadrugu (Figure 2) and Nakaroboyo. Rhythmic hand-clapping was common in kava preparation ceremonies which varied slightly from village to village. Elders commented that cupped hand clapping was a way to awaken their awareness and bring more "life to the supernatural". Laughing, noise and social exchange of jokes, stories and legends were also quite common in all three villages and a way of forging camaraderie and social relations (Figure 5).

CONCLUSIONS

The study concluded that kava remains at the social, cultural and economic centre of many Fijian cultures and communities, particularly in the upper Ba watershed of Viti Levu. Kava is especially important economically for these villages, and provides an important peacemaking function. Navala village represented a more intense and profound symbolic meaning and cultural understanding of kava based on historical accounts and spiritual connectedness to the plant. Village elders upheld and safeguarded kava protocols, stories and traditions. Nadrugu and Nakoroboya however exhibited a less intense cultural understanding of kava based on progressive and/or varying degrees of acculturation and changing traditional mores and customs. Though the economics of *yaqona* was beyond the scope of this study, elders from these later two communities attributed *yaqona's* use value more from an economic standpoint rather than emphasising its spiritual or cultural importance. The cultural significance and social uses of kava (*yaqona*) are important in all three communities studied and contribute to forging strong social and cultural relationships.

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APPENDIX 1

The Fiji kava ceremony

At each fiji-kava-ceremony the following are required:

1. Pounded kava and water,
2. Kava Strainer,
3. Tanoa; a wooden bowl carved explicitly for this purpose, with a length of woven coconut coir attached to a "bulivula" (Ovula ovum) - akin to a golden cowrie seashell,
4. Kava bowls; fashioned usually from coconut shells,
5. A person to mix the kava, flanked by two others on either side of him,
6. A person to deliver the kava bowl to the main guest, and for dignitaries
7. A group to chant the kava dance mantra, for the cup bearer to dance his way to deliver the VIP's bowl of kava.

The "sevusevu"

If the welcoming party is aware of the visiting delegation, it is customary they present their "sevusevu" first before the visitors reciprocate.

After this "sevusevu" presentation, a round of kava drinking ensues from the mixture made ready before the "sevusevu" was presented.

Alternatively, if the visitor arrives unannounced then the visiting delegation ought to present their "sevusevu" first.

After the visitors or welcoming party have presented their "sevusevu", it is received with great solemnity by the leader of the unit, or one of his nominees.

After the "sevusevu" presentations have ended, small talk then ensues which should lead into the matter to be discussed. It should be noted that at some point before the meeting is ended, both parties' kava "sevusevu" should be drunk, as fulfillment of the reception

*[Adopted from: Fiji Taro and Kava (2012), and Lester, R.H. (1941), Kava drinking in Viti Levu. Oceania **12**: 97-124).*

APPENDIX 2

Free, Prior and Informed Consent Procedures

Step 1: Determined who the main stakeholders were, and why they were interested in the project.

Step 2: Requested information from the project and distributed this to key community stakeholders.

Step 3: Held discussions with the community. This was done through previous contact in the post graduate level Climate Change post graduate level course (EV414).

Step 4: Identified community facilitators or negotiators for undertaking the project.

Step 5: Sought independent advice through the USP-PACE-CCA (Climate Change Adaptation) project and other experts in community based vulnerability and assessments.

Step 6: Made community decisions (by consensus) and joint collaborative efforts locally.

Step 7: Maintained on-going communication with FORENET Project**.**

Approach to address bean acidity problems in Papua New Guinea cocoa using solar dryer technology

Noel Y. Kuman[1]

ABSTRACT

Dried cocoa beans from an adaptive solar dryer trial shown a markedly reduced acidity, hence improved other ancillary cocoa flavour attributes. High level of bean acidity would otherwise mask other desirable cocoa flavour attributes. Analysis of variance of solar and conventional dried beans indicated a significant difference in acidity ($P \leq 0.05$) and bitterness ($P \leq 0.05$). Solar dryers technology also has the potential to totally eliminate smoke contamination resulted from beans dried using kiln dryers, which is widely used by cocoa growers in Papua New Guinea.

Key words: Solar dried beans, flavour characteristics.

INTRODUCTION

Papua New Guinea (PNG) cocoa is perceived to contain high levels of acidity and smoke contamination, which reduces its acceptability by consumers. Acidity of beans is one of the major quality problems affecting cocoa produced by non-traditional producers such as of South East Asian origin, including PNG. The bean acidity problem is the result of acids produced during fermentation which migrate into the bean kernel; beans in the pods are usually sterile and have a neutral pH. During drying, most of the volatile acids that build up inside the bean kernel during fermentation are evaporated, while mostly non-volatile acids remain in the beans, eventually giving rise to an acid taste. Bean acidity is measured in pH and Titratable Acids (TA). Detailed investigation of bean acidity has confirmed a very strong correlation (r = 0.98***) between pH and total TA (Chong *et al*., 1978). A study of the citric acid cycle and carboxylic acid, carried out to determine the cause of low pH of cocoa, indicated that carboxylic acid (acetic and lactic) appears to contribute most to low pH (Rohan & Stewart, 1965).Traditional box fermentation of South East Asia produces beans that have excessive acidity (pH 4.4-4.7). Chocolate derived from these beans is not entirely acceptable having bitter taste and lacking chocolate flavour strength (Shepherd, 1976). Biehl *et al.* (1985) reported that cocoas exhibiting lower than desirable levels of chocolate flavour may have higher levels of acidity. Generally, the levels of acetic and lactic acids are considerably higher in beans produced by non-traditional cocoa producers imparting the overall flavour balance of cocoa (Wood & Lass, 1985). The broad ranges of acids found in cocoa beans are acetic, lactic, citric, malic, oxalic, propionic, succinic and tatartic acids. The major acids found in large proportions are lactic and acetic acids.

Holm & Aston (1993) proposed that lactic acid had a greater influence on the acidic taste of cocoa than acetic acid; the latter plays a secondary role. While acetic acid greatly influences pH and TA, it does not influence acidic flavour, unlike lactic acid which suppresses desirable flavour characteristics. The oxalic acid concentration correlates positively with cocoa flavour and is associated with desirable flavour characteristic. Holm and Aston's results may elucidate a possible correlation between flavour and organic acids but not all the compounds that have the potential to affect flavour were investigated.

PNG has been marketing its cocoa based on it unique flavour attributes that need to be protected and improved. However, the future marketing prospects of PNG cocoa would decline, including losing its current and potential consumers, if the current quality

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problems are not seriously addressed. Given that cocoa remains as the major source of income for a majority of smallholder famers in the coastal regions of the country, any changes in marketing of cocoa would affect their main source of income. A study by Yabro & Nobel (1989) indicated that between 80-100 percent of the smallholder farmers in East New Britain, East Sepik and Oro province depend on cocoa as their main crop for cash income. Smallholder farmers contribute 75 percent of PNG's total cocoa export volume, while the remaining quantities are supplied by the plantation sector.

The flavour potential of any genotype cannot be fully appreciated if the beans are not correctly processed. Defects in post-harvest processing such as in fermentation and drying can alter or misrepresent the flavour profile. Non-fermented (slaty) or partly fermented (violet in colour) beans lack cocoa flavour. Slaty beans produce an acid and stringency flavour profile, while violets beans produce a bitter and harsh flavour (Kattenberg & Kemmin, 1993). Over-fermentation produces beans with dark-coloured cotyledon and little chocolate flavour (Wood, 1975). A putrefying odour is produced from over-fermented beans or beans from failed fermentation.

Deterioration in export bean quality is one of the major problems affecting the PNG cocoa industry. Major importers of PNG cocoa such as European buyers have raised concerns about poor bean quality (PNGCCRI, 1988). The major quality and flavour concerns raised are bean acidity and smoke contamination. Cocoa flavour is contaminated when beans are dried using kiln dryers that are not properly constructed or lack proper maintenance (PNGCCRI, 1995). Smoke contaminated beans cause a smokey off-flavour in the chocolate, which cannot be removed during the chocolate manufacturing process (BCCCA, 1996). Smoke contamination generally results from processing deflect but some genotypes are also known to produce smoky and phenolic off-flavours (Clapperton, 1994).

Under the Cocoa Quality Improvement Program (CQIP) of the PNG Cocoa and Coconut Research Institute (PNGCCRI), funded by the Australian International Development Assistance Bureau (AIDAB), the major quality issues including high bean acidity and smoke contamination were addressed. Solar dryer technology is considered as an alternative drying method that has the potential to alleviate high bean acidity and smoke contamination problems. Different types of solar dryer prototype models were developed and tested to assess suitability and performance under the agro-ecological conditions of PNG (Kuman, 1997). A suitable solar dryer prototype developed from this trial would provide an alternative method of drying cocoa beans to address smoke contamination and reduce bean acidity.

From the research conducted, a solar dryer prototype was selected based on its performance and suitability. The new solar dryer is constructed as an A-frame of timber and clear laminated plastic sheeting. Black painted rocks heat up in the sun and the warm air passes by convection through the drying rack (Hollywood *et al*., 1996). A total of 30 solar dryers of the selected prototype were constructed and distributed to smallholder farmers around the Gazelle area of East New Britain province during 1996-1998 to assess their performance under field conditions. The solar dried beans from the adaptive trial were collected on a weekly basis and their organoleptic attributes were analyzed. The average results of the quality assessment are presented and discussed in this paper.

Objective

A relative assessment of the organoleptic properties of cocoa dried using solar or kiln and diesel fired dryers.

MATERIALS AND METHODS

Experimental design

Cocoa beans were fermented using the mini- fermentation box described by Kuman & Hollywood, 2009.

Sample collection & preparation

Approximately 500 g of dried beans were collected from each of the 30 solar dryers distributed throughout the Gazelle area of East New Britain province on a weekly basis from 1996 to 1998. Representative samples from the solar drier trial were randomly collected together with equal quantities of conventionally dried beans. The samples were prepared at the PNGCCRI cocoa quality laboratory. The samples were oven dried (Contherm, New Zealand) at 115 °C for 15 minutes to standardize moisture content to less than 7 % before being emptied into a quartering device and thoroughly mixed. The samples were bagged and sent to Nestle, UK, for flavour assessment. Ghana samples were used as an industrial standard for "bulk" cocoa and were included as references for organoleptic assessments.

Flavour assessment

Organoleptic evaluation was conducted by trained taste panelists following a described procedure (BCCCA, 1996; Sukha, 2001). The flavour intensity was estimated using a 0-10 scale, with 0 being weak and 10 being strong. Individual flavour attribute scores from the flavor profiling were used to determine the mean. Variance component were investigated using analysis of variance (ANOVA) to determine significant differences between treatments and the significance of interactions.

RESULTS

Figure 1 shows that solar dried beans on average have lower levels of acidity. The mean pH values for solar and conventionally dried beans were 4.80 units with a TA of 0.243 and 4.60 units and 0.26 milligrams equivalent (meq) citric acid /100 g respectively (Table 1). In a few cases, acidity levels of solar dried beans were the same as conventionally dried beans as the result of a bed loading less than 50 kg /square meter (kg / sqm). The solar dryer prototype has the potential to dry cocoa at a bed loading rate of 70-72 kg / sqm, which is equivalent to 280-290 kg of fermented beans (Kuman, 1997).

The solar dried beans on average have lower level of residual acidity as compared to conventionally dried beans which are expressed by the pH and TA values.

The cut test results in Table 2 indicate that solar drying produced a higher percentage of brown and partly brown beans with less purple as compared to beans dried using conventional dryers.

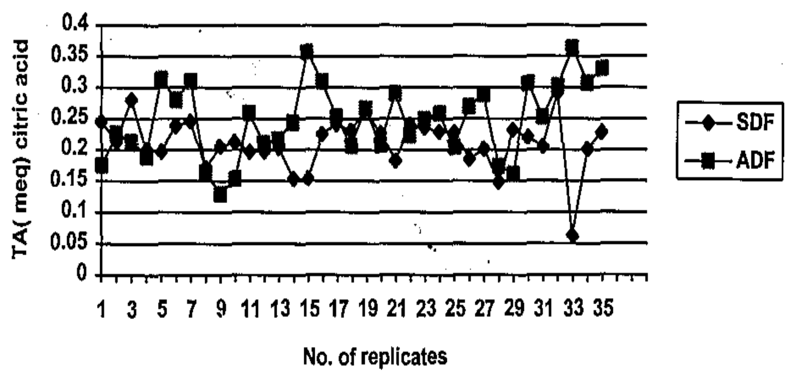

Figure 1. A comparison of acidity levels of artificially and solar dried beans.

Table 1. Mean quality attributes of solar and conventionally dried beans.

Mode of drying	pH	Titratable acidity (TA)
Solar dried bean	4.80 (±1)	0.24 (± 0.2)
Commercially dried beans	4.6 (± 0.6)	0.26 (±1 0.1)

Note: The higher the pH value, the lower the acidity, or vice versa. The higher the TA value, the lower the acidity or vice versa.

Table 2. Average cut test result of solar dried beans from adaptive trials.

	Quality attributes						
Mode of drying	Brown	Partly brown	Purple	Germinated	Slaty	Criollo	Mouldy
Solar dried beans	44	32	20	-	-	4	-
Artificially dried beans	39	30	27	-	-	4	-

The flavour profile results shown in Table 3 indicate that PNG cocoas are dominated by strong fruity and acidic flavours which are quite different from the Ghana reference sample. There are significant differences in bitterness and acidity between solar dried and conventional dried beans.

Discussion

Analysis of variance of solar dried and conventionally dried beans has indicated that there are no significant differences ($P > 0.05$) in any flavour attributes except acidity ($P \leq 0.05$) and bitterness ($P \leq 0.05$). However, there are clear differences in fruity ($P \leq 0.001$), acidity ($P \leq 0.05$), cocoa (chocolate) ($P \leq 0.001$) and bitterness ($P \leq 0.05$) flavour attributes of both solar and conventional dried beans when compared to the Ghana reference sample. PNG cocoa does not achieve the chocolate, brown fruit/winey flavour intensities like the Ghana reference samples.

The other important achievement for the solar technology is that it totally eliminates smoke contamination, which addresses one of the biggest complaints regarding PNG cocoa resulting from beans dried using kiln dryers that are not properly maintained.

The solar dried beans have lower residual acidity as indicated by higher pH and lower TA values as compared to commercial fermented beans (Table 1). Solar dried beans were dried at a slower drying rate allowing more volatile acetic acid to evaporate. The permeability of the bean shell is maintained over a longer period of time, providing adequate time for the volatile acids to evaporate. On the other hand, beans dried using kiln or diesel dryers are dried at a faster rate resulting in a more rapid hardening of bean shells which prevents evaporation of all volatile acids thus giving rise to high levels of bean acidity. Sensory tests for solar dried beans have shown them to have distinct chocolate and other ancillary flavours with lower astringency and bitterness as compared to kiln and artificially dried beans (Kuman, 2009).

The slower drying rates of solar dryers also allow sufficient time for completion of oxidative reactions resulting in the conversion of bitter polyphenols to insoluble tannins and browning of beans. Polyphenols are responsible for bitterness and astringency (Rehm & Reed, 1983). Browning of beans is considered to be the most important change

Table 3. Comparison of flavour profiles of solar dried beans against conventionally dried beans and the Ghana reference sample.

Flavour attributes	PNG standard (conventionally dried bean)	Solar dried beans	Ghana reference sample
Cocoa (chocolate flavour)	6.5	7.5	9.5***
Acid (acetic)	5.0	3.6*	2.9***
Bitter	4.4	3.9*	3.4
Burnt	1.6	1.0	1.4
Winey	8.5	7.8	9.4
Brown fruit	3.1	5	2***
Floral/fruity	3.7	2.6	3.2*
Green	3.1	2.1	1.8
Astringency	4.7	3.6	2.6

*$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$ Not significant (NS) $P > 0.05$

i) The chocolate flavour of Ghana cocoa is significantly (***$P \leq 0.001$) different to cocoa flavours of conventionally and solar dried beans. The flavours (acid & bitter) of conventionally dried beans are significantly (*$P \leq 0.05$) different to cocoa flavours of solar dried beans and Ghana samples. Brown fruity and floral flavours of Ghana cocoa are significantly (***$P \leq 0.001$, *$P \leq 0.05$) different to cocoa flavours of solar and conventionally dried beans.

ii) Flavour intensity was estimated using 0-10 scale, with 0 being weak and 10 being strong. Flavour intensities scale: low intensities 1-3; Medium intensities 3-6; strong intensities 7-10.

which starts during fermentation and continues during the initial stages of drying.

There were dominant fruity and acid flavours present in all PNG cocoa samples. The fruitiness resembles fresh ripe banana with fruit acid notes balanced with a good basal flavour. The fresh ripe fruit, acids and sometimes "winey" flavours distinguish PNG cocoa from the Ghana reference samples (Table 2). The unique flavour characteristic of PNG cocoa could be the result of the local breeding and selection programmes, the role and influence of local growing conditions (climatic and edaphic - e.g. volcanic soil) or other exogenous factors leading to local adaptability. There are significant differences in acidity ($P \leq 0.05$) and bitterness ($P \leq 0.05$) between solar and artificially dried beans. However, PNG cocoa produces pronounced fruitiness though it does not achieve the cocoa, brown fruit/winey flavour intensities of the Ghana reference samples.

CONCLUSIONS

Solar dried beans have the potential to reduce the bean acidity problem, one of the major quality problems of the PNG cocoa industry, once the solar dryer prototype developed and tested is adequately promoted and widely adopted by the cocoa growers in recommended agro-ecological zones within the country. Reduction in bean acidity has shown to improve other ancillary flavour attributes that would otherwise be masked by the high level of bean acidity. Solar dried beans also have a significantly lower level of bitterness as the result of slower drying rate in solar dryers which allows completion of oxidative reactions responsible for converting bitter polyphenol compounds into insoluble tannins as well as producing a high percentage of brown beans. PNG produces cocoa with unique fruity flavour attributes very specific to local growing conditions as compared to the reference Ghana sample. PNG needs to continue marketing its cocoa by improving and at the same time preserving its specific unique blend of flavour characteristic which is favoured by different manufacturers. Farmers need to follow all standard post-harvesting processing techniques to produce a consistent quality of beans with optimum desirable flavour attributes.

Furthermore, solar dried beans have the potential to totally eliminate smoke contamination resulting from beans dried using poorly maintained kiln dryers, another major quality problem encountered by the PNG cocoa industry. There is no fixed discount on cocoa which is tainted with smoke contamination but it is estimated that a discount of $US135-150 per tonne is usual. Solar technology may provide the best solution of the smoke contamination problem of PNG cocoa. The PNG cocoa industry needs to promote and fully exploit the solar dryer prototype that has the potential to address these two of the major quality problems of the cocoa industry. Cocoa growers need to be supported to adopt the solar dryer technology which is cheap, durable and environmentally friendly. For wetter regions of the country, trials will be conducted to combine solar with kiln dryers or converting existing wood-fired dryers to combined solar and fuel-fired dryers.

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Optimization of flowering, pollen quantity and seed production in taro (*Colocasia esculenta* var. *esculenta*)

Rosalene Sharma[1], Mary Taylor[2] and Anjeela Jokhan[1]

ABSTRACT

Taro (*Colocasia esculenta* var. *esculenta*) is tremendously known for its importance in Pacific people's traditions, and its fundamental role in national food security, economic, sustainable and rural development in the South Pacific region. This paper aimed to optimize flowering and seed production in taro. This was carried out by researching the environmental and physical conditions that best suited to achieve maximal seed production. Taro (*Colocasia esculenta* var. *esculenta*) of the PNG cultivar was used for the purpose of this study. Gibberellic acid at a concentration of 500 ppm was used to promote flowering and hand pollination was carried out to promote fertilization. Taro exhibited a requirement for long day length, total light radiation, warm temperature, and nutrition and water availability to flower efficiently. The success of pollination was dependent on the weather, skills used, the receptivity of the female flowers, quantity of pollen applied on the female flowers and the well-being of the plants. It was obvious that pollen production was specific to warmer temperatures. Berries developed in fruit heads in approximately a week and matured in 30-40 days. The seeds in the berries of the fruit heads that dried up before 30 days were immature. A range of 1-15 seeds were found in different berries and even within the berries of the same fruit head. This research will not only be useful for taro conservation and propagation purposes, but will also benefit taro breeding programmes and related research work.

Key words: Taro, *Colocasia esculenta* var. *esculenta*, flowering, pollen quantity, seed production.

INTRODUCTION

Taro (*Colocasia esculenta* (L.) Schott) is principally propagated vegetatively using suckers (Shaw, 1975; Strauss *et al*., 1979; Kuruvilla & Singh, 1981; Ivancic, 1992) since many taro cultivars do not flower naturally. Some cultivars of *Colocasia* have been reported to flower naturally and in some of these locations naturally set seeds have been collected and germinated (Wilson, 1984). Nevertheless, it has been well documented that applications of gibberellic acid promoted flowering in taro (Hanson & Imamuddin, 1983; Wilson, 1990; Ivancic, 1992). Ivancic (1992) observed that there were several other possibilities for promoting flowering other than the treatment with gibberellic acid, though these were specific to diploid plants only. They are possibly the removal of cormels, suckers, stolon and leaves from well-developed plants, replanting old plants when one flowering cycle is over to enable a new cycle to start and finally inducing stress by drought and excess or cold temperature. However, the effects vary from species to species, from cultivar to cultivar within the same species, from region to region as well as from season to season (Ivancic, 1992).

Generally, plants flower or respond to environmental stimuli, which set off flowering when they have completed a certain period of vegetative growth (Opik & Rolfe, 2005). The timing of the transition from vegetative phase to flowering phase is of paramount importance in agriculture, horticulture and plant breeding because flowering is the first step of sexual reproduction (Bernier *et al*., 1993). A number

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of environmental factors such as temperature, day length and endogenous plant rhythms have been identified as being either essential or may hasten or perhaps delay flowering in plants. Autonomous factors such as size and age of plants, and the nutritional status may also regulate flowering in plants that may be interactive (Taiz & Zeiger, 1998).

The quantity of pollen produced is also of chief importance since they control and dominate the pollination process, which is the integral part of seed production. Several environmental factors such as temperature, herbivory, soil fertility and mycorrhizal infection have been found to affect pollen production in plants by altering pollen grain size, flower number and/or pollen production per flower, and growth and/or competitive ability of pollen tubes of the pollen producing parent (Lau & Stephenson, 1994). In addition, a few studies have demonstrated that environmental conditions during anther development can also affect the chemical composition of pollen (Herpen & Linskens, 1981; Lau & Stephenson, 1994). The environmental effects to taro flowering and pollen production have not been extensively studied (Wilson, 1984), but Onwueme (1999) confirmed that long day conditions promoted flowering in taro.

Taro is a monoecious angiosperm plant where male and female flowers form on the same individual. Cultivars of *Colocasia esculenta* var. *antiquorum* were found to produce large amounts of seeds while cultivars of *Colocasia esculenta* var. *esculenta* yielded a very low number of seeds (Jackson & Pelemo, 1980; Strauss *et al*., 1980). Wilson (1990) pointed out that taro was basically a cross-pollinated species since pollen was carried by water (rain), wind or some insects. The degree of cross-pollination depended on the openness of flower, flower type, weather conditions, wind velocity, presence of insects, nutrition, variety, density of flowering plants, shade and other factors (Ivancic, 1992).

Receptivity in *Colocasia* appears to be variable. Stigma has been found to be receptive before pollination (Ivancic, 1992) for up to 1 to 3 days prior to pollination (Jos & Vijaya Bai, 1977; Jackson & Pelemo, 1980; Pardales, 1980). However, Wilson (1990) disputed this stating that depending on the location and taro cultivar, female flowers may be receptive one day prior or the same day as or one day after pollen shed. Self-pollination in taro was believed to be extraordinary due to the unique arrangement of the male and female flowers that were located in separate regions in the spadix (Prakash & Nayar, 2000). However, pollination can be easily accomplished by hand.

This paper reports the studies on the optimization of flowering, pollen quantity and seed production in taro of the Papua New Guinea (PNG) cultivar in relation to the autonomous factors and environmental conditions that best suit flowering, pollen and seed production in taro that will be of practical importance. This study will compliment the effectiveness of taro seed conservation, breeding programmes and also appreciate the relationship between flowering, quantity of pollen produced and seed production in taro.

MATERIALS AND METHODS

Study species

Taro (*Colocasia esculenta* var. *esculenta*) of the Papua New Guinea (PNG) cultivar is a monoecious plant belonging to the genus *Colocasia*, within the sub-family Colocasioideae of the family *Araceae* (Onwueme, 1999). It is a herbaceous plant that grows to a height of 1-2 m. The plant consists of a central corm that is the main stem, leaves, fibrous roots and stolons that grow laterally along the surface of the soil for some distance and root down at intervals to give rise to new plants. The distinguishing feature of the PNG cultivar is the purple colour of its petiole. PNG cultivar was selected for this study as it is incapable of natural flowering. Experimenting on this variety showed that the methods used for seed production could work with any taro cultivar if it worked well with the present cultivar.

Study site

This experiment was performed in the glasshouse and the experimental plot land at the University of the South Pacific in Laucala Bay, Suva, Fiji (18°09' S, 178°27' E) from June 2007 till January 2010. The climate was warm and wet during November through April and cool and dry from May through October. Taro suckers were planted in five different batches at different times of the year and in different locations to understand its flowering, pollen and seed production at different seasons and environmental conditions. Suitable environment for flowering was created inside the glasshouse by illuminating the glasshouse with 12 hours of light daily and using two 1000 watts lights (30 000 lux) to provide warmth. The soil used for planting was a mixture of one part of poultry manure, one part of river sand and five parts of garden soil. Normal agronomic practices were carried out to maintain the good health of the plants. Data loggers were used to measure the ambient temperature and humidity in the glasshouse and in the field. The temperature in the field ranged from 22-26 °C during the cool months and 28-34 °C during the warm months whilst the temperature in the glasshouse ranged from 23-27 °C and 29-35 °C, respectively during the cool and warm months. The relative humidity ranged from 61-87 % in the glasshouse and 61 -88 % in the field.

Flower induction, pollination, harvesting, seed extraction and drying

Flower induction, pollination, harvesting, seed extraction and drying were carried out using the procedures described by Wilson (1990) and Tyagi *et al.* (2004).

Pollen production

The effect of temperature on pollen production was evaluated at two different times of the year: during the cool season (25±1 °C, 50-65 % RH and 10 hours day length) and during the warm season (30±1 °C, 70-85 % RH and 12 hours day length). Data loggers were used to measure the temperature and relative humidity. The pollen production was evaluated by observing pollen grains. Good pollen production was recorded when the male spadix was completely covered with pollen and also some pollen that had fallen off was collected in the spathe, and poor production was recorded when there was little pollen shed.

Taro seed extraction and seed drying

Matured fruit heads that had become soft were harvested from plants and soaked in 10 % sodium hypochlorite solution for two minutes to kill any fungi that might have been present in it. The seed extraction and drying were carried out as described by Wilson (1990) and Tyagi *et al.* (2004). Caution was observed not to keep the seeds near the fan or windy area where the seeds had a chance to blow away after being dried. The data on the mean number of seeds per individual berries was obtained by counting the number of seeds present in ten randomly selected independent berries of the same fruit head. The seed count was repeated for ten randomly selected fruit heads.

RESULTS

Flowering in taro

The effects of gibberellic acid were observed as the signs of flowering that were evident 30 to 60 days after the application of gibberellic acid depending on the season. The observable signs of flowering were patches of purple colour on the leaves that correlated with the colour of the inflorescences, enlarged leaves, elongated petioles, production of more suckers and stolons than usual, incomplete inflorescences and flagged leaves. Suckers that were planted and treated with gibberellic acids during the cool months and short day lengths had more vigorous growth and took a longer time to flower than the suckers that were planted during warm conditions and long day lengths or under controlled conditions. Flowering initiated after 90-120 days following the application of gibberellic acid during the cool season and 60-90 days during the warm season (Table 1).

The inflorescences appeared from the shoot apical meristem and also from the stolons, which was rare. All the plants, planted irrespective of the time of the year and applied with gibberellic acid had flowered (Table 1). There was a significant difference ($P < 0.05$) between the number of inflorescences produced in plants kept under various conditions during the flowering period. The plants that were under full sunlight, watered daily and supplied with nutrients had produced significantly ($P< 0.05$) the most inflorescences per plant (an average of eight inflorescences per plant) during its flowering period than the plants that were kept under other various conditions. An average of seven inflorescences per plant was produced under full sunlight + daily watering + no fertilizer, six inflorescences per plant under full sunlight + water stress + fertilizer, five inflorescences per plant under shade + daily watering + fertilizer, four inflorescences per plant under both shade + daily watering + no fertilizer and full sunlight + water stress + no fertilizer, three inflorescences per plant under shade + water stress + fertilizer and two inflorescences per plant under shade + water stress + no fertilizer (Figure 1).

Table 1. The relationship between the approximate number of days when flowering initiated after the application of gibberellic acid, the percentage of plants that flowered and the environmental conditions during the vegetative and reproductive phases.

Batch	Approximate no. of days when flowering initiated	Percentage of flowering (%)	Environmental Conditions	
			During vegetative phase	During reproductive phase
1	120	100	cool and short day lengths	warm and long day lengths
2	60	100	warm and long day lengths	warm and long day lengths
3	60	100	warm and long day lengths	warm and long day lengths[a]
4	60	100	warm and long day lengths[a]	warm and long day lengths[a]
5	90	100	towards the end of cool season and short day lengths	warm and long day lengths

[a] Controlled environment in the glasshouse during the cool season.

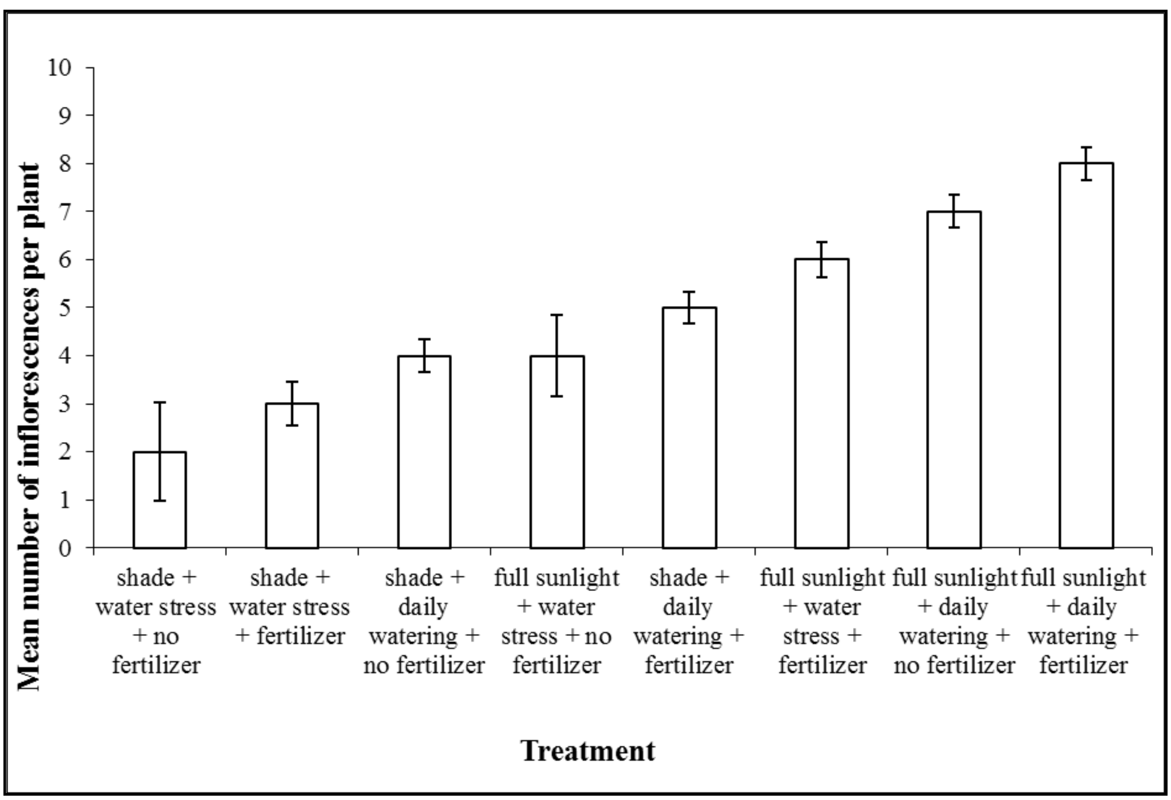

Figure 1. The number of inflorescences produced per plant during its flowering period under the various conditions. Values with ± SEM were derived from 10 plants that were randomly chosen.

Taro inflorescence

The length of the inflorescences ranged from 150-300 mm and the length of the male spadix ranged from 19-52 mm, which all depended on the health and length of the plants, which ranged from 610-1838 mm (Tables 2 and 3). The taro inflorescence was elongate and consisted of a spadix enclosed in a spathe. A few flowers were found to be enclosed in double spathes. The spadix was separated into the male flower (staminate), the constricted region of sterile flowers that divided the male and female flowers, the female flower (pistillate) and the sterile tip. Male flowers were located in the upper region while the female flowers were located on the lower region. The male part of the spadix was yellow in colour whereas the sterile band and the female part of the spadix were purple. The flowers were small and sessile, though the inflorescence was attached to the peduncle. Cracks in the spathes were obvious when the female flowers were receptive with the intention to be pollinated. Female flowers were only observable if the spathe surrounding them was removed. Fertile flowers were mixed with sterile flowers that were scattered and found in varying numbers. The fertile female flowers were green with characteristic stigmas whereas the sterile flowers were purple in colour. The male flowers were observable when the spathe cracked open.

Pollen production

Pollen grains were shed mostly early in the morning if the weather was fine and were found clumped together as a white powdery substance on the male spadix. The spathe opened widely when the pollen was shed. Male flowers produced little or no pollen during the cool months (Table 2) compared to a high production during the warm months (Table 3). The quantity of pollen produced was also proportionate to the health and height of the plants and inflorescences, and the length of the male spadix.

Seed set in taro

Out of all the inflorescences that were pollinated from the five different batches, a high percentage (over 85 %) of the inflorescences had developed into fruit heads (Table 4). However, 17 % of the developed fruits were damaged by cyclone Gene in Fiji in January 2008 from the first batch. Each berry was a fruit and a group of compactly packed berries formed a fruit head. Seed set took place in almost one week following hand-pollination. Only the fertile female flowers developed into fruits. The fruits were green in colour during the early stages of seed set and turned to brown and succulent upon maturity. The berries became soft and black. The peduncle dried when the fruit head matured fully in 30-45 days after fertilization and was ready for seed extraction.

Taro seed

When matured, taro seeds had the characteristics as described by Tyagi *et al.* (2004). The difference between the lengths of the fruit heads and the number of seeds present in the individual berries were statistically significant ($P < 0.05$) (Table 5). Generally, fruit heads measuring from 46-57 mm had higher number of seeds, with the exception of that measuring 51 mm.

DISCUSSION

Flowering in taro

Flowering in PNG cultivar did not occur naturally, but was promoted artificially by the application of gibberellic acid at a concentration of 500 ppm when the plants were in their fifth leaf stage. Flowering initiated in 90 to 120 days during the cool and short day length conditions and in 60 to 90 days during the warm and long day length conditions. However, all the plants that were planted in different batches and sprayed with gibberellic acid at different periods throughout the year had flowered (Table 1). It was clear that flowering was delayed in cool months with short day conditions, though vegetative growth was vigorous. The plants had set off flowering after completing a certain period of vegetative growth.

Plants spend a lot of their energy in producing flowers; as a result, an effective and adequate amount of photosynthesis is required by the plants to switch from vegetative to reproductive phase. It was observed that healthy plants had more and bigger leaves with a higher chance of more photosynthesis taking place and such plants produced more

Table 2. The relationship between the plant height, length of inflorescence, length of male spadix, type of the plant and the quantity of pollen shed at 25±1 °C, 50-65 % RH and 10 hours day length in taro (*C. esculenta* var. *esculenta*) cv. PNG.

Plant height (mm)	Length of inflorescence (mm)	Length of male spadix (mm)	Type of plant	Quantity of pollen shed
610	150	19	weak	--
690	153	20	weak	--
844	177	23	weak	--
932	198	27	weak	--
939	207	30	weak	-
1132	213	31	healthy	+
1150	217	34	healthy	+
1180	226	40	healthy	+
1687	272	45	healthy	+
1766	289	48	healthy	++

(No pollen shed -, little pollen shed +, sufficient pollen shed ++).

Table 3. The relationship between the plant height, length of inflorescence, length of male spadix, type of the plant and the quantity of pollen shed at 30±1 °C, 70-85 % relative humidity and 12 hours day length in taro (*C. esculenta* var. *esculenta*) cv. PNG.

Plant height (mm)	Length of inflorescence (mm)	Length of male spadix (mm)	Type of plant	Quantity of pollen shed
610	150	19	weak	--
690	153	20	weak	--
844	177	23	weak	--
932	198	27	weak	--
939	207	30	weak	-
1132	213	31	healthy	+
1150	217	34	healthy	+
1180	226	40	healthy	+
1687	272	45	healthy	+
1766	289	48	healthy	++

(No pollen shed -, little pollen shed +, sufficient pollen shed ++).

Table 4. The percentage of successful pollination from five different batches in *C. esculenta* var. *esculenta* cv. PNG. The value in parentheses represents the percentage of developed fruit heads that were damaged during cyclone Gene in Fiji in January 2008.

Batch	Number of successful pollinations (%)
1[a]	80 (17)
2[b]	83
3[b]	86
4[b]	89
5[a]	92

[a]Batch of taro suckers planted in the field. [b]Batch of taro suckers planted in pots and kept inside the glasshouse.

Table 5. The number of taro (*Colocasia esculenta* var. *esculenta*) cv. PNG seeds present in each berry of five different fruit heads.

Fruit heads	Number of seeds				
	Berry 1	Berry 2	Berry 3	Berry 4	Berry 5
1[a] (40)	8	10	7	9	10
2[a] (44)	8	1	3	6	4
3[b] (58)	12	11	9	13	10
4[b] (61)	11	15	14	13	13
5[b] (54)	12	15	15	10	11

[a]Fruit head from a weak plant. [b]Fruit head from a healthy plant.
The values in parenthesis represent the length of the fruit head (mm).

inflorescences. The potential factors such as photoperiod, temperature and water availability are perceived by the different parts of the plants. Photoperiod and irradiance are perceived by the matured leaves, temperature is perceived by all parts of the plant and water availability by the root system (Bernier *et al*., 1993). This highlights the importance of maintaining the good health of the plants throughout their lifecycle.

The production of more suckers per plant was an added advantage since the number of flowers produced per plant had increased. The weak plants examined produced a mean number of four inflorescences per plant during its flowering period while the healthy plants produced a mean number of seven inflorescences per plant. The flowering period lasted in approximately 60 days. The inflorescences had appeared from the shoot apical meristem while a few had also appeared from the stolons, which was rare. Physiological process taking place in the shoot apical meristem making it competent to develop inflorescences are accompanied by the biochemical changes taking place at the apex by cytokinins. The colour of the spathe was predominantly purple and correlated with the pigmentation of the whole plant. Autonomous factors were also found to regulate flowering in plants. The plants that were under the conditions of full sunlight, adequate water availability and nutrient supply had produced significantly ($P < 0.05$) more inflorescences per plant (Figure 1).

The inflorescences had a distinctive aroma similar to the smell of an unripe pawpaw, which was apparent when the female flowers were receptive and ready to be pollinated. However, the male flowers dominated the pollination process. The pollen was shed as a cluster of white powdery substance on the male spadix in almost a week following the initiation of the inflorescence formation. The spathe opened widely after the pollen was shed. The lifetime of an inflorescence was no more than a week. Nevertheless, it should be noted that not all the varieties of taro flower with the same intensity. Flowering in taro was found to vary from variety to variety, from region to region and from season to season (Ivancic, 1992).

Environmental conditions that trigger flower formation

In this study, it was noticed that taro plants of the PNG cultivar delayed flower despite its vigorous vegetative growth after the application of gibberellic acid as compared to the suckers that were planted during warm season. Hence, side suckers, extra leaves and stolons had been carefully removed to suppress vegetative growth. This enabled the plants to complete their life cycle faster and also left the plants with no other choice than to finally flower. The cost in terms of reduced growth would have resulted in a trade-off between sexual reproduction and vegetative growth (Fenner & Thompson, 2005). Removal of stolons would have resulted in a build up of gibberellic acids in the plant that accelerated flowering or even directed photosynthates to unproductive growth.

All the plants of the respective batch had started to flower at about the same time and this emphasized the importance that all individuals of a species must flower synchronously for successful cross pollinations and also to complete their sexual reproduction under favourable external conditions (Bernier *et al*., 1993). Longer day lengths and warmer climate favoured flowering. This confirmed that taro plants used environmental cues to regulate the transition to flowering. A possible interaction between exogenously applied gibberellic acid, temperature and daylight had existed. Since taro is a tropical and sub-tropical crop, it was clear that warmer climates and long day lengths triggered flowering in taro. Similar observations were made by Onwueme (1999). Taro suckers were planted under controlled conditions in the glasshouse and flowering initiated in 60 days after the application of gibberellic acid without any delay.

Physiological role of gibberellins

Gibberellins are the growth hormones that trigger the reproductive development in plants (Taiz & Zeiger, 1998). The physiological effect of gibberellins in taro plants is to promote flowering by substituting for the long day requirement. However, the present results support this theory and there was a requirement for warm temperature as well that was interactive. When exposed to long days, the content of active gibberellic acid increases in plants causing the stem to elongate and eventually the flowers are produced (Opik & Rolfe, 2005). The physiological reasons for spraying gibberellic acid to the leaves either early in the morning or late in the afternoon is due to the fact that generally the stomata in the leaves open fully when exposed in the light, but close in the dark and also when the plants are water stressed. Both the upper and the lower surfaces of the leaves are applied with gibberellic acid since stomata is present on both the surfaces of the leaves with the lower surface possessing approximately twice as many. Though, the number of stomata is relatively low in *Colocasia* when compared with other plant species (Strauss, 1983).

Pollen production in taro

It was shown that size and health of plants does not significantly influence number of inflorescences produced. However, size of inflorescences and pollen production are dependent on size and health of plants. The number of pollen grains varied in different inflorescences. The quantities of pollen produced were proportionate to the size of the male spadix. It was also found that the longer inflorescences of healthy plants produced more pollen compared to the smaller inflorescences of weak plants due to the fact that that taller and healthier taro plants showed a tendency of longer male spadixes. Furthermore, this character was particularly correlated with plant height. It was obvious that the plants that were healthy and tall produced bigger inflorescences than the weak and short plants (Tables 2 and 3).

Poor pollen production was one of the serious factors that curtailed fertilization. Pollen production was found to be temperature specific. There were little or no pollen production in flowers during the cool months compared to a lot of production during the warm months (Tables 2 and 3). High humidity and longer day lengths (about 12 hours) during the warm months as well as the healthy plants was also found to favour pollen production compared to the low humidity and shorter day lengths (about 10 hours) during the cool months and also the weak plants. Differences in the geographical location, soil fertility levels and weather conditions may also have affected the rate of pollen germination. On the other hand, Wilson (1990) found that poor pollen production also occurred in naturally produced inflorescence and suggested that it may not be related to gibberellic acid application, but may be genetic or due to environmental stress.

Protocol to optimize flowering and pollen quantity in taro

1. Plant taro suckers closer to warmer seasons and long day lengths.
2. Plant taro suckers in fertile soil for healthy plant growth. Healthy plants produce healthy and more flowers, and high quantity of pollen.
3. Use large and healthy taro suckers for planting and agronomic practices such as applying nutrients such as nitrogen, phosphorous and potassium in particular and weeding should be strictly performed in order to achieve healthy flowers.
4. Water the plants frequently and always keep the soil moist.

5. Apply gibberellic acid at a concentration of 500 ppm to plants at five leaf stage early in the morning on a fine day when no rain is expected. Two to three drops of dish washing detergent should be mixed with the prepared gibberellic acid solution as a surfactant. Since the taro leaves are waxy, surfactants are used to aid the gibberellic acid solution to stick and stay on the leaves for better results.
6. Spray gibberellic acid gently and evenly on both the upper and the lower surfaces of the leaves as well in the cup formed by the petioles.
7. Maintain a warm temperature around the plants during the flowering period.
8. Maintain high humidity for two to three days around the male flowers in order to achieve maximum pollen production. The inflorescence can be covered with a plastic bag to maintain humidity just before pollen is shed since covering the inflorescences with plastic or pollinating bags for a longer period of time may cause the environment around the flowers to become hot and humid and will cause them to become soggy and rot.

Pollination in taro

The male portion of the inflorescence controlled the pollinating process. The inflorescence could only be pollinated when pollen was shed by the male flowers in almost a week after the initiation of its formation. It was also found that the stigmas of the female flowers were receptive one day before till one day after the pollen shed since the flowers that were pollinated at these different times also had their seed set in berries. However, on the day of pollen shed the 'crack' at the base of the spathe had closed and become tight around the band of sterile flowers. This behaviour of the inflorescences seemed to indicate that the inflorescences responded in such a manner to protect the little self-pollination that might have occurred (Wilson, 1980). There were three cases of apomixis (development of fruit without pollination) observed as Ivancic (1992) had experienced a few cases in the Solomon Islands.

Large plants with large inflorescences displays and with large quantities of pollen produced do not necessarily produce more seeds per berry. The number of seeds largely depends on the success of fertilization. Though, this was in response to the quantity of pollen produced. Large amounts of pollen production increase the chance of successful fertilization, thus the amount of pollen arriving on a flower can be an important determinant of seed production. The weather, vigour of the plants, type of inflorescences used for pollinating and the skill used to pollinate affected the success rate of hand-pollination. Like flowering, pollination was also weather-dependant. Unsuccessful pollination was likely due to factors such as longer periods of heavy rain that caused the peduncles of the inflorescence to become soft and fall off. In addition, the female flowers of the spadix may not have been receptive when pollinated or the female flowers were not covered well with pollen due to poor pollen production or the peduncles might have been damaged while emasculating. Flower predators such as ants were also present in most of the flowers and may have fed on the pollen grains before fertilization took place.

Seed set

The high percentage of female flowers that were fertilised successfully after pollinating had their seeds set in approximately one week (Table 4) whereas the female flowers that did not set seeds dried and fell off after about two weeks. Some of the possible reasons as to why the female flowers failed to set seeds after pollination could probably be due to the female flowers not being receptive when pollinated, the pollen being unviable, or the environmental conditions such as low humidity was not favourable for fertilization to occur. Seed set was also weather-dependant similar to flowering and pollination. Fruit heads matured 30- 45 days after pollination.

Upon maturity, each berry generally contained a mean number of 10 seeds (Table 5), but as many as 35 seeds have been reported (Wilson, 1990) that may be due to the differences in cultivars. It was evident that the number of seeds present in each fruit head did not necessarily depend on the vigour of the fruit head, but was dependant on the effectiveness of fertilization. The presence of higher number of sterile flowers than the female flowers did not affect the number of seeds produced per berry. The number of seeds per berry depended strongly on the number of placenta per ovary, number of ovules per ovary, efficiency of pollination, type of pollination, self compatibility, fertilization and several other factors (Ivancic, 1992). As the fruit heads were developing in its early stages of seed set, the sterile flowers had disappeared. It has been reported to be experiencing watery dissolution since the outer faces of the sterile flowers lose their ivory opaqueness and become translucent and grey (Shaw, 1975). The gaps that were created if by the watery dissolution of the sterile flowers seemed to be filled with the fertile berries growing.

Protocol to optimize seed production in taro

1. Where the male flowers produce very little or no pollen, this should be discarded and the stigma could be used for cross-pollination.
2. Use the same inflorescences as both a male and a female parent if there are not enough inflorescences.
3. A male parent inflorescence that is covered with a large quantity of pollen can be used to pollinate two or more female inflorescences.
4. Pollinate the inflorescence at the appropriate time that is at its 'crack stage' when the spathe around the female flowers becomes loose and the inflorescence produce a distinctive aroma. Otherwise, the female flowers loose their receptivity afterwards and fertilization will not occur and hence there will be no seed set.
5. It is important to cover each female flower with enough pollen since fruit heads will not develop unless a number of berries have been fertilized. In case of inadequate quantity of pollen use several pollens from male parents to pollinate one inflorescence on the female parent.
6. Maintain high humidity for two to three days around the female flowers in order to increase the chance of successful fertilization. The female flowers can be covered with a plastic bag to maintain humidity for three days after pollinating the flowers. However, the flowers should not be covered with plastic or pollinating bags for a longer period of time as this will cause the environment around the flowers to become hot and humid and will cause the developing fruit to become soggy and eventually fall off.
7. Shade the plants from rain to facilitate favourable conditions for pollinating the plants since there is a risk of loosing pollen by rain that will wash off pollen.
8. Use healthy taro suckers for planting since the well being of the plant determines the health of the flower, the berries and finally the seeds. Healthy flowers have more berries in the fruits and more berries produce more seeds depending on the success of fertilization.
9. Skill, care, pollinating bag and sharp scalpel are required to pollinate flowers. The flowers should be emasculated at the right point (constricted point that joints the sterile flowers to the male flowers) and care should be taken not to damage the peduncle while removing the spathe around the female flowers.
10. Keep areas around the plants well-aerated as too much moisture causes the petiole bearing the seeds to damp off and die.

CONCLUSION

Protocols to optimize flowering and seed production were developed successfully. Taro exhibited a requirement for long day length, total light radiation, warm temperature, and nutrition and water availability to flower efficiently. The success of pollination was dependent on the weather, skills used, the receptivity of the female flowers, quantity of pollen applied on the female flowers and the well-being of the plants. Flowering, fruiting and seed setting play an important role in agriculture. Optimization of taro seed production will offer a method for long-term conservation of taro genes. This research will also benefit the Pacific Island countries to maximize and improve taro production (of their suitability) for subsistence livelihood and for export commodity.

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Observations on off-take and nutrient composition of milk from Papua New Guinea goats

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ABSTRACT

In response to the emerging perceived demand for smallholder milk production to meet household level nutritional requirements, this on-station study was carried out to generate information on the potential off-take and nutrient composition of milk of the common type goat in Papua New Guinea (PNG) . Nineteen goats were observed over a period of 19 months, and data was collected from 23 complete lactations. The average daily milk off-take (DMO) of the flock on partial suckling of once a day was 230.35 ± 15.9 g/day with average total milk off-take (TMO) of 22.98 ± 3.18 kg for an average lactation length of 99± 8.8 days. Milk fat, total solids and solids non fat contents of the milk were 7.8, 17.8 and 10 per cent, respectively. Type of udder (extended or small) and parity of doe had significant ($P < 0.05$) effects on milk off-take as well as lactation length, but the effect of litter size was not significant. .. It was concluded that PNG goats can produce adequate nutritious milk for household use as well as sales by smallholder farmers. This can be promoted to smallholder farmers since they have been keeping goats primarily for meat and socio economic services while overlooking the potential of goats as milk producers mainly due to lack of knowledge and technical skills.

Key words: PNG goats, milk off-take, lactation length, milk nutrient profile.

INTRODUCTION

Since their first introduction to Papua New Guinea in 1883 by early explorers, domesticated goats (*Capra aegagrus hircus*) have been mainly used for meat production and income, although particularly the German Missionaries promoted them for both meat and milk production (Quartermain 1982; Vincent & Low, 2000). Milk does not appear in the staple diets of rural people in Papua New Guinea (PNG), unlike sub-Saharan Africa and south Asia.

The breed types of goats introduced to PNG include a variety of European dairy types (Saanen, Alpine, Anglo-Nubian and Toggenburg) and some feral type goats from Australia and New Zealand. It is not known whether any breeding program was followed in the separate breeding flocks or how goats were disseminated to individual farmers; however, descendants of these flocks spread and interbred in rural villages over the past century to result in the present-day admixture populations collectively known as PNG goats (Ministry of Agriculture and Livestock, 2004). It is believed that many of the established breeding flocks were destroyed during World War II and only isolated populations remained in the hands of rural people and therefore no systematic breeding was practiced. It appears that uncontrolled breeding over many years and the degree of adaptation to various environments has had significant reduction in animal body size and milk yield. And Knights and Gracia,1997 highlighted that goats that have adapted in the tropical climates owed it to their heat tolerance, adaptation in feeding and their resistance to *Haemonchus contortus* and *Trypanosomiasis.*

The PNG goat population was estimated at around 5 000 in 1985 and gradually increased considerably to about 17 000 in 1992 (Vincent & Low, 2000). The current official figure of this population of 3 000 at FAOSTAT (2011) is considered here as an underestimate. To date, the goat population

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of PNG is largely concentrated in the highlands region of the country particularly the Eastern Highlands, Simbu and Western Highlands provinces and this was largely facilitated by church missions and government agencies over the last 30 years. Some districts in Morobe province also maintain some flocks. Since their introduction goats have adapted well to a wide range of environments and pasture conditions. Small body size, high reproductive rate and broad feeding habits relative to the cow may explain its spread in subsistence smallholder farming communities (Aregeore, 2000).

Despite early efforts by Missionaries to promote goats for milk, this production function has not gained popularity, mainly due to lack of knowledge and skills in using goats for milk production until very recently and the general lack of taste and demand for milk. However, in light of chronic nutritional problems of children and mothers rural areas (Gibson, 2001), there is an emerging perceived need for smallholder milk production at household level. The goat can have an important role to play by producing milk in suitably small amounts to meet nutritional requirements of especially children and vulnerable members of subsistence families.

Goat milk is rich in protein (3.0 - 4.0 %) and its fat (4.5 %) and milk sugar (lactose) (4.0 %) contents are similar to that of human milk (Peacock, 1996; p. 3). Unlike cow's milk, goat milk has small size fat globules and casein that are easier to digest. Additionally, it aids in the digestion and metabolic utilization of minerals such as iron, calcium, phosphorus and magnesium, and can help prevent diseases like anaemia and bone demineralization (Science Daily, 2007).

The National Agricultural Research Institute (NARI) has been promoting goats for milk since 2008. As part of this effort, this study was undertaken at its Livestock Research Station, Labu to assess potential off-take as well as nutritional profile of milk from PNG goats.

MATERIALS AND METHODS

Location

The study was conducted at the Livestock Research Station of NARI, at Labu, outside Lae, Morobe Province, PNG. It is situated at about 6º 40' 23" South of the Equator and 146º 54'31" East of the Greenwich Meridian Line with an annual rainfall of 2300 mm and average daily temperature range of 27 to 31 ºC with about 80 per cent humidity.

Experimental animals

The goats maintained at the research station originated from the pool of goats collected from village farmers to establish foundation breeding flocks at the PNG University of Technology (Unitech) in 1975 and subsequently at the Department of Agriculture and Livestock (DAL) goat breeding station at Erap (Quartermain, 2002). Since the station flock was established in 1993, mainly breeding bucks but also some does have been occasionally exchanged with flocks at Erap, Tambul and village farmer flocks, while also continually disseminating breeding stock to interested village farmers. Flock size remained between 50 and 100 and a couple of breeding bucks were maintained throughout for random mating. Replacement breeding stocks have been selected based on early growth and body conformation.

The nineteen does used for this experiment were selected from the flock as they gave birth to kids between October 2009 and February 2010. Each of the does was identified by age, parity, litter size and udder type. Their age at the start of the observation ranged from one and half to three years; parities ranged from one to four; their udder types were either small or extended. A total of 23 full lactation observations were recorded from these animals over a period of eighteen months.

General husbandry

The goats were housed in a permanent concrete floor house of about 85.8 m² divided into three pens, a milking parlor and a tools store and managed under a semi-intensive system. Lactating does were housed overnight separately from kids, non-lactating does and a breeding buck. Experimental does were drenched liquid Panacure that has fenbendazole as its active ingredient at the start of the observation and every two months afterwards for deworming at a ratio of 0.5 ml per kg live weight of the animal. Hooves were routinely trimmed on a monthly basis. A buck was allowed to freely mate with goats but was separated from the lactating goats during the night.

Feeding

The goats were put on copra meal supplements for two weeks prior to start of the experiment. Apart from daily partial gazing, all the animals were fed fresh as well as wilted grass of mixed species comprising of elephant grass (*Pennistum purpureum),* signal grass (*Brachiaria decumbens)* and other tropical grasses which was provided on hay racks on daily basis. Tree legumes such as glyricidia (*Sepium gliricidia)*, leucaena (*Leucaena* sp.*)*, and mulberry (*Morus* sp.*)* were also cut and fed to the animals as supplements once or twice a week. Other legumes and forages fed on availability include centro (*centrosema pubescens*), greenleaf desmodium (*Desmodium intortum*), vines as well as tubers of sweet potato (*Ipomea batatas*), banana (*Musa* sp.*)* leaves and stems. All experimental animals were grazed together and in isolation from other goats and sheep at the station. Wheat mill-run and copra meal mixed at a ratio of 2:1 were given at average rate of at least 150 g per day to lactating and pregnant goats and 100 g per day to non lactating goats. In addition lactating does were given extra 50 g per 100 ml of the mix during milking. Clean water and nutritional mineral lick were freely available throughout the observation period.

Data collection

Data collection started in November 2008 and continued to May 2010. Recording of milk off-take started two weeks after kidding for does that gave birth during the observation period and the does were trained for milking one week after kidding. Records were taken once in the morning daily from all lactating goats. The udders were thoroughly washed with warm water and soap and dried with clean towels before milking by hand. All milk was stripped off gently from the lactating does by hand and milk let down was encouraged by feeding copra meal concentrates to the doe. The presence of the kids often disturbed the does while being milked on the milking platform. Kids were therefore kept away during milking times. Milking was done by the same person throughout the observation period. Kids were separated overnight from their lactating dams until the next morning after milking. They were allowed to suckle their dams throughout the day.

Weights of kids and does were recorded weekly and total milk off-take from all lactating does for the day was recorded daily. The recording of milk off-take from a doe ceased when the doe produced less than 100 g of milk for three consecutive days. Body weights of the does were taken weekly to monitor weights and advanced pregnancies. To determine cost of supplementary feed, daily concentrate intake was recorded against the unit cost of concentrate. All milk collected on the monthly recording date was pooled and mixed before two samples of 100 g milk were taken in labeled and sanitized bottles. The bottles were stored in ice cube boxes and taken to the laboratory the same day for analysis of milk fat (MF), total solids (TS) and solids-non-fat (SNF) of the milk. The milk equivalent of early kid growth to 6 weeks of age was estimated based on growth ratio of 1.2 and total milk solids content of 17.81% (Peacock, 1996 pp. 57-58), i.e.:

Milk equivalent of kid weight = [(body weight of kid at 6 weeks of age – birth weight of kid) x 1.2)] / (0.1781).

Data analysis

Data were analysed using the GenStat (3rd edition of Discovery version (Lowes Agricultural Trust, 2005). Descriptive statistics was use to analyse daily milk off-take, lactation length and milk off-take equivalent of early growth rate by parity, litter size and sex of kid. Paired t-tests were applied to compare means between categories of parity, litter size and sex of kid.

RESULTS

Milk off-take

The overall average daily milk off-take of 23 full lactation records (DMO) based on partial suckling and one morning milking per day was 230.3 g, with total milk off-take of

23.0 kg over an average lactation length of 95 days (Table 1). DMO ranged from a minimum of 100 to a maximum of 675 g, with a median of 208 g. Likewise, total milk off-take (TMO) for the lactation period ranged from 4.6 to 68.7 kg. Does with extended udders had on average significantly ($P < 0.05$) greater DMO and TMO. Milk off-take tended to increase with parity, but statistically significant differences were detected only between parities 1 and 4. Similarly does with twin kids tend to yield more milk than those with single kids, although the differences were not statistically significant.

Lactation Length

Observed lactations extended from a minimum of 29 days to a maximum of 225 days, with a median of 100 (Table 1). Litter size did not influence the length of lactation, but udder type did. Does with extended udders had a significantly ($P < 0.05$) longer lactation length than those with small udder by on average 37 days. Lactation length appeared to have increased with parity, but the differences between parities were not statistically significant.

Milk off-take equivalence of early kid growth

The overall body weight gain of all the 20 kids born to experimental does during the observation period from 1 to 6 weeks of age was estimated to be equivalent to 23.2 kg of milk off-take (Table 2). This value did not vary between sexes of kid, udder type or even litter size, perhaps because of the small sample size (Table 2). Nevertheless, it appears that individual kids in twin litters gain less weight within this period than do single born kids,

Table 1. Average (mean ± SE) daily milk off-take (DMO), total lactation milk off-take (TMO) and lactation length (LL) of PNG goats by litter size, udder type and parity.

Parameter	Number of observations	DMO (g)	TMO (kg)	LL (days)
Overall mean	23	230.35 ± 15.9	22.98 ± 3.18	95.00 ± 8.8
Overall minimum	23	100	4.61	29
Overall maximum	23	675	68.7	225
Overall median	23	208	18.49	100
Litter size				
1	16	215.4 ±19.31	20.49 ± 3.32	89.94 ± 8.63
2	7	264.6 ± 24.83	28.50 ± 7.19	106.6 ± 21.58
Standard error for difference of means		33.59	6.86	19.13
t-value		-1.46	-1.77	-0.87
P		0.158	0.256	0.394
Udder Type				
Small	10	178.0 ± 9.77[a]	13.14 ± 1.65[a]	74.20 ± 9.39[a]
Extended	13	270.6 ± 21.2[b]	30.46 ± 4.15[b]	111.0 ± 12.19[b]
Standard error for difference of means		23.34	4.812	16.19
t-value		-3.97	-3.60	-2.27
P		0.001	0.003	0.034
Parity				
1	4	172.8 ± 12.9[a]	14.64 ± 1.92	84.25 ± 7.93
2	6	215.8 ± 33.1[ab]	16.96 ± 6.63	92.50 ± 18.67
3	9	250 ± 28.73[abc]	24.60 ± 4.16	98.22 ± 9.79
4	4	265.6 ± 28.8[bcd]	31.90 ± 12.40	117.2 ± 37.84

Means within a column with different superscripts are significantly different at $P < 0.05$ on unpaired two-sided T-test.

although when the twin kid weights are combined, the aggregate weight, and hence the milk off-take equivalent, becomes markedly bigger than those of single born kids. The sum of this milk off-take equivalence of early kid growth and the recorded overall milk off-take of 23.0 kg gives an estimated total milk production from these does of 46.2 kg over the average lactation period of 95 days.

Milk composition

Monthly pooled milk samples of the 23 observations had an average milk fat of 7.8 per cent, ranging from a minimum of 3.6 to a maximum of 13.0 per cent. The non-fat milk solids also had an average value of 10.0 per cent with minimum of 9.0 and maximum of 11.0 per cent. These give an average total milk solid content of 17.8 per cent (Table 3). These values are very high compared to values reported in the literature from commonly milked goats. Some plausible explanations for these high values are the facts that 1) the sample goats have not been milked before, 2) their milk off-takes were relatively low, and 3) minimum levels of supplementary concentrates provided.

Table 2. Average (mean ± SE) milk off-take equivalence of early kid growth to 6 weeks of age by sex of kid, udder type of dam and litter size.

Parameter	N	Milk yield (kg)
Overall	20	23.2 ± 1.8
Kid sex		
Female	11	20.8 ± 2.5
Male	9	25.2 ± 2.5
Standard error for difference of means		3.57
t-value		-1.66
P		0.226
Udder Type		
Small	7	19.3 ± 4.0
Extended	13	25.3 ± 1.6
Standard error for difference of means		3.62
t-value		-1.66
P		0.114
Litter size		
1	12	26.0 ± 2.42
2	8	19.0 ± 2.0
Standard error for difference of means.		3.40
t-value		2.50
P		0.055

Means within a column of the same variable were not significantly different from each other $P < 0.05$ on two sample unpaired two-sided T-test.

Table 3. Monthly average milk fat (MF), total milk solids (TS) and solid-non-fat (SNF) values of pooled milk samples of PNG goats (n=13).

	MF (%)	TS (%)	SNF (%)
Mean	7.8	17.8	10.0
Minimum	3.6	12.6	9.0
Maximum	13.0	23.4	11.00

Lactation curve

The average (flock level) lactation curve appeared to have peaked during the first weeks of lactation and steadily dropped thereafter to the end of the lactation period (Figure 1). The first week of the lactation refers to the week that recording of milk off-take from the does started thus excluding the two weeks of nurturing and adaptation of the kids. However, the individual lactation curves show considerable variation (Figure 2). By week three or four of the lactation period, almost all of the individual goats have reached peak daily milk off-takes. Invariably recording of milk off-take started two weeks post parturition. A good number of individual lactation curves appeared to have had their highest milk off-take already by week one, suggesting even an earlier tendency to peak.

There was one intriguing lactation curve of a doe that showed signs of drying off around week 17 of the lactation period but continued to increase for eleven more weeks to the second peak and dropped off sharply after week 30 to the end of the observation period. The doe did not show signs of abortion or any other ill health before daily milk off-take started rising to the second peak.

DISCUSSION

The average DMO and TMO values found in this study were in agreement with other such reports from the warm tropics, such as with local goat breeds in India, Bangladesh, Malaysia, Brazil and South Africa (Serradilla, 2001). In general milk production in the tropics is affected by factors such as body size and weight, age and parity, breed, udder volume, litter size, nutrition, management and environmental factors (Devenda & Burns, 1980; Gall, 1981). Similar significant effects of litter size on DMO and TMO, and in particular the significantly higher milk off-take from does with twin kids than those with single kids, were reported on Maltese goats (Carnicella *et al*., 2008) and Bengal goats (Hossain *et al*., 2004). This was explained by Hayden *et al*. (1972), who found out that plasma lactogenic activity was regulated by the number of kids born thus allowing more milk with increasing litter size. The significantly greater milk off-take from does with extended udders than those with small udders concurs with the assertion that udder volume is highly correlated to milk yield (Devendra & Burns, 1983). The tendency for milk off-take to increase with parity was also reported on the Red Sokoto, Sahel and the West African Dwarf local goats of Nigeria for three parities (Zahraddeen *et al*., 2009).

The overall average lactation length observed in this study was longer than those of some indigenous goats of the tropics such as the Bengal goats of Bangladesh (Hossian *et al.,* 2004) with 64.99 ± 1.08 days and the Sahel , the Red Sokoto and West African Dwarf goats of Nigeria with 80, 70 and 98 days respectively (Egwu *et al*., 1995). The fact that twin litter does had eight more days of lactation than those with single kids was also reported on the Jamunapari goat of Bangladesh under similar semi-intensive management system (Hassan *et al*., 2010), although lactation length is known to vary with the level of management as well as age of the doe (Hossain *et al*., 2004).

The average fat content of milk found in this study was higher than those of temperate breeds (Jenness, 1980). This may be explained by performance orientation of the breed being more of a meat than a milk type (Gall, 1981), but may not necessarily hold for PNG goats which are considered descendants of the original introduced stock of milk type goats. Locality is also known to affect milk fat content. Besides, following the argument by Greyling *et al.* (2004), lower levels of milk off -take are associated with higher milk fat content. The minimum levels of supplementary concentrates provided to does could also be another explanation.

The total milk solids content was higher than the value reported for the Indian local goats that had total milk solids of 12.33, 12.60, 13.20 and 13.67 per cent, respectively, for the first to fourth lactations (Bhosale *et al*., 2009). Similar trends were found in the Nigerian African Dwarf in two studies that had 17.87 and 18.68 per cent and a higher trend in the Pygmy goats of United States of America (USA) summarized by Jenness (1980). Devendra & Burns (1983) noted that the high fat percentages relate to higher total milk solid contents.

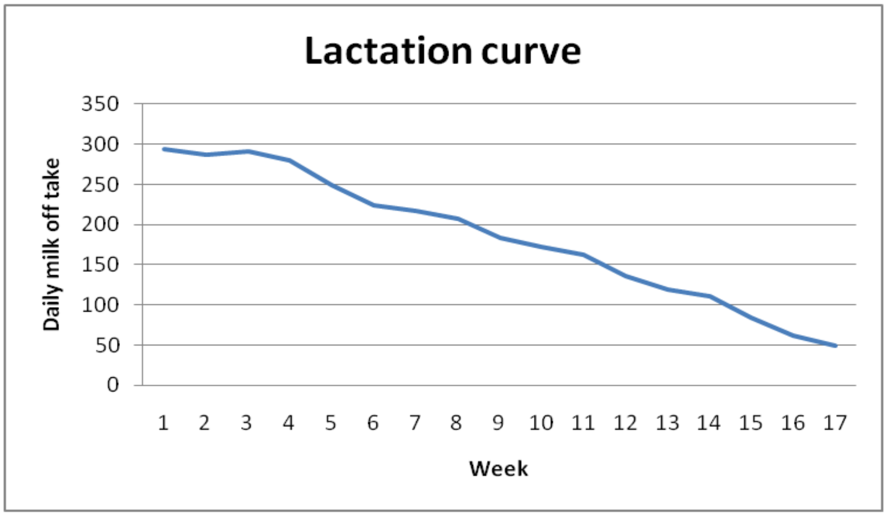

Figure 1. Weekly overall average daily milk off-take of PNG goats from week 1 to week 17 (n=23).

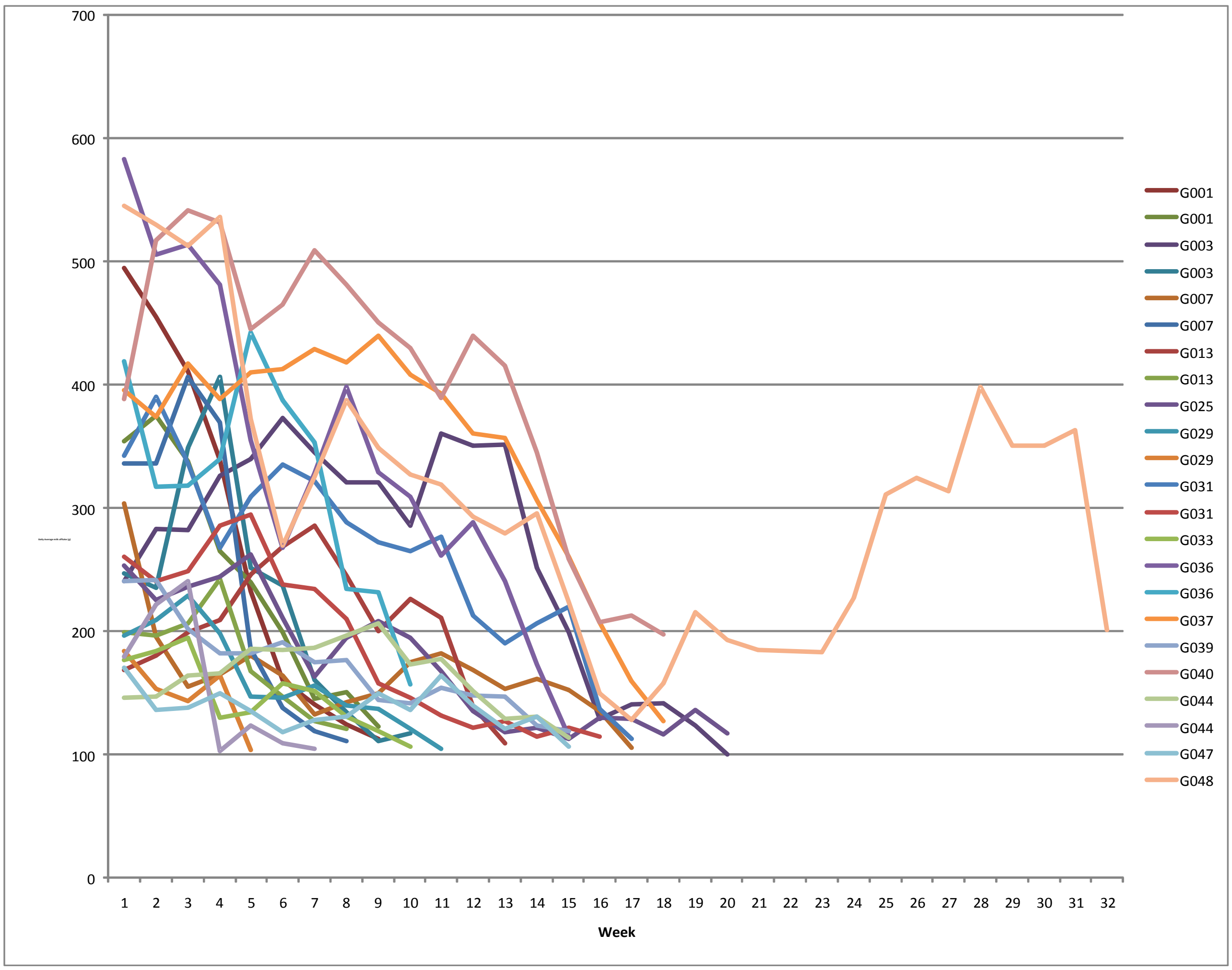

Figure 2. Lactation curves of individual lactation records.

CONCLUSION

The result from this study shows that PNG goats are able to produce milk at satisfactory levels to meet household needs like other tropical goat breeds, and hence they can be promoted for milk as well. Milk off-take peaked in the first few weeks of milking, with milking starting two weeks after birth. Does with extended udder have capacity to produce more milk, so selection of milk type does can use this criterion. Milk yield tended to increase with litter size and parity.

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Effect of blending sweet potato silage with commercial pellet feed or farm-made concentrate (fish meal and copra meal) on the performance of local crossbred pigs in Papua New Guinea (PNG)

Michael Dom[1], Workneh Ayalew and James Tarabu

ABSTRACT

To make a balanced diet for growing pigs sweet potato silage must be blended with a protein concentrate in the form of a commercially available pig grower pellet feed or a mix of local feeds such as copra meal and fish meal. An on-station growth performance of twelve paired crossbred weaner pigs at three months of age and weighing 20 ±3.28 kg was monitored for eight weeks on three mixed diets balanced for crude protein (CP) and gross energy (GE) content on DM basis. The trial was a continuation of research on sweet potato silage as an efficient preserved carbohydrate energy source, particularly for smallholder farmers with orientation to tapping into emerging pork meat markets. The experimental shed had concrete floor pens, corrugated iron roof and partial open wall. The three diets were: 1) sole diet of a standard commercial pig grower; 2) a mixed ration of commercial pig grower blended 50:50 as fed with sweet potato silage, and 3) mixed ration of sweet potato silage blended with a combination of fish meal and copra meal at 77:4:19 ratio on as fed basis. Dry matter contents of the mixed diets were much lower than that of the control but there were no significant ($P > 0.05$) differences in the dry matter intake. Despite the reasonably good balance of protein and energy in the three diets and similar dry matter intake the mixed diets gave lower performances in average daily gains, feed conversion ratios and mean final body weights than the standard pig grower feed. Results partially supported the hypothesis that growth performance of crossbred pigs fed on sweet potato silage mixed with either standard commercial grower feed or copra and fish meal will not be significantly different. It was recommended that more trials be conducted to test nutritionally balanced, least-cost pig rations based on locally available feed resources, including wheat millrun, poultry offal meal, palm kernel meal, rice millings, cassava, mulberry leaves, taro and other forages, in dried or ensiled form.

Key words: Copra meal, daily gain, dry matter intake, fish meal, growing pigs, sweet potato silage.

INTRODUCTION

The Papua New Guinea (PNG) National Agriculture Research Institute (NARI) has successfully adapted ensiling sweet potato (SP) as a feed preservation/ storage technique for smallholder livestock farming (NARI Nius, 2010) from research conducted in Vietnam (Peters *et al.,* 2001; Peters *et al.,* 2002). Conclusive results were obtained on the advantages of feeding mixed sweet potato tuber and vine silage to growing pigs under on-station as well as on-farm feeding emulating small-scale pig farming in two agro-ecological zones (Dom & Ayalew, 2009a, 2009b, 2010; Dom *et al.,* 2010).

An important outcome of this on-going research was the confirmation that SP silage can replace the traditional practice of feeding cooked tuber and fresh vine without adverse effect on nutritive value and digestibility of the balanced ration. Furthermore, the technology saves daily family labour in feed preparation and fuel for cooking SP tuber. It was demonstrated in on-farm trials that adequate balanced diet based on ensiled SP forage can be made readily available through weekly ensiling of excess, undesirable or un-saleable sweet potato tuber and vine forage sourced from local food gardens, apart from SP tuber bought from a local food market (Dom *et al.,*

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2010). The forage processing was done using simple tools such as kitchen graters and knives in addition to using a mechanical chopping device.

A considerable hindrance to improved productivity for pigs kept in rural villages is the poor storability of common root crops and green forages used as food or feed, which thereby demands continuous cropping on limited available arable land. In addition, livestock are often at the mercy of irregular crop cycles.

Ensiling affords an efficient means of processing perishable fresh forages for longer term preservation over several months. The common staple crops in PNG such as sweet potato, cassava, taro and banana, including those varieties not cultivated for food, are also very suitable for ensiling owing to their high starch content. Ensiled feed is also very palatable to other livestock, such as goats, that are able to digest the plant fibre as well as proteins much more effectively.

Conservation of the valuable feed nutrients well after the lush harvest season enables livestock farmers to provide a consistent plane of nutrition to their animals. This is vital when smallholder farmers venture into more intensive pig farming in response to growing domestic market for fresh meat, as is the case in PNG.

In PNG up to half of the sweet potato produced as food may actually go to feeding pigs in rural villages (Hanson *et al.,* 2001). Despite its predominant use by smallholder pig farmers, there is very little understanding of the importance of sweet potato vines as a feed resource, especially as sources of digestible fibre and protein. Given that sweet potato is also a major fresh produce in local markets (Chang & Spriggs, 2007), with crops grown on a large scale, there remains a need to explore options for promoting its improved use as home grown forage feed resource for livestock farmers. In fact, NARI's poultry research has revealed nutritional and economical benefits of using locally grown tuber crops (SP and cassava) as major energy sources in broiler finisher rations (Pandi *et al.,* In press).

Combined sweet potato tuber and vine silage raises the level of digestible protein in mixed diets fed to pigs (Tomita *et al.,* 1985; in Pérez, 1997; Dom & Ayalew, 2009a), and fermentation of the starch reduces the effects of trypsin inhibitors (Peters *et al.,* 2002). But what is also needed for improving growing pig performance is a fitting protein component that complements sweet potato silage to provide adequate and economical ration.

Commercially available grower pig pellets have been used as nutritionally balanced standard diets and as the protein component of mixed rations. The commercial feed was substituted at 50% of the complete offer as fed, mixed with SP silage, and was proven to be effective for adequate daily feed intake, body weight gain and feed conversion ratio (Dominguez, 1992; Pérez, 1997; Giang *et al.,* 2004; Dom & Ayalew, 2009b).

A related on-farm feeding trial with crossbred growing pigs raised in high altitude highlands of PNG (Dom *et al.,* 2010) compared growth performance of pigs on two SP silage based diets and found similar effects ($P > 0.05$): 1) equal portions of copra meal and fish meal mixed with SP silage, and 2) the commercial pig grower diet mixed with SP silage. Since the copra and fish meals were cheaper and easier to transport and store in bulk than the commercial pig grower ration they were considered a more economical feed ingredient to use by pig farmers in the highlands of PNG than the sole commercial pig grower diet. However, the farmers do not have the knowledge or means to check protein and energy contents of these ingredients to be able to balance the formulated concentrate diets for these nutrients. Both are expected to be good protein sources but their energy content is doubtful and need to be looked into. In the current study we tested the effects of a mixed ration made of copra and fish meal (protein concentrate) and SP silage, where the proportion of cheaper copra meal in the mix was increased from 50% to over 80%. In addition, gross energy of treatment diets was balanced on an 'as fed' basis. The study was designed to test the hypothesis that there was no significant difference in growth performance of crossbred pigs fed on sweet potato silage mixed with either standard commercial grower feed or 80:20 copra and fish concentrate meal. This is a follow-up study to one that established that SP silage, fed *ad libitum*, can substitute 50% of a commercial feed (16% crude protein) while maintaining good daily weight gain, efficient feed conversion and acceptable back-fat thickness but lower dry matter intake (Dom & Ayalew, 2009b).

METHODS AND MATERIALS

Trial location

The trial was conducted at the NARI Labu Livestock Research Station, Lae, Morobe Province. The site is located about 12 km from the Lae town on the Wau-Bulolo Road (Lat. 6° 40' 27" South Lon. 146° 54' 33" East). The altitude is less than 100 masl. The climate at this station is typically warm and wet with an average temperature of 32 °C and humidity of 85 % to 90 %.

Trial design and protocol

The experimental lay-out was a 2 x 2 x 3 and the design was a randomized complete block where twelve weaned piglets at about nine weeks age were randomly selected by assigning pig to six pens and balancing by different progeny, sex and total body weight of paired (male-female) pigs in a single pen (3 x 4 sq. m). The crossbred grower pigs came from two contemporary litters of a 25% crossbred sow mated with a 50% crossbred boar, both originating from loose admixtures of Large White, Landrace and Duroc breeds and PNG native pig (*Sus scrofa papuensis*) which is a genotype believed to be common in market oriented village piggeries. The crossbred pigs came from two contemporary litters of a 25% crossbred sow mated with a 50% crossbred boar, believed to be common in market oriented village piggeries. Two rows of feeding pens in an experimental shed with concrete floor, corrugated iron roof and partially open wall aligned north to south and facing opposite sides of morning and afternoon sun rays were taken as blocks. There were two replications of each diet on both blocks. Three treatment diets were fed and the testing period lasted 56 days from 2 June to 27 August 2010. The experimental pigs were introduced to the diets soon after weaning at three months age and 20 ± 3.28 kg body weight. The pigs were given an entire day's offer of initially 3000 g dry matter feed per head per day at around 9 am every morning after cleaning and washing down pens and pigs. Piped water was readily available at all times using nipple drinkers. Horizontal concrete feeders covered with pig wire to prevent pigs trampling the feed were used. Feed refusal was collected at 8 am every morning and weighed on a digital balance (1.0 g ± 0.5 g). Feed offer was increased as required by observing the trend in refusal levels. Body weights were determined by placing pigs in a bag and hanging on a Bilda spring-balance (100 kg ± 0.50 kg), with weighing done regularly at 9 am once a week.

Experimental diets

Sweet potato silage was made fortnightly according to an adapted procedure (Dom, 2007). Grated sweet potato tubers and chopped vines were mixed at 50:50 ratio after a few hours of open sun drying to reduce moisture. Salt was added at 0.5% and the mix firmly packed in air-tight plastic garbage bags placed in sturdy 70 kg plastic bins and sealed for fermentation for at least two weeks before feeding the resultant silage. SP tuber was purchased from local urban (Lae) market, while SP vine was sourced fresh from several peri-urban farming families. Copra meal and fish meal were purchased in bulk and stored in a cool, dry location before start of the feeding experiment.

Dry matter, crude protein and energy values for the test diet components and the combined compositions are given in Table 1. The sole standard commercial pig grower ration (PDSTD) manufactured by Goodman Fielders (PNG) Ltd, Lae, was used as a control diet. One batch of 25 bags or one ton was used for the duration of the trial. The second test diet (PGSPS) was composed of standard commercial ration and SP silage thoroughly mixed by hand just before offer at 50:50 on as fed basis (or 75:25 on dray matter (DM) basis. Test diet three (FCSPS) was farm concentrate made of fish meal and copra meal and mixed with SP silage at a ratio of 4:19:77 on as fed basis (or 8:37:55 on DM basis). Dry matter was estimated from past data using similar feed materials, while values for crude protein (CP %) on dry matter basis and gross energy (GE MJ/kg) on 'as fed' basis were derived from the literature. Other proximate nutrients

Table 1. Components and composition of dry matter (DM), crude protein (CP) and gross energy (GE) values for components as well as whole rations of test diets on as fed basis.

Test diet‡	Component	Composition (%) on DM basis	DM (%)*	CP (%)	GE (MJ/kg)†	DM (%)	CP§ (%)	GE§ (MJ/kg)
PGSTD	Pig grower	100.0	91.8	16.0**	14.0	91.8	17.4	15.3
PGSPS	Pig grower	75.0	91.8	16.0**	14.0	63.7	14.6	15.2
	Sweet potato silage	25.0	33.2	4.0†	5.0			
FCSPS	Fish meal	8.0	94.8	52.0**	17.5	46.9	16.2	16.7
	Copra meal	37.5	92.2	21.0**	17.3			
	Sweet potato silage	54.5	33.2	4.0†	5.0			

*Determined on-station by drying in hot air-draft oven.

**Reported on product labelling on as fed basis.

†Values from Tacon (1997) cited in Miao, Z. & Glatz, P.C. 2005. Feed ingredient fact sheet for PNG and Solomon Islands. Pig and Poultry Production Institute. Roseworthy Campus. Roseworthy. South Australia.

§ On DM basis.

‡Test diets: PGSTD = sole diet of standard commercial pig grower ration, control diet; PGSPS= a mixed ration of commercial pig grower blended with sweet potato silage 50:50 as fed; FCSPS=a mixed ration of sweet potato silage blended with a combination of fish meal and copra meal at 77:4:19 ratio on as fed basis.

were not determined.

Feeding regime and body weight

The daily ration offered on a dry matter basis was based on the overall mean body weight of all twelve pigs for three periods: week 1 to week 3 (inclusive), week 4 to 7 (inclusive) and week 8 and beyond. At the beginning of Week 1 the overall mean body weight was 20.0 kg and feed offered during first period was 3000 g DM/pen/day; at the beginning of period two (Week 4) the overall mean body weight was 30.4 kg and feed offered during this period was 4000 g DM/pen/day; for period 3 beginning with Week 8 the mean body weight was 48.2 kg and feed offered was 5000 g DM/pen/day.

Data analysis

Analysis of variance for means of daily intakes, weekly body weights and body weight gains was done using GenStat® (Lawes Agricultural Trust, 2005). The block effect, or side of the experimental shed, did not contribute significantly to the variation in feed intake and weight gain. It was therefore removed as a classification variable, and similar pens of the same treatment on either side of the shed were subsequently treated as replications.

RESULTS

Feed intake, body weight gain and feed efficiency

Mean weekly feed intake and body weight gain on each of three treatment diets are shown in Table 2. Estimates of the average daily intake, weight gain and feed conversion ratio are shown in Table 3. Overall results show a distinct lowering of mean body weights on FCSPS away from PGSPS and PGSTD after the fourth week of feeding, whereas high and low means were due to individual variations (Figure 1). FCSPS attained a mean final body weight at end of week 8 of 10 and 17 kilograms lower than PGSPS and PGSTD, respectively (Table 3).

The differences in feed intake among treatment diets on a fresh weight (or 'as fed') basis was highly significant ($P < 0.002$) perhaps because of bulkiness of the SP based diets (Table 1). However, the weekly dry matter intake was not at all different ($P > 0.05$), which may have been also affected by the predetermined weekly offer within the individual periods. In particular, except during the first ten days of the trial all feed offered in the control diet (PGSTD) was completely consumed leaving no residue, suggesting that

Table 2. Average fresh weight (FW) and dry matter (DM) intake per animal of growing pigs offered three treatment diets over eight weeks.

Parameter	Grand mean	Treatment diets‡			sed	l.s.d	F Pr.
		FCSPS	PGSPS	PGSTD			
FW intake (g)	2941	3733.5[a]	2932.0[b]	2157.0[c]	352.95	757.05	0.002
DM intake (g)	1881	1751.0	1911.5	1980.5	230.15	493.6	0.603

Means within a row with the same superscript are similar at the 5% level.

Intake mean values are average per pig of pen paired male and female pigs.

‡Treatment diets: PGSTD = sole diet of standard commercial pig grower ration, control diet; PGSPS= a mixed ration of commercial pig grower blended with sweet potato silage 50:50 as fed; FCSPS=a mixed ration of sweet potato silage blended with a combination of fish meal and copra meal at 77:4:19 ratio on as fed basis.

Table 3. Average daily feed intake per animal (ADI), daily weight gain per animal (ADG) and feed conversion ratio (FCR) of pigs fed SP silage based diet.

Parameter	Treatment diet‡		
	FCSPS	PGSPS	PGSTD
ADI (g/day)	1681	1800	1866
ADG (g/day)	442.1	634.1	743.4
FCR	3.80	2.84	2.51
Mean initial BW* (kg)	22.9	23.8	25.2
Mean final BW* (kg)	45.4	55	61.8

*Differences between means of test diets not significant ($P > 0.05$).

‡Treatment diets: PGSTD = sole diet of standard commercial pig grower ration, control diet; PGSPS= a mixed ration of commercial pig grower blended with sweet potato silage 50:50 as fed; FCSPS=a mixed ration of sweet potato silage blended with a combination of fish meal and copra meal at 77:4:19 ratio on as fed basis.

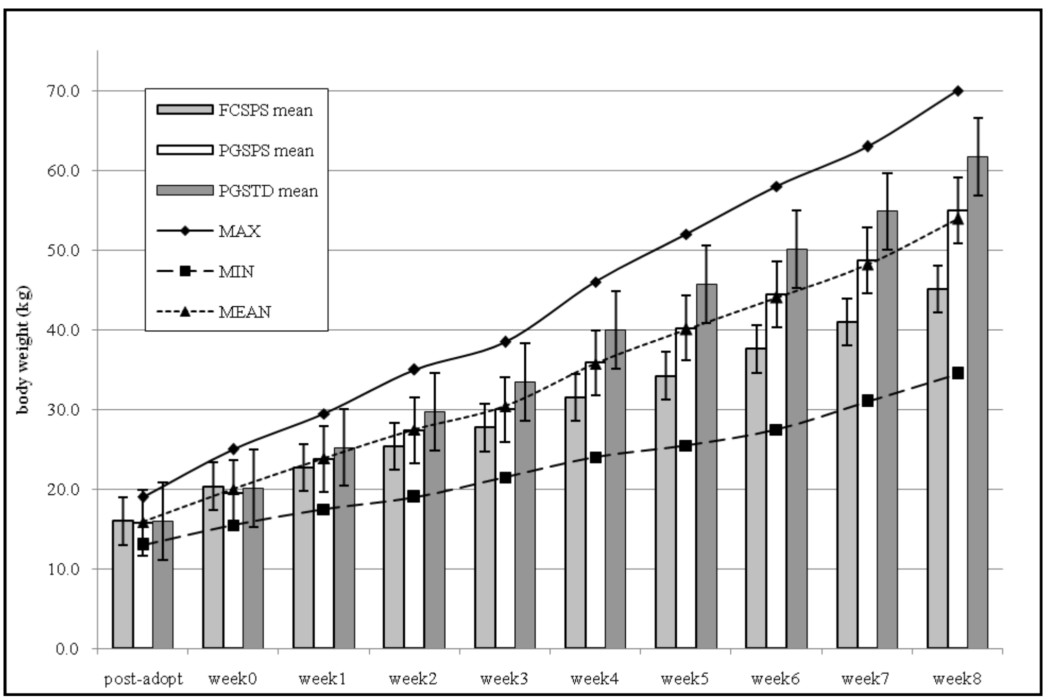

Figure 1. Changes in average body weights of growing pigs fed three test diets‡ (FCSPS, PGSPS, PGSTD) over eight weeks.

‡Diets: PGSTD = sole diet of standard commercial pig grower ration, control diet; PGSPS= a mixed ration of commercial pig grower blended with sweet potato silage 50:50 as fed; FCSPS=a mixed ration of sweet potato silage blended with a combination of fish meal and copra meal at 77:4:19 ratio on as fed basis.

pigs needed extra feed offered. But as the quantity offered of PGSTD was related by design of the experiment to the amount of this standard grower ration to be mixed with silage to make diet 2 (PFSPS), the offer of PGSTD was not increased.

Body weight gains were significantly ($P < 0.05$) different during the third, fourth and eighth weeks of the feeding trial., especially differences between FCSPS and PGSTD. At week three there was a very marked drop in body weight gain on all three diets ($P < 0.006$) for unknown reason but apparently the effect was equally observed on all trial pigs regardless of diet type or quantity offered. So the cause of this decline must have been environmental and not lack of feed. On that week the commercial standard was superior to both mixed diets PGSPS and FCSPS ($P < 0.05$). The very significant gain in body weight ($P < 0.009$) at week four can be explained by the increased intake when the feed offered was raised from 3000 to 4000 g DM/day/pen. In addition, as the average body weight gain subsequently declined over the next three weeks while this offer level was maintained, animals may have exhibited compensatory growth during week 4. It appeared that the same response was repeated after the increased offer at week eight (5000 g DM/day/pen). It is probable that the greater weight gains were due to the availability of more feed initially satisfying the pig's appetite but not for growing needs *per se*.

Feed cost comparison

The unit costs of feed components are shown in Table 4. The mean daily cost of intake as fed per animal was higher for FCSPS than both PGSPS and PGSTD (Table 5). Based on feed costs alone FCSPS was the most costly diet to raise four growing pigs while the commercial pig grower PGSTD was the least costly; however, the current prices of these components were particularly high at the time due to high prices of these export commodities on the world market. During the same year local market price of fish meal fluctuated from K1.65 to K2.20; similarly copra meal market prices were 25% lower later in the same year.

Table 4. Unit costs of the feed components used for blending the three diets.

Components	Unit cost (Kina)
Pig grower[1]	1.50*
Fish meal[2]	1.80*
Copra meal[3]	1.65*
Sweet potato silage	1.25**

*Based on suppliers prices in July 2010 (+VAT): Goodman Fielder[1] (PNG) Ltd, IFC Ltd[2] and Farmset Ltd[3].
**Based on the cost of market sourced SP tuber at Kina 0.75 per kg bag and fresh vine at Kina 0.50 per kg.

Table 5. Total feed intake of four pigs as fresh weight (or 'as fed' basis) and cost of each diet.

Diet‡	Total feed intake (kg)	Total cost (Kina)	Average daily cost (Kina) ± St. dev.
FCSPS	803.1	1,082.68	9.67 ± 1.66
PGSPS	617.4	852.12	7.61 ± 1.48
PGSTD	455.3	682.93	6.10 ± 1.13

‡Diets: PGSTD = sole diet of standard commercial pig grower ration, control diet; PGSPS= a mixed ration of commercial pig grower blended with sweet potato silage 50:50 as fed; FCSPS=a mixed ration of sweet potato silage blended with a combination of fish meal and copra meal at 77:4:19 ratio on as fed basis.

DISCUSSION

Despite the rather large differences in dry matter content of the treatment diets (Table 1) the mean dry matter intake by pen of the two blended SP silage diets were not at all significant ($P > 0.1$). The much higher fresh weight (FW) intake of the farm made concentrate diet (FCSPS) had compensated for the lower DM content of SP silage in the other two diets (Table 2). The comparable level of feed DM intake signifies the high palatability of protein concentrate rations blended with SP silage. This is an important finding, since the FCSPS diet was composed entirely of locally available copra meal., fish meal and SP silage, with the latter contributing 54 % of the DM, in contrast to the commercial pig grower ration made primarily from imported energy (wheat, sorghum) and protein (soybean) sources.

The average daily weight gains (ADG) were improved for all three diets by comparison to previous feeding trials using similar feed components as mixed offer to growing pigs (Dom and Ayalew, 2009b). As expected, the PGSPS containing 75 % commercial grower pellets provided a better ADG of 634 g/day than in a previous trial at the same location where it constituted only 50 % of the ration and gave ADG of 540 g/day.

In this trial the FCSPS diet made up of 8 % fish meal and 37.5 % copra meal was less efficient (FCR = 3.80) but the ADG was 442 g/day compared to 371 g/day (FCR = 2.99) on a farmer's own ration (FFO) which consisted of copra meal and fish meal in equal proportion offered at 500g per animal along with SP silage at *ad libitum* offer (Dom *et al.,* 2010). On the other hand, the sole fed commercial pellet diet (PGSTD) had improved FCR and ADG in this on-station trial than in the previous on-farm trial where it was also offered to similar growing pigs. Therefore, considering the cooler high altitude climatic conditions (altitude of 2250 m and mean daily temperatures of 20 °C) of the highlands expected to be conducive to growth, the improved performances on the present warm and humid lowland environment may be attributed to a better nutritional balance of the diet.

On the premise that feed intake in growing pigs goes primarily to satisfy energy needs for growth (ARC, 1981) , and that the dry matter intakes were similar, it is asserted that the SP silage based blended diets can provide adequate gross energy like the commercial pig grower ration, as was also indicated by the calculated nutrient compositions.

In addition, the calculated crude protein level of the FCSPS (16.2 %), mainly from copra meal., was slightly higher than that of PGSPS (14.6 %); so it is argued that there were other factors responsible for the lower growth performance on the FCSPS diet, in particular for the drop in the average weight gain of 192 to 301 g/day (Table 3). The PGSPS diet with the 25 % SP silage blended with 75 % commercial pellet diet had an ADG of 634 g/day, which was on par with predicted daily weight gain of 640 g/day for growing pigs in the tropics (Durrance, 1971; As cited in Payne, 1990).

It is noteworthy that the growth performance on these simple farm-made diets was similar to those of more comprehensively formulated rations of sweet potato silage tested by Giang *et al.* (2004). It is therefore hypothesised that further improvements to the FCSPS diet ingredients may raise the performance of growing pigs. Conversely, at the time of this trial the fish and copra concentrate meals were in short supply at the local stock feed distributors and thus accounting for the higher unit costs of fish meal and copra meal at the time (Table 4) and consequently the FCSPS diet proved to be the most expensive to feed on a daily basis (Table 5).

CONCLUSIONS AND RECOMMENDATIONS

The daily feed intake on the SP silage mixed with either commercial pig grower (at 75 %) or a combination of fish meal and copra meal (at 45 %) or the sole fed commercial feed (100 %) were not significantly different (at least at $P > 0.05$). But weekly body weight gain showed highly significant differences (at least $P < 0.05$) that were more indicative of disparity between the commercial pellet feed and the fish meal and copra meal concentrates mixed with SP silage.

Commercial grower pellets are nutritionally balanced using imported soybean, sorghum, corn meal and other grains. and hence their high retail prices. It is likely that a lower cost diet composed of locally available feed resources, namely sweet potato, copra meal and fish meal, may be further enhanced by improved feed formulations which also include other local ingredients that contain a better balance of nutrients, particularly protein. Likely ingredient inclusions are millrun, poultry offal meal, palm kernel meal, rice millings, cassava, mulberry leaves, taro forage, as well as using varieties of the locally grown forage feeds, by processing into dried or ensiled form to increase their palatability.

Since these feed resources are more readily available than the grain based commercial feeds and are required in less bulk order, which also entails shipment or cartage costs, there may be economic incentive to maximizing their use as animal feeds. Further research into effective, least cost rations is recommended to improve the feeding options for smallholder pig farmers, particularly those with interests in entering the competitive commercial fresh meat markets.

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Evidence of environmental effects on cocoa flavour attributes

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ABSTRACT

Local Papua New Guinea cocoa clones were compared over two successive years for flavour attributes. There is strong evidence of marked environmental factors such as climatic and edaphic influences of the growing environment on cocoa flavour. Restriction Maximum Likelihood variance estimation for crop year effects indicate a significant difference in floral ($P \leq 0.001$), chocolate ($P \leq 0.01$) and acid ($P \leq 0.05$) flavour. Analyses of variance for sets of cocoa clones show significant ($P > 0.05$) differences in flavour attributes between crop years.

Key words: Environmental effects, cocoa flavour attributes.

INTRODUCTION

Environmental effects (mainly soil and climate) and methods of post harvest processing have been proposed as being responsible for the Arriba flavour of Ecuadorian beans (Enriquez, 1993; Wood & Lass, 1985). Other work (Clapperton, 1994) has indicated that the same genetic material planted in different environments exhibits similar flavour characteristics when processed in a similar manner. Recent studies have shown that flavours developed from different plantings are clearly distinguishable and differ in cocoa flavour intensity, acid taste, bitterness, astringency and fruity/floral notes (Clapperton *et al.,* 1991, 1994). The majority of the flavour characteristics are heritable (Clapperton, 1993). The quality characteristics of cocoa have been shown to be significantly influenced by genotype; however, they can also be influenced by environmental factors. Bean quality has been shown to be influenced by rainfall (Wood & Lass, 1985) and other environmental factors such as nutrients and water availability. However, beans of the same genotype harvested from two different locations, but subjected to the same post-harvesting processing techniques before their flavours were assessed, indicated that the environment appeared to have no effect on flavour (Figueira *et al.,* 1997) but Wood (1975) reported that the same genotype planted in different locations produced different bean quality. The genotypic variation in cocoa bean quality has been reported from several studies (Chong & Sidhm, 1991; Lambert *et al.,* 1996; Tucci *et al.,* 1996; Clapperton, 1996; Pires *et al.,* 1998). It has been recognized that flavours differ between origins and some are associated with distinct varieties and environments of origin. Mouth feel or viscosity of cocoa liquor is under genetic control (Clapperton *et al.,* 1994c). The influence of local breeding and selection programmes and local growing conditions, together with other exogenous factors, are manifested in specific cocoa flavour. The bean quality of cocoa is influenced by genotype and genotype x environment interactions. Papua New Guinea is known to produce a unique blend of flavour classified as being fresh ripe, acid or winery flavour that transits to produce pleasant moderate and basal flavour (Kuman, 2005).

Genotype x environment interaction is a widespread interaction indicating the reaction of genotypes to the environment in which they are grown (Weber *et al.,* 1996). The bean quality of a genotype can be influenced by confounding effects such as genotype x location x year (Bramel-Cox, 1996). Most of the literature discusses the genotype and post harvest processes and their influence on cocoa quality. This paper is concerned with the effect of environmental factors on cocoa flavour as indicated by year to year variation.

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MATERIALS AND METHODS

Four local fine flavour KA clones (KA1-106, KA 16-2/3, KA 37-13/1 & KA 73-14/1) and local bulk clones (NAB 11) were evaluated for their flavour attributes in the 2003 and 2004 crop years at the Papua New Guinea Cocoa and Coconut Research Institute. The flavour attributes of each clone were compared against each other and against the Ghana reference sample. Ghana is the industrial standard for "bulk" cocoa and is included and used as a reference for organoleptic assessment. The KA hybrids represent available local fine flavour clones which were developed by crossing original local Trinitario and Amazonian clones, while NAB 11 represents local bulk cocoa.

Sample collection and preparation

Post harvest processing is critical for all cocoas and is essential for the development of cocoa flavour. In this trial, all the samples were subjected to the same post-harvesting processing techniques to minimize any processing defects that may affect optimum flavour development. Wet beans were only collected from fully matured, undamaged and healthy pods. For each micro-fermentation, samples of about 3 kg of the fresh beans were collected and placed inside a labelled 24 x 80 cm nylon bag of 10 mm mesh and 0.7 mm thread diameter. The micro-fermented samples were buried 30 cm from the top of a sweatbox of dimension 60 cm x 60 cm x 60 cm (width, length and depth respectively) filled with 200-250 kg wet beans of mixed hybrids. The top of the sweat box was covered with banana leaves and jute sacks to keep the beans moist throughout the duration of fermentation. Turning of the buried test samples was achieved by uncovering, holding the ends of the nylon bags and shaking the bag to mix the beans inside, and after turning the bags were reburied at approximate the same depth. Fermentations were done for 168 hrs. After fermentation, the beans were removed from the nylon bags, labelled, spread out on the drying floor of the solar dryer and dried between 120 to 144 hrs depending on weather conditions.

Secondary processing

The drying of the beans was completed in an oven (Contherm, New Zealand) at 115 ^{o}C for 15 min to reduce moisture content to less than 7 percent before the beans were emptied into a quartering devise, and in this process any debris that came with the beans was removed. The bean shells were manually removed and the nibs were collected and stored in sealed food-grade plastic containers. The nibs were ground for 90 min into cocoa liquor using a rotating mortar and pestle. During blending in the mill, the motor part of the unit (bottom half) was changed periodically to prevent overheating. After milling and blending, the cocoa liquor was transferred from the mill to 120 mL capacity sterile specimen containers and stored at - 8 to – 20 ^{0}C prior to organoleptic evaluation.

Organoleptic evaluation

The organoleptic evaluation was conducted following the procedures described by Sukha (2001) and the American Society for Testing of Materials (ASTM), 1992.

Data analysis

Individual flavour attribute scores from the profiling forms were entered into a data template in Microsoft Excel. Variance components were investigated using Restriction Maximum Likelihood (REML) variance estimation with Genset 4.24 DE. Analysis of variance (ANOVA) was calculated using MINITAB Release 14 to determine the significance of treatment effects and interactions using pooled data for all flavour attributes.

RESULTS AND DISCUSSION

The flavour profiles in Figures 1 and 2 reveal that local clone KA 73-14/1 showed a marked floral note in the 2003 crop year which was not observed in 2004. Data from these two local clones (KA2-106 & KA 73-14/1) were also analyzed by REML variance estimation of crop and year effects which showed a significant difference in floral ($P \leq 0.001$), cocoa ($P \leq 0.01$) and acid ($P \leq 0.05$) flavour between years. ANOVA of flavour attributes indicates significant differences between clones within the two samples (data sets with or without Ghana) for each respective crop year.

The ANOVA of flavour assessment

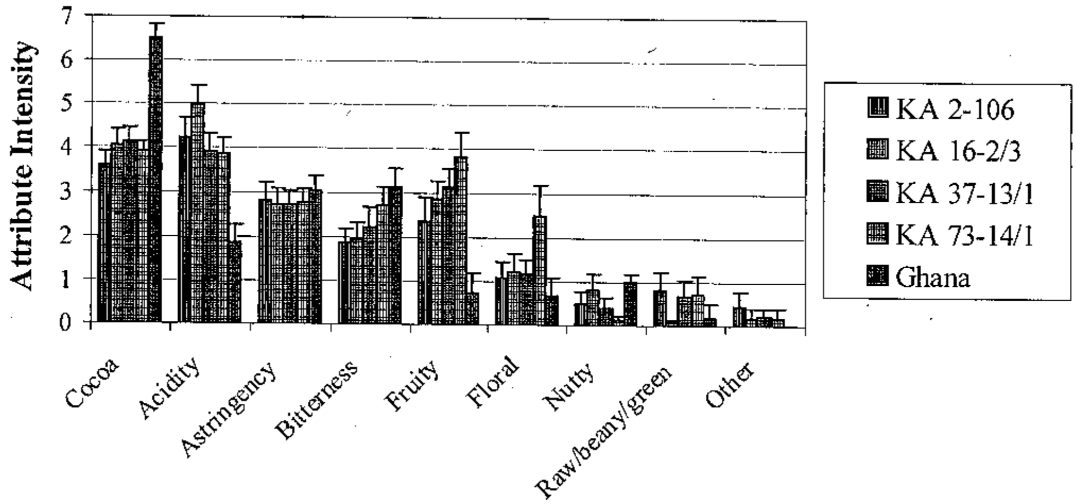

Figure 1. Average flavour profiles for KA local clones 2003 crop year compared to Ghana reference sample.

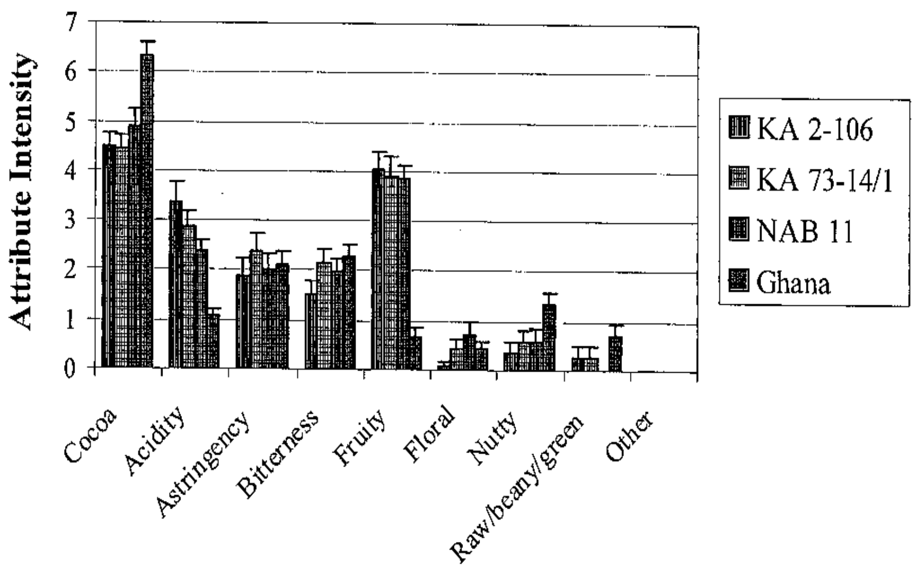

Figure 2. Average flavour profiles for KA and NAB local clones in 2004 crop year compared to Ghana reference sample.

shown in Table 1 indicates that there were no significant differences between the flavours of local clones harvested in 2003. However, the same clones harvested in the 2004 crop year show significant differences between them in acid, bitter and floral flavour. The 2003 clones also show significant differences in all flavours except astringency and nutty flavour when compared to the Ghana reference sample. For the 2004 crop year, the local clones were dominated by strong fruity and acid flavour notes, quite different from the strong cocoa flavour in the Ghana reference.

CONCLUSION

The results from this study indicate that there were no significant differences in flavours between local clones harvested in one crop year (2003) but there were significant difference in the following year (2004). The same applies to the flavour of local clones when compared to the Ghana reference. These results provide strong evidence of marked environmental effects on flavour in addition to genotypic effects, given that all samples were subjected to the same post-harvesting processing techniques. Aspects of the environment that could affect flavour include climatic and edaphic influences of the growing environment. Similar results were obtained by Wood and Lass (1985) and Enriquez (1993). However, Figueira *et al.* (1997) showed that

Table 1. ANOVA of local clones with and without comparison to the Ghana reference.

Flavour attributes	Local KA clones (2003 crop year)		Local KA clones (2004 crop year)	
	Without Ghana	With Ghana	Without Ghana	With Ghana
Cocoa	NS	***	NS	***
Acidity	NS	***	*	***
Astringency	NS	NS	NS	NS
Bitterness	NS	NS	*	**
Fruity	NS	***	NS	***
Floral	NS	*	*	NS
Nutty	NS	NS	NS	NS
Raw/beany/green	NS	NS	NS	*
Other	NS	NS	-	-

**P≤ 0.05 **P≤ 0.01 *** P≤ 0.001 Not Significant (NS) ≥ 0.05* - Anova not possible due to 0 scores

beans harvested from the same genotype at two different locations produced similar flavour. This could be the result of genotypes showing similar responses under the different environmental condition or the two locations may have similar climatic and edaphic conditions influencing the flavour. Flavour assessment conducted in different countries provides strong evidence that each country produces unique fine flavour cocoa due to the combination of genotype and local environment conditions. There is a need to develop well-buffered genotypes that can adapt to transient environmental fluctuations and at the same time produce consistent flavour attributes.

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Comparative study of mutant and normal segregant seedlings of cocoa (*Theobroma cacao* L.)

Eremas Tade[1], Doug A. George[2], Richard R. Williams[2] and Peter Bapiwai[1]

ABSTRACT

A mutant cocoa genotype, MJ 12-226, with abnormal growth characteristics was identified at the Cocoa and Coconut Institute of PNG. The comparative study of mutant and normal cocoa seedlings revealed distinct vegetative differences between the two genotypes at the nursery stage. The largest effects of the mutant genotype are on stem elongation, short internodes, multiple stems, root growth and leaf growth. It was initially hypothesized that the dwarf cocoa mutant genotype was probably deficient with gibberellic and auxin, however, chemical analysis clearly showed that endogenous GA_1 and IAA were not limiting.

Key words: Cocoa, mutant, genotype, SCA 12, NA 149, IAA, GA_1.

INTRODUCTION

The dwarf mutant, MJ 12-226, with abnormal growth characteristics was identified at the Cocoa Coconut Institute of PNG. The mutant, found among progenies of the cross SCA 12 x NA 149, was characterized by short stature, small and narrow leaves, a small root system and multiple stems with strong branching habit (Efron *et al.,* 2002, 2003a, 2003b). The parents SCA 12 originated from Peru and NA 149 from Ecuador (Pound, 1948). After germination, all the seedlings looked the same, but the phenotypes of mutant and the normal phenotypes were clearly noticeable after two months. Most of the mutant seedlings produced multiple stems that developed into multi-stemmed short and compact trees. Orthotropic buds from the mutant genotype were bud grafted onto normal rootstock to develop the clone MJ12-226. All the grafted seedlings showed similar short compact dense growth with high branching habit and small narrow leaves. The pods and seeds were also of normal size and number of seeds per pod was the same as normal cocoa with an average of 37 seeds per pod.

This study evaluates the morphological characteristics of the cocoa dwarf mutant in comparison with normal segregant seedlings. The objectives are; (1) to verify that the growth characteristics of the mutant dwarf are different from normal segregant seedlings; (2) to measure endogenous levels of gibberellin and auxin in mutant and normal cocoa seedlings.

MATERIALS AND METHODS

Glasshouse: The experiments were conducted in a glasshouse of the School of Land, Crop and Food Sciences at the University of Queensland, Gatton Campus. The experiments were carried out between October 2005 and March 2006. Temperatures in the glasshouse ranged from 20 °C at night to a maximum 40 °C during the day in summer and 14 °C to 26 °C in winter.

Plant Materials: Seeds were obtained from open pollinated MJ 12-226 mutant cocoa clones grown at CCI. Seeds were harvested and soaked in a solution of 10 g of metalaxyl fungicide (Ridomil Plus 72) in 1 litre of water. After importation to Australia, the seeds were pre-germinated for 5 days by wrapping them in paper towels soaked in water, and sprinkled with water at 2 days intervals to keep them moist. The germinated seeds were planted in pots with potting mix and placed in the glasshouse. The potting media consisted of 40% pine bark, 40% hardwood saw dust and 20% sand with Osmocote slow release fertili-

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zer (4kg/cm^3) added to the potting mix giving a pH of 5.5-6.0. The pots (180 mm) were filled with 1.5 kg of potting media. The seeds emerged from the pots seven days after sowing. The seedlings segregated into mutant and normal phenotypes six to eight weeks after sowing.

Treatments: At eight weeks after germination, seedlings were sorted into mutant and normal phenotypes and selected for this study with ten replications (10 plants each) in a completely randomized design. Individual plants were replications.

Vegetative growth, seedling height, leaf width and length, leaf petiole and stem were measured with a plastic ruler (30 cm) and stem diameter was measured with digimatic caliper (Model No. CD-6C, Mitutoyo Corporation, Japan) starting at one month after sowing. Leaf number (number of nodes) counts commenced from the first node.

Extraction of IAA and GA: Gibberellin and auxin levels were measured in mutant and normal cocoa seedlings. Gas chromatography-mass spectrometry-selected ion monitoring GC -MC-SIM) with deuterated internal standards was used to quantify GA_1 and IAA level in apical portions. Shoot tips (5-10 mm) excised immediately above the uppermost fully expanded leaf from four month old mutant and normal cocoa seedlings were weighed and wrapped in aluminum foil and then immediately placed in liquid nitrogen for ten minutes. The samples were then freeze dried for 48 hours and then packed in padded bag (Australia Post) and sent to Dr John Ross at the University of Tasmania for analysis. Extraction and quantification of GA_1 and free IAA was performed as described previously (Reid *et al.,* 1992; Ross, 1998, 2002, 2006; Ross *et al.,* 1995; O'Neill & Ross, 2002).

Statistical analysis: Data were analysed with GENSTAT Release 7.2 – Discovery Edition 3 statistical analysis software (Lawes Agricultural Trust, Rothamsted Experimental Station, UK). Data from this experiment was analysed by analysis of variance (ANOVA) using a completely randomized design.

RESULTS

Seedlings emerged seven days after sowing and percentage germination was 98% two weeks after sowing. Two months after sowing the seedlings segregated to 111 seedlings mutants and 90 seedlings normal out of the 201 seedlings that were sown in the glasshouse giving a 1:1 ratio (Chi-square = 0.52; $P = 0.25 - 0.50$).

The mutant phenotype was visibly distinct (about 50% shorter) from the normal seedlings. At first, after germination, all the seedlings looked similar in appearance (Figure 1). The phenotypes of the mutant and normal phenotypes could only be seen after two months; mutant plants were shorter with smaller leaves (Figure 2). Most of the mutant seedlings produced multiple lateral shoots on the cotyledon node (Figure 3A) about six to seven weeks after sowing. The most obvious features of the mutant phenotype included greatly reduced plant height, thin stems, tiny leaves, a smaller root system, development of multiple stems from the basal nodes, resulting in a shorter compact growth habit (Figures 4 and 5). These seedlings would later develop into multi-stemmed short and compact trees with highly branching habit and smaller root systems (Figure 5).

The mutant genotype affected a wide range of vegetative traits. Changes in some vegetative traits were very large indeed. The height ($P < 0.01$) of the mutant is about half that of the normal seedling (Figure 6A). Stem diameter (Figure 6B) was significantly ($P < 0.05$) reduced in the mutant compared to the normal genotype seedling (Figure 6B). However, the number of leaves was not significantly altered (Figure 6C). Measurement of seedling height, stem diameter, leaf length and leaf width of mutant and normal seedlings from one month to five months after planting showed some marked differences between the two phenotypes (Figures 6A and 6B, Figures 7A, 7B and 7C). The leaf length and leaf width was also greatly reduced ($P < 0.01$) (Figures 7A and 7B). Root morphology (Figure 7C) obtained from 3 month old plants of the mutant and normal genotypes indicated that the mutant had significantly reduced mean tap root length (less than 70% of the normal genotype, $P < 0.01$).

Chemical analysis of endogenous GA_1 and IAA revealed that the levels were almost similar for mutant and normal genotypes in 4 months old seedlings (Table 1), which show that the natural auxin IAA and gibberellic acid (GA_1) are not limiting in the mutant genotype. This suggests an abnormal transport of gibberellin through the mutant plants that may have resulted in the dwarfing characteristics.

Figure 1. Mutant and normal seedlings look the same at one month after sowing.

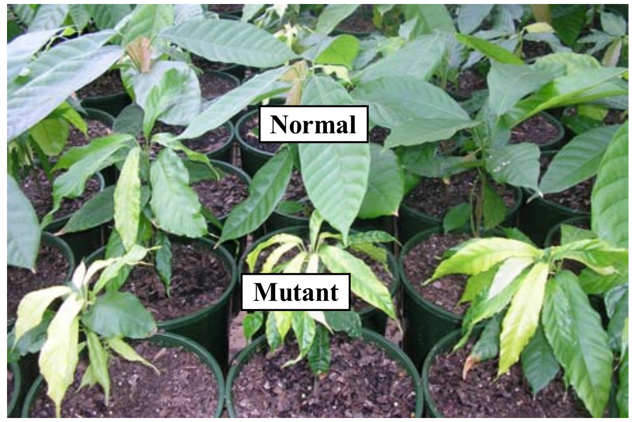

Figure 2. Two months after sowing the segregated seedlings are distinguishable in the glasshouse nursery. (The main features noticeable in mutants are smaller leaves and development of multiple shoots on the first node.)

Figure 3. Lateral shoots developing on first node (cotyledon node) of mutant stem (A) and buds remained completely dormant on normal (B) cocoa seedlings 7 weeks after sowing. (Note the cotyledons have dried and fallen off from the first nodes of both genotypes.)

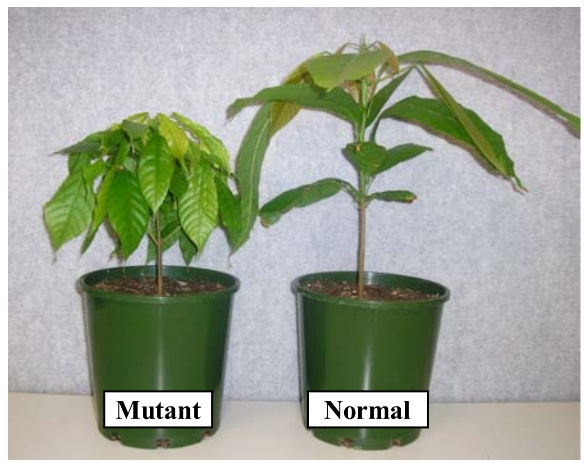

Figure 4. Growth habit differences between mutant (left) and normal (right) cocoa seedlings at four months.

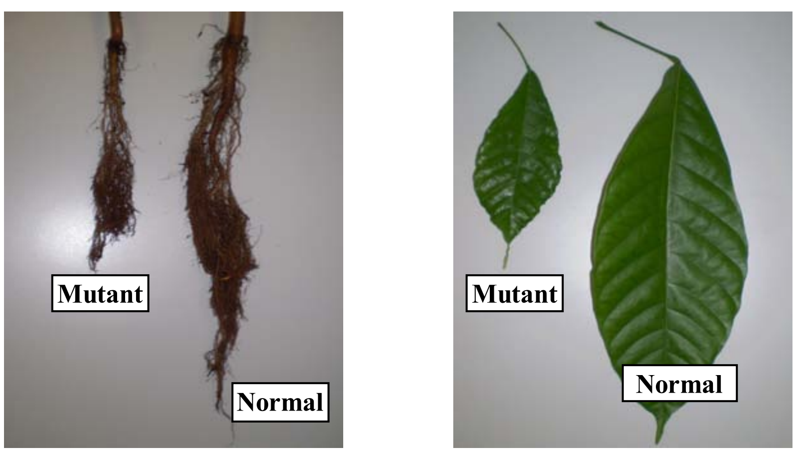

Figure 5. Root systems (left) and leaf characteristics (right) of 4 months old mutant and normal cocoa seedlings. (The root system and leaf size of the mutant genotype are much reduced compared with the normal genotype.)

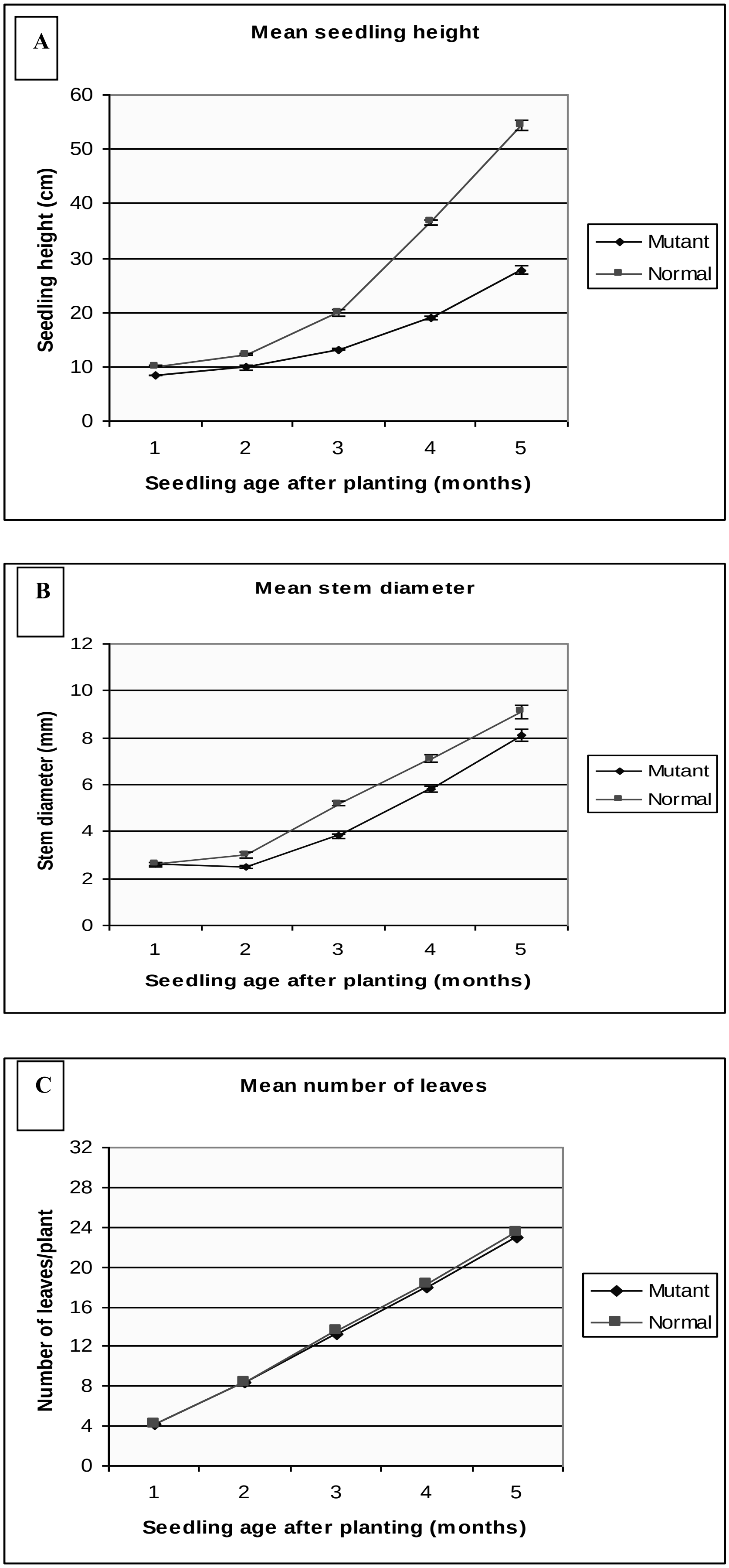

Figure 6. Seedling height, number of leaves and leaf length of mutant compared with the normal cocoa seedling (n = 10). The error bars are standard error of mean.

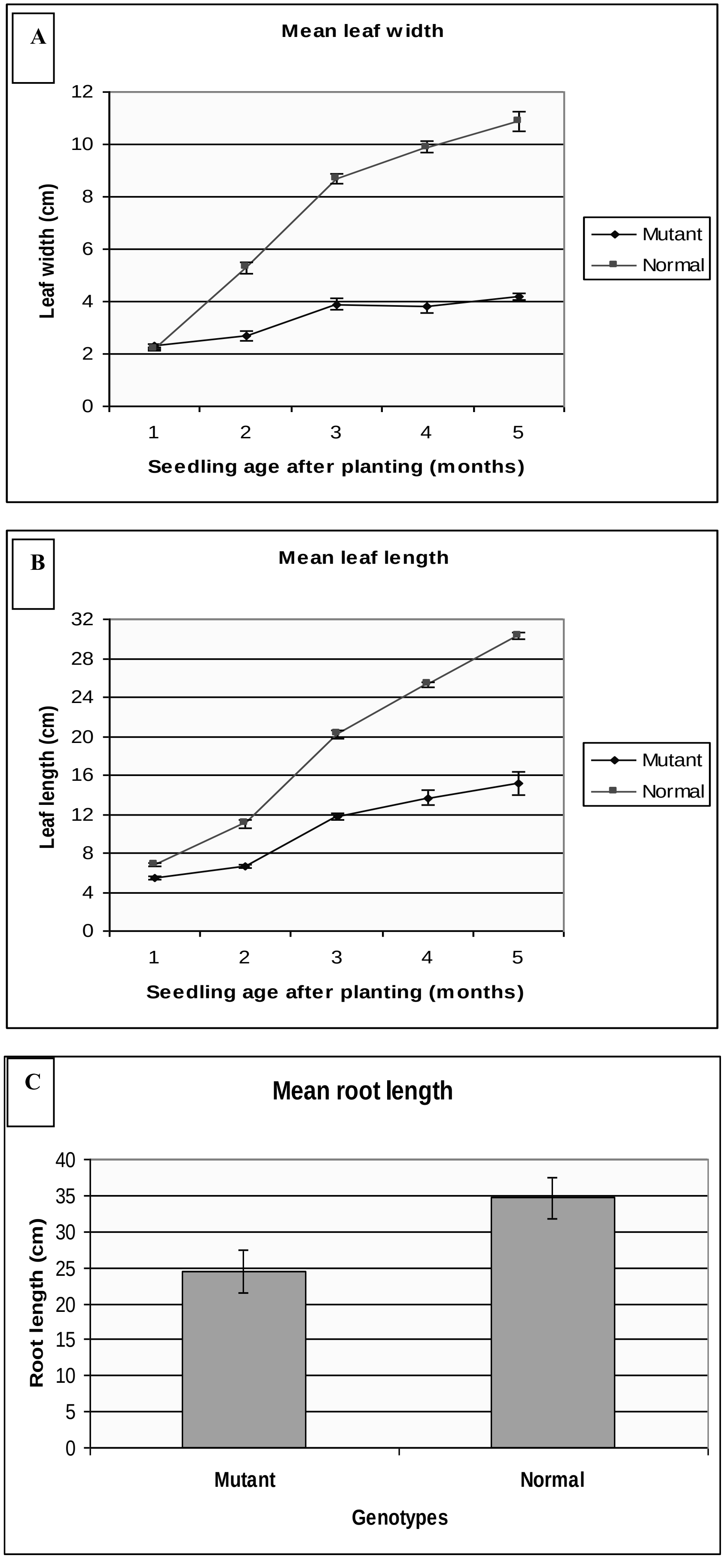

Figure 7. Seedling leaf width, stem diameter and root length of mutant compared with the normal cocoa seedling (n = 10). The error bars are standard error of mean.

Table 1. Endogenous levels of GA_1 and IAA in four months old seedlings measured from the shoot tips of mutant and normal cocoa seedlings. Apical portions consisted of all tissue above the second uppermost fully expanded leaf.

Genotype	GA_1 ng/gram fresh weight	IAA ng/gram fresh weight
Mutant	1.4	15.5
Normal	1.2	14.2

DISCUSSION

It has been reported that the most important and consistent morphological trait contributing to expression of dwarfism in four woody plants studied was the reduction of final internode length along the entire shoot axis (Brown *et al.,* 1994). They discovered that the reduction in final internode was attributed to inhibition of mitotic activity in developing internodes which resulted in decreased final cell number, and not cell length. In contrast, reduction in internode and stem length of *bsh* pea mutant was due primarily to reduced cell length (Symons *et al.,* 1999).

The mutant cocoa has several notable features. The mutant genotype has pleiotropic effects on a wide range of vegetative characteristics including shoot elongation, leaf growth, stem diameter, root morphology, and branching. Similarly, the dominant pea mutant *bsh* (*bushy*) branches profusely from the basal nodes unlike the *rms* mutants; it has a strongly pleiotropic phenotype with short thin stems, tiny leaves, and reduced lateral root development (Symons *et al.*, 1999). In contrast to pea mutant *rms1, rms2, rms3, rms4, rms5*, the *bsh* mutant is deficient in auxin and has elevated levels of cytokinin (Symons, 2000).

Branching at the vegetative node of *rms* mutants of pea occurs during several stages of plant ontogeny and in the presence of a vigorous shoot tip (Beveridge *et al.,* 2003). In pea, the branching phenotype is also influenced by gibberellin status. Mutant plants deficient in gibberellin, such as the widely used *le* dwarf cultivars, have a greater tendency to produce lateral shoots from the basal nodes than tall wild type counterparts (Floyd & Murfet, 1986; Murfet & Reid, 1993; Murfet & Symons, 2000). Mutants in other species have been essential in identifying mechanisms of shoot branching in intact plants. Arabidopsis (*max*), petunia (*Petunia hybrida; dad*), and rice (*Oryza sativa;* e.g. *Dwarf3*) have been identified as showing increased shoot branching in intact plants (e.g. Foo *et al.,* 2005; Snowden *et al.,* 2005; Bennett *et al.,* 2006). Considering the growth habit of the mutant cocoa, it is assumed that the mutation affects the quantity and/or the balance of plant growth hormones, or both.

The mutant cocoa has similarities with three pea mutants (*le, bsh* and *rms6*) with genetic alterations that modify apical dominance. The pea mutants and the cocoa mutant have several features in common: multiple branching from the basal nodes, reduction in internode length, and reduced apical dominance. It can be noted also that, initially, after germination, all the seedlings looked the same and mutant segregants were not visible until about two months after seedling emergence. These observations indicate that mutant cocoa seeds have the key growth substances necessary to support normal germination and the effect of the mutation is only expressed in the shoot as supplies of key substances from the cotyledons decrease. In this experiment it was observed that the cotyledons start to dry out and fall off from the seedlings between weeks 7 and 8 after emergence at which point the segregation to mutant and normal genotypes were also clearly distinguishable. In pea, the effect of *bushy* mutation is visually apparent about 6-8 days after seedling emergence which was also suggested to be related to diminished supply of growth hormones as cotyledons die (Symons *et al.,* 1999). Similarly, *early dwarf* in apples became apparent four weeks after germination and *sturdy dwarf* was distinguishable at eight weeks after emergence (Alston, 1976).

In addition, flower size, pod size, seed size and number of seeds per pod (average of

37 seeds) of mutant cocoa was similar to normal cocoa (Efron *et al.,* 2002). This suggests that the mutation had little or no direct effect on reproductive traits. Similarly, in pea, the *bsh* mutant produced fertile flowers, pods and seeds of normal size comparable to the wild type phenotype (Symons *et al.,* 1999). It is possible that the essential plant growth substances affecting the mutant phenotypes are not involved in pod and seed development but it is possible that there are some genetic interruptions of hormone biosynthesis.

The physical appearance of the mutant cocoa suggests disturbance in plant hormones, such as auxin and gibberellin. The effects can be seen as reduced apical dominance that leads to production of multiple basal lateral shoots (auxin effect) and reduction in stature (GA effect). The mutant phenotype probably combines traits associated with auxin, cytokinin overexpression, and GA limitation. Undoubtedly, it is necessary that further experimentation on the dwarf mutant will involve an analysis of plant hormone concentrations.

It was initially hypothesized that the proliferation of lateral branches on the basal node in the mutant genotype was due to weak apical dominance which is related to auxin deficiency, and it was postulated that the dwarf stature was probably due to GA deficiency. However, the results of this study (Table 1) from chemical analysis of shoot tips of four month old mutant and normal seedlings revealed that the content of endogenous levels of GA_1 and IAA were almost similar in both genotypes. This could be explained in several possible ways. Firstly, the analysis only showed results for endogenous GA_1, however, other GAs were not tested and should also be considered for examination in the future to confirm these findings. Secondly, the methodology used to assess GA_1 and IAA levels was developed for peas (a herbaceous plant) and may not be applicable to woody species such as cocoa; this therefore may cast some doubt on the results. If GA and IAA are not limiting in the mutant genotype, then what causes the mutant to develop shoots on the basal node? It is postulated that the promotion of shoots on the basal node of the mutant genotype was probably related to cytokinin/ auxin ratio.

CONCLUSIONS

The comparative study of mutant and normal segregant cocoa seedlings revealed distinct vegetative differences between the two genotypes at the nursery stage. The results show that the largest effects of the mutant genotype are on stem elongation, short internodes, multiple stems, root growth and leaf growth. These characteristics of the mutant indicate the possible involvement of auxin and/or gibberellin. The loss of apical dominance suggests the possible involvement of auxin or cytokinin, and the dwarf stature of the mutant implies that gibberellin is involved. Further studies will include investigation of the feasibility of using a dwarf mutant as rootstock for hybrid cocoa clones.

The dwarf cocoa mutant genotype was probably limited in other forms of GAs although the analysis showed sufficient levels of GA_1 (bioactive form of GA) in the stem. The proliferation of basal shoots on the mutant genotype could be due to higher levels of endogenous cytokinin. It is proposed that future research should include analysis of endogenous cytokinin and other forms of GA in both mutant and normal cocoa seedlings to verify these findings.

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Climate change and food security – some conceptual considerations

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ABSTRACT

Research on climate change and the impact on food security needs to incorporate changes in perspectives and priorities that came up in the past 30 years with emerging new paradigms in the field of food security research The challenges ahead, when looking at climate change and its impact on food security for the societies of Pacific Islands, is to embrace more holistic community -based approaches that take into account cultural, social, environmental and economic realities of small island societies that continue to depend on a mix of subsistence and commercial economy. It is particularly necessary for disciplines that have played a major role in food security discourses in the past (and need and will do this also in future) to embrace the paradigm changes of the past 30 years. Sadly, many science disciplines are not fully aware of how issues of food security are discussed outside science, and what social scientists consider crucial when assessing food security. Under such conditions interdisciplinary research efforts remain often unsatisfactory, providing few or no solutions.

Key words: Climate Change, Food Security, Livelihood Security, Pacific Islands.

INTRODUCTION

Today there is little doubt that the earth's climate is changing. The IPCC in its latest reports is rather clear that climate change is not something that will become reality for future generations, but we are in the middle of it (IPCC, 2007). Many parts of the world have to pre-pare for a more risky future where climate and other environmental factors are distinctively different from today. The process of transition, when people adjust/adapt to these new situ-ations is most challenging. Among many other aspects climate and environmental change need to also urgently look at issues of food security.

Until not long ago matters relating to climate change have been mainly seen from a per-spective of mitigation: what can be done to prevent climate change? Today these questions remain, but new ones have come up; they are starting to dominate discussions, research and policies. A distinct paradigmatic shift happened once the scientific community realized that climate change is real and mitigation, even if successful today, would not be able to prevent serious changes for at least another generation, possibly even much longer, or never. The ma-jor questions today are therefore: how can societies adjust, adapt or at least cope with the impacts arising from climate change?

With adaptation taking greater importance close cooperation between pure sciences and social sciences becomes more crucial than ever before. When assessment of the extent and nature of climate change and mitigation stood centre stage in scientific research, discussions were largely dominated by science disciplines. This has changed with more holistic, interdisciplinary, and increasing -ly community or grass-roots-based approa-ches becoming the order of the day. The goal is to integrate pure and applied science with social sciences to help making societies more resilient.

Providing a conceptual frame for research on climate change and food security should be the obvious first step to bridge this gap. This paper constitutes an effort to initiate discus-sion on such conceptual framework for scientists, both pure and social, to better understand how a more holistic approach can help Pacific island nations and communities; communities, arguably among the most vulne-

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rable in the world to the impacts of climate change.

Food security as access to food

Food production is affected by climate change; no doubt about this and we need to con-tinue looking at how this affects Pacific Island countries. People cannot eat food that has not been produced. However equally important is that food security is also much about access to food: people cannot eat the food that is there, when they don't have money to buy it. People cannot produce own food (and therefore don't need to buy it) when they don't have access to resources that are indispensable for food production: land, forests, fishing grounds. This tru-ism is central for food security in Pacific Islands, where access to resources often is managed through traditional systems that come under severe pressure through processes of modernization. Food security is also about food prices and the income of people, about the factors that enable/disable people to buy whatever they need for a healthy life. In many instances food insecurity is not a result of too little food being produced. We know even of situations, where people starve right next to supermarkets with all sorts of food available to buy. In the Pacific Islands there are many countries that import huge parts of their food requirements. They be -come more and more highly dependent on what is happening elsewhere, how commodity prices are developing. Hunger in such scenario often is the result of poverty (of countries as well as individuals) rather than insufficient food production (Dreze & Sen, 1991; Sen, 1981).

In his book *Poverty and Famines* Amartya K. Sen challenged the paradigm that famine is mainly caused by insufficient food production (Sen, 1981). His analysis of the Bengal Famine of 1943 and famines in Africa and Bangladesh in the 1970s concluded that it often was not a failure of food production, but of other factors that caused famine. Sen highlights that many people did not have the means to buy the food which actually was there. Sen calls this a decline in entitlements over food, a Food Entitlement Decline (FED), a decline of people's capabilities to buy food or to produce it (for recent discussions of the approach see: Elahi 2009, 2006; Rubin, 2009; Sohlberg, 2006; Yaro, 2004).

Entitlements over food can mean a number of different things, such as access to land and the ability to grow own food; or to have sufficient financial resources to buy food, or to get free or subsidized food through Government programmes. Among many other aspects in a Pacific Island context this relates to changes in land tenure systems, privati-zation of erstwhile common or group resources, increasing dependencies to imported food, and changes in dietary preferences that devaluate traditional foods. Also decent employment, earning enough that people are able to satisfy their basic needs constitutes entitlements. The same is for social se-curity systems, which come for support when people, for whatever reasons, are unable to satisfy their food and other basic needs.

From Sen's detailed analysis it also became evident that hunger and starvation do not hit all groups in a society in the same way and to the same extent. When rice prices sky-rocketed in Bengal farmers and grain merchants did very well. However artisans, fishermen, landless laborers and other people suffered who did not grow food, but had to buy it. Their income did not increase enough to compensate the high increase of food prices. From this example it becomes clear that food insecurity is often very group specific. To draft proper policies it is necessary to identify those groups that are in particular vulnerable to hunger and famine. Learning from this for Pacific Islands countries means to developed instruments to identify the most vulnerable sections in society and policies and measures of how to support them.

It was Sen's achievement to show that hunger has many faces, and that insufficient food production is only one of them. Sen directed attention to the whole food system: to production, distribution and consumption of food. He highlighted that hunger often has a lot to do with prices and incomes, with distribution of and access to food and productive resources and people's position in economic processes and the power structures of societies.

The vulnerability of marginal people

The British social scientist Robert Chambers (1988) came up with a concept of social vulnerability which also is suitable to apply to food security research. According to Chambers, vulnerability has two sides: an external side of risk, stress and pressure individuals and groups are exposed to; and an internal side, which are the capabilities, the abilities of people and groups to cope with such external pressures (ibid, 1). Vulnerability is much more than the economic status of poverty. It relates to the potentiality of being negatively affected by external events. It covers a wide range of economic, social, cultural and political aspects. Analysing these help us to better understand which people are most vulnerable and why, and ideally also where they live.

Watts & Bohle (1993a, 1993b) took Chamber's definition of vulnerability and developed a concept to better understand structural dimensions of vulnerability. They highlight the adverse consequences when people are not able to recover from events of deprivation quickly and sufficiently. According to them social vulnerability to food crisis has a distinct structural dimension, which is created over a long time and is rather stable. Inappropriate coping mechanisms can protect people in the short run against external stress (see Figure 1).

In the long run however they often increase what Watts & Bohle (1993a) call people's baseline vulnerability. In many cases a food crisis is the result of the accumulation of negative events. A single event, a drought or a cyclone, usually is not enough to trigger such crisis, but when many adverse events come together or quickly after one another then people's vulnerabilities become bigger. It then needs just a trigger, an event which in itself might be even of relatively minor nature, to reach a situation when the coping capacities of people are no longer suitable to withstand external stress. This then is when a catastrophe strikes; this is when a natural hazard such as cyclones becomes a disaster.

This is also when an economic crisis with a high degree of unemployment, or political instability and the collapse of public and private support mechanisms affect people to an extent that they can no more cope with what is happening to them from outside. So, people's baseline vulnerability or susceptibility turns into a food crisis or famine, when additional critical events happen that are beyond people's coping capabilities to withstand such external stress or pressures. Such trigger events can be droughts, earthquakes, floods, but also war, civil war and economic crisis.

Social scientists like Sen, Chambers, Bohle and Watts analyze the connection between the way societies organize themselves and

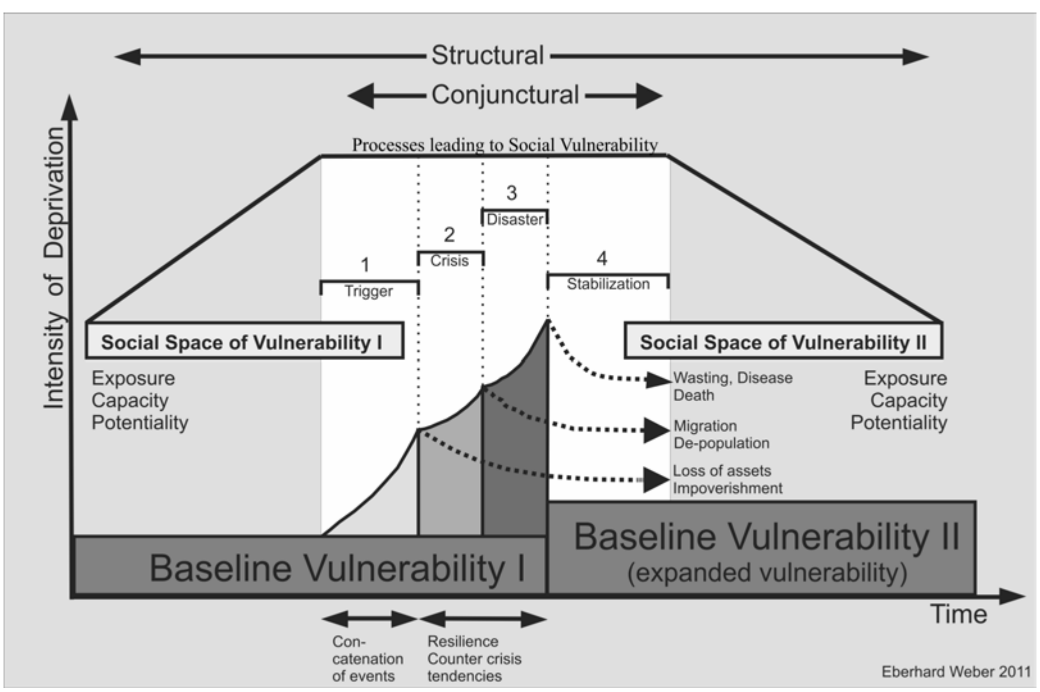

Figure 1. The structural dimension of hunger. (Adopted from Watts & Bohle, 1993)

vulnerability to hunger. Solutions to end hunger by producing more food, but which do not articulate inequality, unequal distribution of means of production, resources, incomes, wealth and other assets do not address all causes of hunger.

Looking at climate change, at insufficient food production, at natural hazards is not enough. It is essential to analyze who are the most vulnerable sections of society and what con -stitutes their vulnerability. It is also crucial to have better knowledge about possible events that can trigger a crisis. And: after the crisis often is before the crisis. We have to realize that people weaken through coping. They lose assets, become impoverished, they become sickly, social networks are destroyed through migration and death of family members. When the acute crisis is over people and communities are weaker than before. This is enormously important to realize. Their baseline vulnerability has increased and in future it requires less to trigger the next crisis. Here state intervention is urgently required to rehabilitate people after a disaster stroke in a way that they are prepared to withstand future pressures. This also refers to intervention that makes vulnerable people and communities resilient and better prepared to face the challenges of climate and environmental change.

After Sen and Chambers, various Sustainable Livelihood Approaches took up similar perspectives integrating them into much broader concepts (Bohle, 2009). Many authors highlight the importance of different capitals that help people to secure sustainable livelihoods. Figure 2 presents the Sustainable Livelihoods Framework as it had been developed by Oxfam. Here the following capitals are seen as crucial: natural capital which means access to land, marine and other natural resources and the quality change of these resources; physical capital, mainly seen as an asset arising from access to infrastructure, communication and information; human capital meaning skills, formal qualifications, health; financial capital seen as incomes of all sorts, savings and assets that can be converted into money whenever need arises. Another of the capitals that various sustainable livelihood concepts see as crucial is social capital, the belong-ing to formal and informal social networks that provide support and security to overcome difficult situations (Carney *et al.*, 1999).

In addition to these five livelihood capitals, which most Sustainable Livelihood approa-ches recommend to consider, there are strong reasons to include legal as well as cultural capital as own categories. Legal capital refers to supportive structures and processes that have legal foundations (e.g. Human Rights, social security legislation entitlements versus voluntary social welfare measures) and that enable people to enforce a claim. Cultural Capital refers to a society's normative structures that strengthen solidarity and mutual support, such as ethical principles

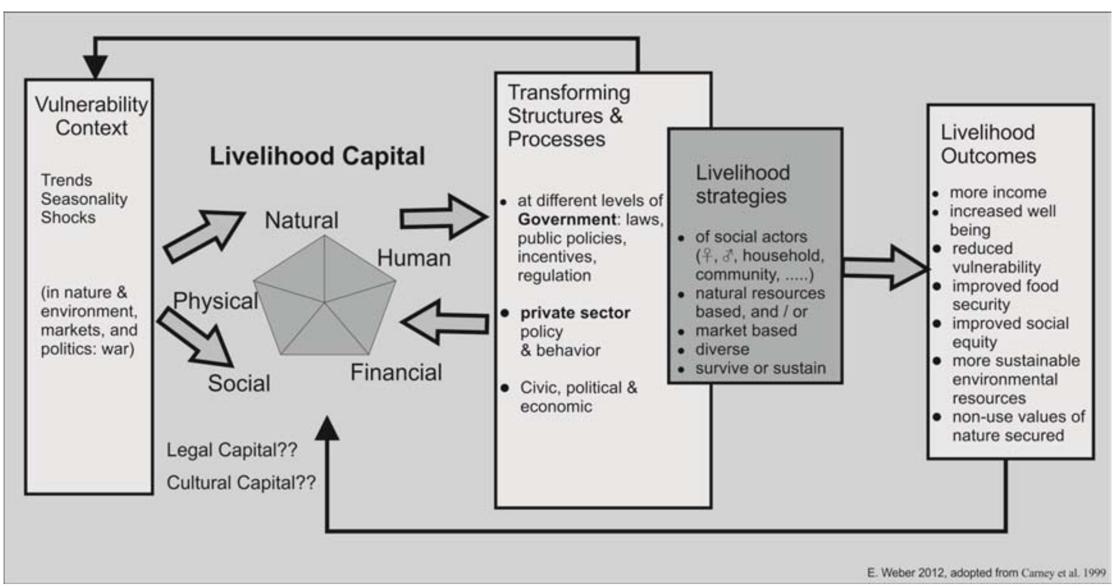

Figure 2. Oxfam Sustainable Livelihood Framework.

that are contained in all religions. With the event of such sustainable livelihood frameworks the concept of food security often was replaced by a wider, more comprehensive perspective of livelihood security. Realizing that food security is an important aspect of people's well-being, but not the only one, sustainable livelihood perspectives consider food security an important outcome to achieve, but directed attention also to other outcomes, especially such that fit nicely into concerns arising from climate change and disaster risk management discourses (see Figure 2).

Such new perspectives of food and livelihood security are complex and often very difficult to implement, to draft research activities or to work out recommendations and implementation strategies. Generally, however, such a new approach looks at strengths, potentials and weaknesses people and communities have and try to help communities to become more resilient. Details need to be worked out by case to case. Resilience then provides protection against all sorts of stress ranging from natural hazards to human-made disturbances of lives and livelihoods.

Earlier, when food insecurity was seen as the result of insufficient food production or na-tural hazards that destroyed crops in the fields, it was easier to draft "solutions": to increase food production, to achieve a Green Revolution (Baker & Jewitt, 2007; Brown 1970; Chakravarti, 1973; Frankel, 1971; Ladejinsky, 1970; Shiva, 1992; Vasavi, 2009).

Even today modernization of agriculture is what people think of first when impacts of climate change on food security are discussed. A changing climate foremost has impacts on agricultural production systems. At the same time it would be many steps backwards, if one ignores what has been achieved in the past three decades in food and livelihood security research: to analyze the entire food system from production through distribution to consumption. This has to be done when analyzing climate change impacts on food security.

Today we know that economic, social and cultural access to food is equally important than the (physical) availability of food. We realized that not everybody in the same way and to the same extent is vulnerable to hunger and food insecurity and that a food crisis is the cumulation of a number of events that increase vulnerability step by step, sometimes over a long time. Like mentioned above a small trigger event can be sufficient to cause a food crisis, and even when societies and individuals have recovered from an acute crisis their baseline vulnerability is usually much higher than before the crisis, i.e. it does not need much to trigger another crisis in future.

When looking at food security issues related to climate change we need to reflect of how climate change impedes on people's access to food, who are the most vulnerable groups exposed to these threats, where do these people live, and what are the mechanisms and processes that constitute vulnerability. To develop long-term perspectives it is also important to know, how exposure to the impacts of climate change increases people's baseline vulnerabilities, and what might be potential triggers that can cumulate in a food crisis. All this knowledge needs to translate in efficient policies and instruments to make people, make communities stronger.

Only if we have such information at hand it will become possible to make reliable state-ments on the impact of climate change on people's food security. A farmer in Fiji might be able to adapt to climate change by using improved seeds that are more suitable to changing climate con-ditions. However people living in low-lying, flood-prone squatter settlements that are resettled to the outskirts of cities gain little from agricultural modernization. The same is true for many societies in the Pacific Islands that depend to a large extend on food imports. Here not own agricultural production is what constitutes food security, but secure supply of food and low import prices.

Important questions are also how societies in the Pacific can cope with extreme weather events, with tropical storms, floods and droughts and other hazards. In isolated and remote places it can become a question of life and death of how easily people can cope with the destruction of their crops. Important questions are also what response mechanism communities traditionally have to cope with such hazards, and how such response systems are altered/weakened in changing societies. How resilient are the communities that have to deal with climate change and what is it exactly that constitutes resilience or that weakens comm-unities? To answer these and many more questions easily take us away from the climate change discourse to the analysis of society, to the questions of power, distribution of resources, participation in decision making and many other relevant issues.

Who goes hungry today and why?

As highlighted above food security is not only about food production. Especially when looking at the level of households other aspects become crucial. Here access to food is in the center of interest, people's capabilities to produce own food, to buy it or to get it through other means, e.g. through state transfers in form of subsidized food for the needy or other social welfare measures. These later aspects become crucial when natural hazards strike and successful emergency relief is an expression of a state's administrative, logistical and resource capacities. On the people's side their income and access to productive resources, such as agricultural land, pastures, fishing grounds and forests, is of major importance for food and livelihood security.

In 2003 the United Nations published a typology of hunger as it exists in today's world (Scherr, 2003; see also Bals *et al*., 2008). According to this report more than two billion people globally suffer from malnutrition. Strangely enough food insecurity is mainly a rural phenomenon. About 70 to 80 per cent of people suffering from hunger and malnutrition live in the regions, where food actually is produced.

As Table 1 reveals, more than half of the world's undernourished people live in peasant households, with insufficient access to land. They produce less than they need for their own needs, thus they need to buy parts of what they eat. According to the report these are people living in drylands and mountain areas. One easily could add small island locations. One also could highlight that these people often live in parts of the world where colonialism had resulted in wide-spread changes in ownership of resources (mainly agricultural land) and where as a result meaningful sections of society lost the ability to grown enough own food for their daily needs. These people in many cases are marginalized, like farmers with tiny land holdings in South Asia. Marginalization can also mean that land tenure is insecure, that land titles are not clear and that peasant farmers don't have access to credit which would allow them to increase their productivity. Living in the periphery can also constitute marginalization. Far away from markets, agricultural extension services, often at the mercy of middle-men, who rake in the bigger share of production. Such challenges exist in particular also in island states, where transportation is costly, unreliable and where it takes a long time to bring (often perishable) goods to the market.

For most of these marginalized peasant families' vulnerability is a combination of several factors. Often they belong to the poorest sections of their societies; they have insufficient access to land, and often no access to credit to improve their situation. Their educational status is often low, and they have few alternatives to earn a livelihood other than small -scale agriculture and unskilled labor jobs. The impacts of climate change add to their hardship already and will further increase their vulnerability and insecurity.

Next to marginal agricultural producers there are another 22 percent of people suffering from hunger and malnutrition who live in households, which have no access to land at all. Many of them work as agricultural workers with inadequate income to buy the food they need. No social security looks after their needs when they are sick, pregnant, or become too old to work. Modernization in agriculture over the past few decades has destroyed many jobs, and finding work all year round is one of the major challenges these people are facing. Eight percent of the world's hungry are pastoralists, fishers or depend on forest produce.

From Table 1 it becomes clear that access to land and other natural resources is a crucial precondition to achieve food security. To enable people to produce at least a bigger share of their food requirements is one of the challenges to abolish hunger and malnutrition.

Table 1. Typology of Hunger.

	Main causes of hunger/ undernutrition	% / # of under-nourished	Distribution in developing countries	Geographic 'Hotspots'
CLASS OF FOOD-INSECURE				
Low-income farm households	Increased production pressure on low-productivity, high-risk or degraded lands; remoteness from markets; poor market institutions	50% of total (400 million)	Of 633 million rural poor in higher-risk environ-ments; 355 million rural poor in favoured lands (includes farm and non-farm households)	Drylands: Sahel, Southern Africa, South Asia, N.E. Brazil; Mountains: Meso-america, Andes, E.Africa, Himalayas, SE Asia
Rural landless and low-income non-farm households	Inadequate income; weak social networks; lack access to produc-tive resources; lack of employment	22% of total (176 million)	Of 437 million rural non-agric. people, pro-bably 150-200 million are poor; # poor land-less farm workers hard to calculate	Asia, Central America
Low-income urban households	Inadequate income to purchase food; weak social networks, low productivity, wages	20% of total (160 mln)	25% of poor are urban; urban undernutrition seems to be lower than rural in large countries	China, India, Zambia
Poor herders, fishers, forest-people dependent on community or public resources	Pressure on natural re-sources; pollution; dis-ruption of resour-ce flows; loss of local rights	8% of total (64 million)	25 million pastoralists;60 million fishers; 250 million forest- dependent	Drylands: Africa, lowland Asia; forests: Amazonia, Himalayas, SE Asia
CROSS-CUTTING ABOVE GROUPS				
Pregnant and lactating women	Added dietary needs for pregnancy and breast-feeding, inadequate food and micronutrient intake	Several hundred million	60% of women in South Asia; 40% in Southeast Asia are undernourished	South Central Asia, Southeast Asia
Newborn infants	Inadequate fetal nutrition due to maternal malnutrition	30 million	Infants born undernouri-shed; 11% of developing country births; 21% SE Asia	South Central Asia, Southeast Asia
Children under 5	Inadequate child care, poor feeding practices, infectious disease, poor water, low status of women	170 million	33% of under-5 child-ren are malnourished; malnutrition a factor in 5 million child deaths p.a.	East Africa, South Central Asia, West Africa, Southeast Asia
Victims of extreme events (natural disasters, war & civil conflict, economic crises)	Disruption of food systems, loss of assets; aid not deliver-ed, low farm investment	60 million	60 + million in 2002 (range 52 to 67 million, 1999-2002); 12 million refugees, 25 million displaced people	Recent victims in Sahel, Horn of Africa, southern Africa
HIV/AIDS and other adult disabilities	Inability to produce or access food; increased dependency ratio; depleted social networks	36 million infected	25 mln in Sub-Saharan Africa; 150 million people affect-ed by sick family member	Sub-Saharan Africa, but moving to Asia
Micronutrient-deficient individuals (includes at least 1.2 billion not otherwise undernourished)	Teenage girls and wo-men (iron); nutrient-de -ficient diets/ soils; lack of sunlight; lack of protein, fruit, vegetables	2 billion people	Vitamin A: 100-140 million children Iodine: 1.6 billion Iron: 42% of women, 25% men, 48% of children under 2 years	Widely distributed (Adopted from: Scherr 2003.)

The poorest groups of many societies spend 70 – 90 percent of household expenses on food alone. When people are able to produce a major share of food for their subsistence the need for cash income is going down drastically. Equally important is the generation of rural employment outside agriculture that allows people to earn enough to buy whatever food they need for a healthy living. Such "ways out of agriculture" benefit also those farmers who remain in production as they are able to enlarge their holdings when others give up farming.

Traditional land tenure systems make access to land reality for large sections of societies in the Pacific Islands. Such systems have come under severe pressures, partly because of population pressures, partly through the idea that private land is more productive and efficient. Changes in occupational preferences also reflect on the image the professions of farmers and fishers have in society. Their status is often devaluated, and in many cases these professions also receive only marginal incomes compared to non-farm employment. The wish to give up agriculture is real for many and this wish often leads to rural – urban migration and the expansion of urban informal sectors.

Looking at the typology of hunger in Table 1 it is also important to note that Small Island Developing States are not identified as Geographic "hotspots", neither in the Caribbean nor in the Pacific Ocean. Like in many other publications on development issues these locations are also forgotten, when it comes to aspects of hunger and malnutrition although their exposure to a whole range of challenges is rather high and therefore it is dangerous to leave these states out, creating the impression that supply and access to food is secure in these islands. The impacts of climate change will have severe consequences on food and livelihood security in Small Island Developing States (SIDSs) as highlighted in Table 2.

SIDSs often are left out as they have what people might call "negligible" population sizes: the 22 Pacific Islands states and territories have just reached 10 million people in 2011 and Papua New Guinea alone is accounting for about half. Quite a number of the bigger megacities in the world have bigger the particular challenges of SIDSs are not considered adequately in considerations and policy formulation by global institutions. It is therefore crucial that these small countries put in much emphasis to be heard and seen and not forgotten.

Adaptive capacities in Pacific Island countries

A crucial question for small island societies in the Pacific is about their adaptive capacities. While governments and scientific institutions in developed countries have already started to assess the impacts of climate change and prepare for it not much has been done in the majority of developing countries, neither in the Pacific nor elsewhere. Although tropical and subtropical countries are particularly at risk to the impacts of climate change the public and government offices take only very slowly notice of it. Islands of tropical regions are exposed to the impacts of climate change in several ways. Often these islands are very restricted in land size and even more restricted in good agricultural lands. Sea-level rise, coastal inun-dation and erosion as well as destruction of freshwater lenses have serious impact on food production and freshwater supply. Already today there are very high population densities in central locations as a result of migration of people from outer islands to the capitals. This is particularly true for a number of places that are anyway not able to sustain internal food supply and have become increasingly dependent on food imports such as the capital atolls of Kiribati, Tuvalu and the Marshall Islands.

Damages happening to SIDSs from natural hazards are often involving major areas of these islands and require huge proportions of government revenue and GDP in the recovery and rehabilitation process. These SIDSs were vulnerable to economic and environmental shocks even before risks from a changing climate became evident. Due to their small economic base they are usually not in the position to negotiate favorable economic conditions and must accept whatever outside powers are willing to offer to them.

In developing countries at times official rhetoric takes reference to climate change, but little has been done so far to really start taking up the challenge and make people and commu-

Table 2. Impacts and Vulnerabilities to Climate Change in Small Island Developing States.

Impacts	**Sectoral vulnerabilities**	**Adaptive Capacity**
Temperature –All Caribbean, Indian Ocean and North and South Pacific small island States will experience warming. –Warming will be lower than the global average. **Precipitation** –Decrease in summer rainfall in the Caribbean in the vicinity of the Greater Antilles. –Increase in annual rainfall in the equatorial Pacific and in the northern Indian Ocean, in the Seychelles and the Maldives. –Decrease in rainfall in the vicinity of Mauritius, in the Indian Ocean, and east of French Polynesia, in the Pacific. **Extreme Events** -Increasing intensity of tropical cyclones, storm surge, coral bleaching and land inundation.	**Agriculture and food security** –Agricultural land and thus food security affected by sea-level rise, inundation, soil salinezation, seawater intrusion into freshwater lenses, and decline in freshwater supply. –All Agricultural production affected by extreme events. –Fisheries affected by increasing sea surface temperature, rising sea level and damage from tropical cyclones. **Water** –Water sources seriously compromised due to rising sea level, changes in rainfall and increased evapotranspiration, e.g. in the Pacific, a 10% reduction in average rainfall (by 2050) would lead to a twenty percent reduction in the size of the freshwater lens on the Tarawa Atoll, Kiribati. **Health** –Increases in the intensity of tropical cyclones increase risks to life. –Heat stress and changing patterns in the occurence of disease vectors and climate sensitive diseases affect health. **Terrestrial Ecosystems** –Replacement of local species and colonization by non-indigenous species. –Forests affected by extreme events are slow to regenerate. Forest cover may increase on some high latitude islands. **Coastal Zones** –Most infrastructure, settlements and facilities located on or near the shore and will be affected by sea-level rise, coastal erosion and other coastal hazards, compromising the socio-economic well-being of island communities and states. –Accelerated beach erosion, degradation of coral reefs and bleaching will all have impacts on incomes from fishing and tourism. –Habitability and thus sovereignty of some states threatened due to reduction in island size or complete inundation.	Small islands, whether located in the tropics or higher latitudes are especially vulnerable to the effects of climate change, sea level rise and extreme events. Characteristics such as limited size, proneness to natural hazards and external shocks enhance the vulnerability of islands to climate change. In most cases they have low adaptive capacity, and adaptation costs are high relative to GDP. (Source: UNFCCC 2007)

nities more resilient. Activities on macro and regional levels dominate and are often in the field of policy and regional networking that rarely leads to activities on the ground, in the villages and communities. Negligence of rural areas dominated the past few decades in many developing countries and also today often shapes governments' action. National elites have not been interested in what was happening in rural areas for decades. Such attitude seems to continue also into the future. Many countries have weak governments, which are chronically short of funds. Revenue is insecure and state institutions are often breeding grounds of corruption. Many developing countries also lack good research institutions and scientists that could become focal points for so urgently needed beginnings. Finally, the poorest of the developing countries not always lack financial resources to start adaptation measures. Although huge amounts of funds are available for climate change related activities few of these activities seem to take up the actual challenges in an applied way, preparing people for change. Many developing countries are struggling with their immediate needs and have little time, resources and motivation to think even ten years ahead. They have enormous challenges to apply for climate change related funds and even if they receive bigger amounts of such funds they often are not in the position to utilize them constructively. The windows of opportunity are tiny and it requires not only resources, but also visionary leaders, who are able to take up the challenge and make a difference for their countries.

How to study the impacts of climate change on food security in Pacific Islands?

It is important to reflect about the future of whole regions, to see how climate change puts people's livelihoods at risk, including their food security. This knowledge provides the precondition to strengthen economic development, education and health infrastructure, pro-ductive capacities and resilience. In many places new approaches to regional development are needed to address the impacts of climate change appropriately. Many regions will suffer under these changes, when crops that had been their economic backbone no longer flourish, when fertile land is eroded away, when natural hazards put threats on people's lives and livelihoods. Many regions will face difficulties to adjust to these changing conditions. However people are creative, people have strengths which are often best displayed when the challenges are big and almost overwhelming. Although people can achieve a lot we should not underestimate the dimension of the challenge ahead: there is no doubt that they need support, and best support is such, where they are respected and trusted, where they can be part of the decision process deciding on their future, where they are seen as equally important stakeholders as government officials and scientists. Since long Pacific Islands have come under severe stress what the quality of these resources is concerned. Land e.g. is a rather scarce resource in many of these tiny island states and equitable access as well as the quality of the land and its potential to cater for growing societies is already compromised today and is getting under extra pressure through the impacts of climate change. In many Pacific Island states there had been strong structures that attached the majority of people to land. The incidence of landlessness was low, but things are changing. Already during colonial times in many Pacific Island societies' new sections of population were added that were excluded from traditional land tenure systems.

Important is not only how much food a family has, but also what kind of food. Food security is more than just having enough energy in forms of calories, other micro nutrients are equally important. People cannot just live on rice or wheat, or taro and cassava. Here changes in nutritional preferences experienced in Pacific Island societies play a serious role that wea-ken individuals (life style diseases) as well as countries (increasing dependency on imported foods). Often these nutritional challenges are left out when talking about food security and malnutrition. Systematic approaches must consider the entire food systems of Pacific Island countries. Baseline information is required urgently for each and every individual country to be able to estimate how climate change and its impacts expose governments, people and particular locations to risk and stress that require support from outside.

People therefore need to realize that one of the biggest nutritional problems in the Pacific Islands today is obesity rather than hunger. Although prevalence of poverty and hunger should not be left entirely out of consideration fairly little in the food security debate is about over-nutrition, about life-style diseases and threats to human's well-being because people consume too much of the wrong food. It is not that these aspects are unknown in Pacific Island countries. There is much talk about it from health officials, but the literature on food security does not really take such matters up, especially not when the discourse is about climate change.

To provide rural people in the Pacific Islands opportunities to have secure incomes, both agricultural as well as non-farm incomes, will help to slow down migration to the cities. This is extremely relevant for many Pacific Island societies, where outer islands already today already lost a big share of their populations in the age groups of economically active population.

A more holistic approach has to consider the entire width of the food systems in PICs. Here the details depend fairly much on the individual countries. Places such as Kiribati, Tuvalu, and Nauru, where food production anyway is very restricted due to varying reasons need to be treated differently in the analysis compared to countries where food production is diverse and able to produce much bigger parts of the national consumption. To start with it would be crucial to analyze the food systems of all the Pacific Island countries separately and to analyze the major threats to the countries and to most vulnerable groups arising from climate change. Such a start is essential to get a better understanding about the food and livelihood systems of each individual PIC in order to be able to predict of how climate change will show impacts, and what strategies individual PICs best would take up to become more resilient to these impacts. Figure 3 summarizes the major aspects of a comprehensive food system and gives hints regarding potential threats arising from climate change. Exposure happens to countries as a whole as well as to particular regions and households. It might be necessary to study sub-systems of the food system, e.g. to look which locations are in particular at risk or which are the most vulnerable people, and start with policies and support for them rather than to take up everything everywhere: this won't be possible. The biggest challenge therefore will be to set priorities. When doing this it needs to be safeguarded that inclusive processes enable all to become part of decisions that will be affected by them. Only then it will be possible that people take ownership in many crucial questions concerning their own future and the future of their children. In some instances this future will happen elsewhere to where people live today. Many will lose their homes, entire countries will disappear and the need for international cooperation, solidarity and innovations will be great. Only if this happens another great challenge of humankind can and will be mastered.

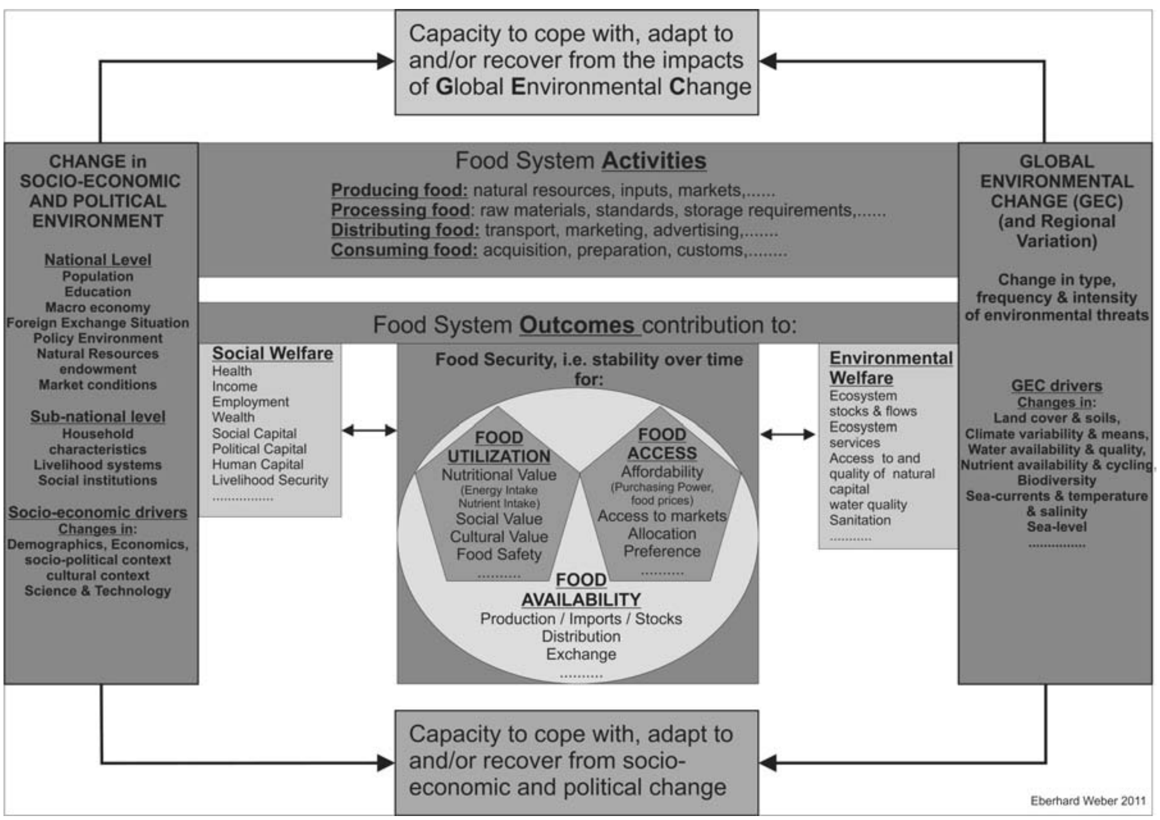

Figure 3. Food System and Climate Change—A theoretical frame.

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What Ails Rural Economy of Fiji? A Diagnosis and Prescription

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ABSTRACT

In Fiji majority of population live and earns their income from agricultural sector. Therefore, development of agriculture can serve as the engine of economic growth for the whole economy. But many constraints hinder sustainable development of agriculture. Hence, understanding of the root causes of poor performance of agricultural sector will help formulate problem-solving development strategy for enhancing productivity of rural sector of Fiji. This paper analyses malady of the primary sector and outlines a demand-driven policy framework which will help create conducive macroeconomic environment in the country to encourage innovation and agripreneurship to boost farm production. The paper argues that strengthening of rural infrastructure and linkages of farmers with agribusinesses and consumers would provide both the basis and means of rural economy contributing to the overall sustainable development of the country.

Key words: Agricultural problems, Agricultural and rural development policies; Agri-input supplies.

INTRODUCTION

There is probably no greater challenge facing development planners in small island countries such as Fiji than the problem of agricultural development. Fiji is an island country located at the centre of the Pacific Ocean. The bulk of population in Fiji earns its living from employment in agriculture. A productive rural sector in Fiji would not only help alleviate rural poverty. It would also broaden the domestic market to absorb the output of a growing manufacturing sector in the country. In other words, strengthening of agricultural development programmes in Fiji islands would provide both the basis and means for a broader and more rapid growth of the island economy. But, the progress of agricultural sector will not take place in a vacuum. It is constrained by various factors and very much depends on the policies that the government uses to change the social and economic context within which agricultural production and marketing takes place.

Diagnosing the constraints and challenges faced by agricultural sector in small island countries, like Fiji is important for several reasons. Firstly, primary production is the main activity in these countries as the level of industrialization is very limited. Secondly, it is now well known that growth of rural economy is important for poverty reduction, with important implications for progress towards the Millennium Development Goals (MDGs). Thirdly, there are significant gaps in our understanding of the main causes of low agricultural productivity and the efficacy of agricultural policies to stimulate growth in the rural sector. In essence, there is an understanding of the basic ingredients that make up a successful growth strategy, but there is a need to deepen our understanding, including of how to apply strategies to the economic and political context of the particular country. Fourthly, it will help ensure that the development policies are research-evidence based and aligned with the felt needs of the rural people minimizing waste of resources on non-demand driven government programmes.

The objectives of the paper are:

(i) to highlight the major problems and challenges faced by farmers and agri-entrepreneurs in Fiji; and
(ii) to identify the need-based problem solving

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agricultural development policies that are required to provide a framework that allows farmers to shift from traditional farming systems to more productive, science-based production methods and allows adoption of commercial farming systems on a sustainable basis.

The paper would be of interest to agricultural policy makers, extension officers, and others who have interest in accelerating the development process in the underdeveloped rural areas especially in the small island countries like Fiji.

The paper is organized in six sections. The next section provides an overview of the general features of rural economy of Fiji. The third section highlights the symptoms of poor health of rural economy in Fiji. In the fourth section factors hindering domestic production of agricultural commodities are described. In the sixth section, a strategy for agricultural development and diversification is outlined which could provide a socio-economic framework to motivate farmers to shift from the traditional farming system towards a more productive commercial mode of production. And finally in the sixth section, summary and conclusions are presented.

General Features of Fiji's Rural Economy

To understand progress of agricultural sector and formulate development strategies for enhancing incomes and employment of people, it is essential first to know the rural scenario and understand agricultural situation there. Data about the basic features of Fiji's rural economy are presented in Table 1. As already pointed out, Fiji is an island nation located at the centre of the Pacific Ocean. The archipelago has about 330 small islands with a total land area of 18,333 km^2. Its two largest islands Viti Levu and Vanua Levu make up 88% of the total land area. Fiji is a multiethnic country with a total population of 837, 271 as of 2007. Almost half the population lives in rural areas and earns its livelihood from agriculture. Fiji is a multiracial country. In the total population, indigenous Fijians account for 56.8 percent, Indo-Fijians for 37.5 percent and others (mainly of Chinese and European origin) account for 5.7 percent population. The density of population is about 46 persons per square kilometre. But most areas of the country are hilly and mountainous and thus only 30 percent land area is suitable for agriculture.

Although average size of farms is 6.2 hectares, but the majority of them (56.2% of the total land holdings) are small each having less than 2 hectare area. Contributions of different sectors of the economy to the gross domestic product of Fiji are also shown in Table 1. It is clear from the table that manufacturing and services sector are dominant but agricultural sector is also a major contributor to the economy. Agriculture (inclusive of fisheries and forestry) contributes around 13 percent to the gross domestic product of Fiji.

About 87 percent of total land in Fiji is owned by indigenous Fijians under the collective ownership of the traditional Fijian clans by law and through very complicated traditional arrangements. The government owns six percent land and the remaining portion (7% land) is freehold that can be bought and sold by individuals of any ethnicity. The land ownership pattern is frozen by law and native land sales are prohibited. The Indo-Fijians, who make up around 38 percent of the population and are descendants of the indentured labourers brought over by the British to work in sugar and coconut plantations during the last quarter of nineteenth century, are largely landless. About 90 percent of the sugarcane crop (the main export crop) is produced by Indo-Fijians farmers on leased-in land. The land owned by native Fijians under the communal tenure is under the jurisdiction of the Native Land Trust Board (NLTB), a statutory authority created in 1940 under the Native Lands Trust Ordinance, now known as the Native Land Trust Act (NLTA). NLTB controls and administers lease dealings in native land. Tenancy conditions are regulated by the provisions of the Agricultural Landlord and Tenant Act (ALTA) (1976). ALTA is a successor of the Agricultural Landlord and Tenant Ordinance of 1966.

Symptoms of Poor Health of Agricultural Economy

Primary production includes agriculture (crops and livestock) and forestry and fishery sub-sectors. Further breakup of the primary sector to its components is shown in

Table 1. Basic features of Fiji's rural economy.

Particulars	Extent
Total population (2007 census)	837,271
- Native Fijians (%)	56.8
- Indo-Fijians (%)	37.5
- Others (%)	5.7
Rural population (%)	49.3
Total land area (km^2)	18,271
Agricultural land area (km^2)	5,480
Arable permanent crops area (km^2)	2,850
Average farm holding size (ha)	6.2
Percent of total holdings below 2 hectares (%)	56.2
Proportion of land area by tenure system:	
- Land under communal tenure (%)	87
- State or public land (%)	6
- Freehold land (%)	7
Gross National Income per person (2007) (USD)	3,750
Structure of the economy:	
- Share of agricultural sector in the Gross Domestic Product (%)	13.1
- Share of industrial sector in the Gross Domestic Product (%)	21.1
- Share of services in the Gross Domestic Product (%)	65.8

Source: *Fiji Key Statistics*, Fiji Islands Bureau of Statistics (FIBS), Suva, 2009.

Table 2. Crops and livestock subsector account for 77 percent of primary sector while fishing activity and forestry account for 14.26 percent and 8.74 percent respectively. Within agricultural production the main activity is crop production while contribution of livestock production is a minor component. In this section status of agricultural economy of Fiji is analyzed, especially with respect to its growth rate and the export performance.

Slow Growth of Agricultural Sector

Data in Table 2 shows changes in the contribution of different sub-sectors to overall agricultural production and their annual growth rates in recent years (2003 - 07). The overall annual growth rate of Gross Domestic Product of Fiji was 1.45 percent during 2003 - 07, but the growth of agricultural sector was very slowly (0.58% per annum). Within agricultural production the proportionate share of crops has declined and that of livestock is increasing. Growth of sugarcane production which alone accounts for bulk (23.6%) of agricultural production, was negative (-3.45% per annum). However, the growth of production of other crops (roots and tuber crops) has a positive trend (6.77%). Similarly, livestock sector which currently has a low base was growing steadily (6.8% per annum). Since there is plenty of fodder resources (sugarcane top and pasture lands) in Fiji, livestock production has vast potential for further growth. Although Fiji has plenty of ocean resources, the annual growth in fishing sector was 1.76 percent only.

The main cause of dismal performance of agricultural sector as a whole in Fiji was the negative growth rate of sugarcane production. Interestingly, in Fiji sugarcane is mainly produced by Indo-Fijians who work on leased -in land. The other crops (cassava, taro, sweet potato, coconut, etc.) are mainly produced by

Table 2. Changes in contributions of different sub-sectors of agriculture to the total agricultural sector in Fiji (2003-07) (GDP at Factor Cost: 1995 prices).

Sub-sectors of agriculture	2003		2007		% Annual growth rate (2003 - 2007)
	(FJD 000)	% share in total agriculture	(FJD 000)	% share in total agriculture	
Agriculture	334,620	77.00	342,372	77.44	0.58
- Total crops	187,257	43.90	188,460	42.63	0.16
Sugarcane	121,070	27.86	104,340	23.60	(-)3.45
Other Crops	66,187	15.23	84,121	19.03	6.77
- Livestock	19,019	4.38	24,213	5.48	6.83
- Subsistence	120,528	27.73	122,756	27.76	0.46
- Public Sector	7,815	1.80	6,943	1.57	(-)2.79
Fishing	61,959	14.26	66,310	15.00	1.76
- Fishing	33,465	7.70	37,270	8.43	2.84
- Subsistence	27,552	6.34	28,061	6.35	0.46
- Public Sector	942	0.22	979	0.22	0.98
Forestry	37,997	8.74	33,429	7.56	(-)3.00
- Forestry	20,736	4.77	15,945	3.61	(-)5.78
- Subsistence	16,626	3.83	16,934	3.83	0.46
- Public Sector	635	0.15	550	0.12	(-)3.35
Total primary sector	434,576	100.00	442,110	100.00	0.43
Gross Domestic Product	2,784,385		2,946,284		1.45

Source: FIBOS (2010) Key Statistics (p. 25).

the native Fijians. Main reason for this negative trend in sugarcane production is the expiry of some land leases and uncertainty about the renewal of others. Thus the sugar industry in Fiji is declining at a rapid rate due to a number of reasons: chiefly the land tenure problems since mid-1990s, declining milling efficiency and declining price of sugar in recent years due to the withdrawal of preferential treatment by the European Union. Thus, the challenge facing development planners in Fiji to strengthen and diversify the rural economy is enormous. It entails the task of establishing sound agricultural economy that involves people at various levels and where many creative policies are applied and the markets are surveyed periodically (see EU 2009).

Rising Food Import Bill

Data on Fiji's exports and imports of agricultural products are presented in Table 3. In Fiji main agricultural export is sugar. Other exports are root crops (taro, cassava), spices (chillies) and processed wheat and cereals. The major imported crop products are wheat, rice, vegetables, fruit and nuts. The livestock products imported include meat and milk products. Data reveal that Fiji's import bill of agricultural products has a rising trend. It is because domestic production of food products is not keeping pace with the rising domestic demand and thus the gap is filled by imported quantities of food items. The food import trend is expected to worsen as the rural to urban influx of population in Fiji continues mainly due to expiry of land leases of tenant farmers.

Data in Table 3 also shows that country is highly deficient in production of vegetables, rice, and milk and meat products. However, this should not have been the case for Fiji as it has sufficient agricultural resources like land, labour, climate as well as human resources to produce these products domestically (Prasad 2010).

Prolonged shortages and the inability of farmers to respond to shortages in supply to meet the food demand are normally construed as food security issue. Such issues are not well understood in Fiji. This domestic supply-demand mismatch of food products in Fiji is mainly because government intervention policies are not effective.

In view of the weak health of agricultural economy in the country, the dependence on traditional farming methods

Table 3. Fiji's average imports and exports of agricultural products, 2002–2005 (USD '000).

Product (1)	Exports (2)	Imports (3)	Balance (2 – 3)
Wheat & cereals	12,755	24,904	(-) 12,145
Rice	304	11,074	(-) 10,770
Roots, other products	13,543	--	(+) 13,543
Vegetables	--	19,680	(-) 19,680
Fruits and nuts	724	4,119	(-) 3,395
Sugar	120,745	3,075	(+) 117,670
Spices	3,966	1,279	(+) 2,687
Total crop products	152,037	64,131	(+) 87,906
Live animals	54	569	(-) 515
Meat of bovine	9	3,256	(-) 3,247
Other meat	4,329	20,230	(-) 15,901
Eggs and birds	72	1,383	(-) 1,311
Milk and milk products	866	18,800	(-) 17,934
Total livestock products	5,330	44,238	(-) 38,908

Sources: *International Trade Statistics*, ITC, UNCTAD/WTO, 2002-2005.

needs change towards more productive methods with application of appropriate scientific technology and knowledge about crops, soil, and the environment. However, before formulating any strategy for this purpose the economic context within which farm production and agribusiness occurs needs to be properly understood.

Diagnosing Causes for Dismal Agricultural Progress

Assessment of problems, needs and priorities of farmers provides development planners with a broad framework for understanding the range of issues involved in bringing about substantial changes to the agricultural sector that could improve the farmers' supply responsiveness to the demand for farm products. A thorough understanding of the root causes of low supply of farm products help in formulation of effective action plans for boosting agricultural production and would reduce the problem of demand and supply mismatch.

The challenges and constraints of farmers in production and marketing of various types of agricultural products have been identified by farmers. The data is summarized in Table- 4. Though many farm problems are common to all types of farmers, but some problems are specific for production and marketing different types of farm products. The discussion in this section is organized under two broad categories of farm products, *i.e.* for crop products and livestock products.

Causes of Low Supply of Crop Products

Major causes for the declining trend in sugarcane production in Fiji are: (i) lack of land tenure security of sugarcane farmers, (ii) lack of credit availability to farmers, and (iii) lack of extension services (Lal, 2008 & 2009; Prasad, 2008). Furthermore, cost of sugarcane production has increased due to increased price of fertilizer, cost of cartage, cost of harvesting and labor cost, while the price of sugar has declined due to erosion of preferential markets. The overall decline of infrastructure, falling mill efficiency and the declining prices have also resulted in the decline in sugarcane production (Island Business, 2010).

Various factors constrain production and marketing of root and tuber crops and vegetables in Fiji (Nacoke, 2007: Remudu, 2006). Lack of roads and transportation faculties for most of farmers result in (a) limited access to the market; (b) delays in delivery causing spoilage and lowering the

Table 4. Problems in production and marketing of farm products in Fiji.

Problems	Problems of farmers producing:			
	Sugarcane	Taro & Cassava	Vege-tables	Livestock
1. Insecure land tenure	√	√	√	√
2. Lack of irrigation facilities	√		√	
3. Lack of credit facilities	√	√	√	√
4. High cost of inputs—fertilizer, feed, etc.	√		√	√
5. Lack of skills in modern farming techniques	√		√	√
6. Lack of road networks in rural areas	√	√	√	√
7. Lack of transportation facilities		√	√	√
8. Lack of marketing yards/centers		√	√	
9. Lack of agro-food processing facilities		√	√	√
10. Unscrupulous behavior of marketing agents		√	√	
11. Lack of storage facilities		√	√	
12. Lack of marketing information		√	√	

Sources: Aregheore *et al*. (2001); Aregheore *et al*. (2008); Bolasui (2008); Nacoke (2007); Prasad (2008); Remudu (2006); and Vorelevu & Bhati (2006).

quality of the products; and (c) long cartage distance on poor roads increases damage and the marketing costs. Marketing agents collecting farm products from farmers do not have organized plans for uplifting the produce from villages which adversely affects farmers in two main ways: (a) waste of perishable products harvested for supply on a particular day which were not lifted by the agent, and (b) loss of weight and quality of fresh produce during waiting time. Lack of storage facilities at the collection centers results in theft, damage or waste of farm products. Lack of marketing information to farmers about the market situation and prevailing prices in major markets affects the whole agricultural supply chain. Insufficient knowledge of farmers about the post-harvest handling of agricultural products also affects marketing process and the quality of the product. Interior and riverside farmers need varied transport systems like boats and small utility vans. Insecure land tenure contributes to lack of improvements or investments in land for drainage, etc. Lack of institutional credit facilities to tenant farmers is also a problem. Farmers lack skills of scientific methods of vegetable production. Farmers also reported that prices of fertilizer and other agro-inputs required for crop production are quite high (see Table 4).

Problems of Livestock Farmers

. In Fiji there are very few large commercial scale farms and most animal husbandry is done at subsistence level. These farmers convert low value forages and crop residues into animal feed. In most cases, farmers use family labour to sustain these small-scale livestock rearing, which supplement their family income. Even though in some areas a lot of fodder resources and grassland exists in Fiji, animal husbandry is not so common, particularly on commercial basis for which reason Fiji is not self-sufficient in meat and milk production.

Some recent studies about livestock farming in Fiji (viz., Aregheore *et al.,* 2008; Bolasui, 2008; Vorelevu & Bhati, 2006; Aregheore *et al.,* 2001) revealed that various constrains are faced by farmers in the production and marketing of livestock products (see Table 4). The major problem, that in general there is a lack of veterinary extension services in most of the areas. Farmers say they do not have adequate training and education about the modern methods of livestock rearing and pasture management to boost production. Short-term and customary land-tenure system under which many cattle farmers operate hinders them from making long-term capital investment required in cattle farming. Also, lack of property right on lands affects availability of institutional credit for investment in cattle farming or pasture improvement. Due to poor road conditions and lack of transportation facilities marketing of livestock products is a costly affair especially for small-scale cattle farmers. Farmers also reported that supply of livestock inputs (concentrated feeds and medicines) was inadequate and irregular in their areas. (see Table 4).

As also pointed out previously, Fiji is not self-sufficient in milk and meat production and thus a considerable amount of foreign exchange is spent on importing these products. Therefore, there is a need to fully understand the importance of livestock production not only as a medium for rural development and import substitution but also from the human nutrition point of view. Problems faced by cattle farmers in Fiji need urgent attention so that livestock sector could achieve its full potential.

Farmers' Poor Linkages with Agribusinesses and Consumers

Due to increasing urbanization of the population there is a need to move more food from rural to urban areas to meet the increasing demand of primary agricultural products in urban areas. Farmers reported that they face difficulties in marketing their surplus food products (see Table 4). McGregor (1999) also pointed out that there are unreliable and inadequate agricultural marketing services in Fiji. Under such a situation domestic production and supply of fresh perishable agricultural products, such as meat, milk, vegetables and fruits, are badly affected. Then it is not surprising why the island country is so highly dependent on imported food products from other developed countries. Data in Table 5 shows that money spent on importing food products has been rising in recent years.

If the marketing channels are not adequately linked to the farmers the price signals do not reach them and thus their supplies generally do not respond to the increased urban demand... Since supplies of farmers in Fiji are not adequately and efficiently linked with the urban demands, the gap between domestic demand and supply is being filled up by the imported food products. In the absence of robust domestic agri-supply chains, the wholesalers and retailers of food products distribution in Fiji find it much easier and reliable to import from other countries rather than meeting their orders of farm products from the domestic producers. Supply chains from foreign suppliers are well management and properly linked with local wholesalers and retailers while those connecting local farmers are poor, inadequate and unreliable to meet the demanded quantity and quality on timely and sustainable basis.

Farmers often face the prospect of glut in the market when the season sets in since supply side information is often not available and even if it is there, it is often too late to make any adjustments. Such commodity gluts in the market cause prices of agricultural commodities to spiral down causing significantly revenue loss to farmers. Some reasons are forwarded here about why the domestic farm production in Fiji fails to respond to demand of food commodities. The key problem in Fiji is the lack of information about the demand side of the market, to which farmers could match their supply and storage and preservation activities. The government however, has recently launched a web based market watch publication which is meant to provide market information to the farmers (MPI 2010b & 2010c). But most of the farmers in Fiji are not computer literate and lack access to internet facilities.

Table 5. Absorption of imported food products in Fiji ('000s of FJD).

Broad Category of Food	2004	2005	2006	2007	2008	2009
Primary Food Product	57,387	55,711	63,219	69,493	85,350	73,287
Processed Food	205,558	206,709	202,775	199,578	260,095	300,394
Total Absorption	262,945	262,420	265,994	269,071	345,445	373,681

Source: *Fiji Key Statistics*, Fiji Islands Bureau of Statistics, Suva, 2010.

It is a big challenge before the policy planners and development agencies to harness this opportunity of increased urban demand in Fiji by expanding and strengthening the local agro-food supply chains linking farmers and urban consumers in the country.

Inadequate Agricultural Finance

Farmers of all types whether sugarcane farmers of producers of root crops or of vegetables or of livestock products all have mentioned shortage of credit facilities as a significant constraint for their production and marketing activities (see Table 4). In Fiji agricultural credit facilities have been low since early 1990s and declining due to a number of reasons. First, the uncertainty about the land tenure since early 1990s was the main cause of this decline in loans to farmers. As a result of looming expiry of land leases since 1997 the investment confidence of the farmers declined and banks have refused to issue loans to tenant farmers. Secondly, the government development policies since early 1990s up until recently become inherently passive towards agriculture and more active towards tourism and manufacturing. The data in Figure 1 shows very low levels of credits for agriculture. However, recently as shown in the Figure 1 there seems to be a significant increase in the agricultural loans which is a sign of change in the government policy towards this sector of economy. Apart from the Fiji Development Bank, which is government owned entity; a lot of commercial banks' activities have been encouraged by the government in this area recently. This is very encouraging for the smallholder farmers who were unable to borrow and expand their farm activities due to lack of credit.

Strategies for Strengthening Rural Economy in Fiji

The process of transforming rural economy depends largely on the government policies that change the social and economic context of production and marketing of farm products. The analysis of problems faced by farmers provides the basis for more concerted policies and support schemes for agricultural and rural development. The concerns and problems pointed out by the farmers (see Table 4) in fact stem out from their unfulfilled needs and priorities for a long time. Policy failure is the basic reason for the current rural scenario in Fiji where agricultural production is hardly sufficient to meet its domestic demand. Strengthening rural sector and establishing new agribusinesses enterprises would provide a sound basis for the growth of the rural economy in Fiji. However, this process of economic transformation and expansion is likely to be severely hampered by various inherent constraints such as land

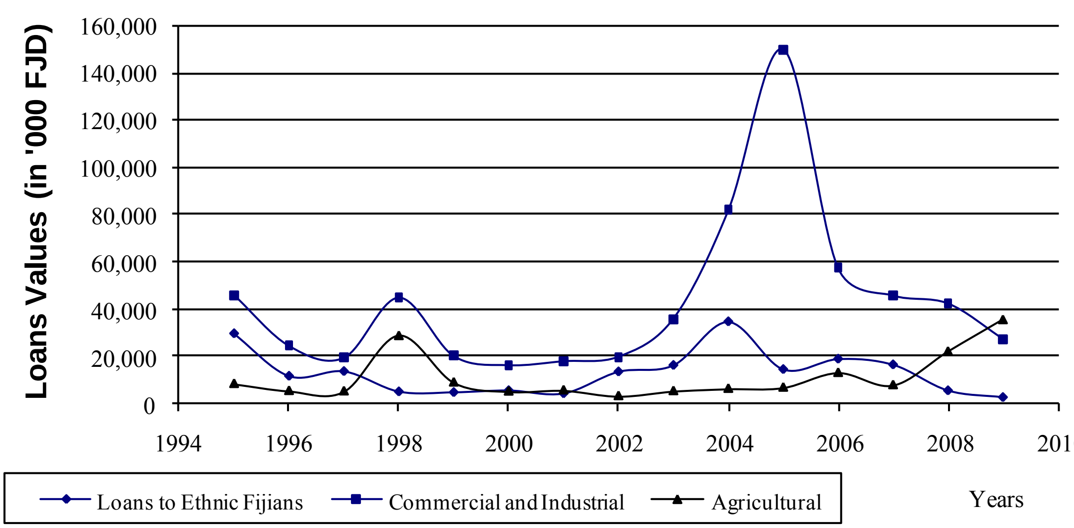

Figure 1. Fiji Development Bank Loans.
Source: FIBOS (2010) Key Statistics, Fiji Islands Bureau of Statistics.

tenure, lack of investments and many other challenges faced by the agricultural sector (Prasad & Kumar, 2000; Barbour & McGregor, 1998; Ward & Proctor, 1980). The agricultural transformation process would depend significantly on the creation of new mechanisms for agricultural production and value addition such as processing, packaging, transportation and marketing. This would include the whole spectrum of activities from crop production and animal husbandry to agribusiness and export initiatives to expand and diversify the rural economy. Such an approach will broaden not only the supply side of food products but also the demand side and domestic market as a whole (see ADB, 2010; Naude, 2010; Oxfam, 2010; Prasad, 2010; Qamar, 2005). Some good policies are currently being facilitated by government in Fiji but the actual outcomes are not visible yet (see for instance MPI, 2010a, b & c). To boost the production to meet local demand and for exports, well-planned and structured government policies are needed. Such well-planned policies would help fulfil the much needed aspirations of the farmers and also resolve a number of their business constraints. Some of the issues that need attention of the policy makers are discussed below.

Marketing Mechanisms and Networks for Farm Producers

Since most farms are small and widely dispersed throughout the countryside, a correspondingly widespread transportation network is required to channel supplies to the market centres in the urban areas. Easily available and efficient transport mechanisms to move farm products such as milk, cattle, vegetables, fruits and root crops to the market area are essential for the system to work. Since farm products are bulky and highly perishable, they often require special care during transportation, which is non-existent in Fiji.

On the whole, an efficient and dependable market chain system needs to the developed to link farmers with consumers in the domestic as well as the external markets. Majority being of smallholder family farms the economies of scale are not there to facilitate an independent market supply system. Government facilities and regulation of agricultural market are nonexistent. Transport linkages to the rural areas are not sufficient. The essential transportation and storage facilities should be provided and supported by the government. It may be provided through private initiatives but with some government support and supervision.

The development of more effective transportation and storage system through government initiative could be a key strategy. It is a well-known fact that the existence of agricultural market structures is the most important condition for enhancement of output and efficiency (FAO, 2008). The absence of storage and transport infrastructure in Fiji is an insurmountable constraint for smallholder farmers, who can only ill-afford such facilities to preserve their produce. If efficient marketing systems are established solving the production problems would become much easier.

Providing Training to Farmers

Farmers generally lack knowledge and are almost totally unaware of new ideas and technologies useful for farm production. Fixing these problems crucially depends on multiple dimensional approaches Farmers need immediate up-gradation of their skills for mass production of agricultural commodities on commercial basis. The younger generation also needs attention of the policymakers and needs to be motivated towards agriculture by portraying it to them as a scientific, modern and high income venture.

Instituting farmers training programs would lead to substantial gain in enhancing the supply of farm products and fulfil the demand-supply gaps that exist at the moment. The training and extension process is already underway at the Ministry of Primary Industries (MPI) to some extent but sufficient information is still not flowing to the farmers. There is dire shortage of extension officers in Fiji. Therefore, training the trainers is of utmost importance. This would help the MPI personnel to reach out to the farmers who are the real actors in the business of agriculture (see MPI, 2010d). Government's extension services have been in ruins since early 1990s due to institutional neglect.

Local Supplies of Farm Inputs and Equipment

Enhancing agricultural production would need special farm equipments, material inputs and seeds etc. Such inputs need to be made available locally at reasonable prices. The MPI in Fiji is making a reasonable effort towards these goals but facilitation of private sector involvement would supplement in this respect. There are many sectional political objectives at play in efforts to develop the agricultural sector which hinder the commercialization process quite significantly. For instance, pilot projects should be selected on the merit of farmers rather than on ethnic or provincial basis.

Credit Facilities for Farm Investment

Credit facilities for the agricultural sector are low in Fiji. The supply of credit needs to be matched with increasing demand for credit due to agricultural modernization process. Apart from access issues for the farmers, success also depends on reasonable cost of credit. Therefore, the rate of interest needs to be maintained at reasonable levels and also to provide enough time for the farmers to meet repayment. This measure is important if farmers are to succeed in competitive markets domestically as well as globally.

Encouraging Farmers' Cooperatives

Because agricultural products are bulky and highly perishable, their transport system needs to be fast and cost effective, which could make small scale production profitable. This is where local cooperative systems would become useful for farmers. Furthermore, the small scale producers are often in a weaker and vulnerable position in the market place. Hence, farmers should be encouraged to forming cooperative marketing societies to take joint action in an organized manner to address market related problems including joining hands to create economies of scale. This kind of voluntary group action by farmers in the form of cooperative is important for enhancing agricultural development within local communities, which would have wider national effect.

Farmers' cooperatives can be formed to take responsibility of transporting, processing and marketing farm products. The supply of farm inputs can also be organised in this way much more cheaply. However, the establishment of such cooperative systems would need considerable government involvement and support.

Expanding Agriculture Area with Long-term Land Tenure

The much needed confidence among farmers is grossly lacking due to numerous problems but mainly due to land tenure conflicts that have existed for long.. Only one-third proportion of land in Fiji is under cultivation and there is a scope for bringing substantial new land under plough (see Table 1). But the problem of insecure land tenure has daunted farmers for long. On the one hand the demand for food products is increasing in Fiji while on the other hand outward movement of human resources from rural areas to urban areas is taking place at an alarming rate due to expiry of land leases As a result of this substantially fertile areas of land are lying unused. Also, marginal and waste lands which are also currently unused require development strategies to spin-off some form of production such as livestock production and planting fruit and other tree crops from these lands. Agricultural production and land tenure are intricately linked with the agricultural productivity in the South Pacific island countries (Acqaye & Crocombe, 1984). Long term land lease be provided to tenant farmers. The shorter and insecure land tenure system hinders long term investment growth strategies of farmers (such as in land levelling, terracing, drainage and irrigation system development), and thus agricultural productivity on tenancy farms.

SUMMARY AND CONCLUSIONS

The paper highlights the need for increasing agricultural production to improve food security and reduce dependence on imported food items in Fiji. To formulate an effective action plan for boosting agricultural production, it is essential to understand the problems faced by the farmers. A need-based agricultural development strategy has been outlined in the paper to transform the rural economy of Fiji. Prospects for higher earnings of farmers and other rural dwellers due to better market networks, agro-processing activities and more efficient transportation system and rural infrastructure development have been highlighted. It is suggested that a simultaneous change both in the skills of farmers and the availability of new technologies and allied inputs would effectively change the farm production systems and marketing pattern of agricultural products for the betterment.

Having a more productive and price responsive agriculture and interlinked agri-businesses in the rural areas of Fiji would not only generate higher income and help diversify rural economy but would also weaken the stream of rural-to-urban migration of people, especially the young people. It will reduce dependence on imported food products. Improvements in incomes and employment facilities in rural areas would in turn lead to higher rates of absorption of domestic products in rural areas. It is argued that the task of sustainable development of rural sector would require sound economic policies with the aim of creating more agriculture-based entrepreneurship. Agricultural policy planners in Fiji have been reacting to situations instead of strategizing. The long term agricultural strategy would entail more productive agricultural sector with multilayered stakeholder interests.

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Food production and climate change in Pacific Islands Countries and Territories

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ABSTRACT

This paper is a review of climate change trends and projections for the Pacific region and discusses the implications of climate change for food production. Observed climatic data and climate trends and projections for the Pacific region are presented and their current impact on food production and implications for the future are discussed. The climate of the Pacific region is changing and people are now experiencing increase in intensity or severity of extreme events like cyclones, storm surges, floods and droughts. These extreme events are causing substantial damage to agriculture and fisheries and associated infrastructure with negative impact on food production. Although effects of increasing temperature, changing rainfall patterns, sea level rise, salt water intrusion, and acidification are less immediate, food production is also under stress from these climatic factors but it remains difficult to predict the likely outcomes with certainty because of limited empirical data for the Pacific region.

Key words: Climate change, Food production, Pacific Island Countries and Territories.

INTRODUCTION

There is increasing concern over the consequences of climate change on food production amongst the Pacific Island Countries and Territories (PICTs). Already, the changing weather patterns is having some effects soil fertility, pests and diseases, increased heat stress on plants, changes in rainfall and soil moisture, salt water incursion from rising sea-levels and increased damage on agriculture and crops from extreme weather events. The fish stocks are also being affected and migration pathways of some fish have changed; for example, tuna are being displaced eastwards in the region and increase in sea surface temperature and acidification is causing coral bleaching. The Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report in 2007 reported with high confidence that it is very likely that subsistence and commercial food production on small islands, including those in the Pacific region, will be adversely affected by climate change. Further, the Asian Development Bank (ADB) 2009 report identified that the PICTs are amongst some developing countries that are likely to face the highest reductions in agricultural potential in the world due to climate change and Food and Agriculture Organisation (FAO) (2008) stressed that the islands and their inhabitants are continuously exposed to a range of natural hazards, including cyclones, storm surges, floods, drought, earthquakes and tsunamis which threatens livelihood of approximately 9 million people in the region. The impact of climate change is however complex. As Allen & Bourke (2009) pointed out, it is difficult to predict the likely outcomes with certainty because there is not enough information about changes in temperature, patterns of rainfall and rainfall extremes, and furthermore agricultural and fisheries responses to climate change will be complex since these sectors represent a nexus between biological/ecological systems and social/economic systems which are difficult to monitor (Secretariat of Pacific Community - SPC, 2010). It is therefore important to continue to collate and synthesize available data and relevant information because information on food production, in both agriculture and fisheries sectors potentially adds to our knowledge on climate induced changes and provide a basis for future planning and adaptation strategies for food production in the Pacific region. This paper

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present some observed climate trends and their implications for food production in the PICTs.

Food Production Profile of Pacific Islands Countries and Territories (PICTS)

The PICTs food production, both subsistence and commercial is derived directly from the regions natural environment. On land, food production practices in terms of size and agriculture production systems are just as diverse according the geographical diversity of the islands. For example, some diverse agricultural systems include the lowland sago management in Papua New Guinea (PNG), systems of intensive dry cultivation of yams in Tonga, sunken fields dug to tap subsurface water for giant swamp taro cultivation on atolls in Kiribati and Tuvalu, and the remarkable landscapes of irrigated and bunded pond-fields for growing taro in New Caledonia and Fiji (Bellwood, 1989). The countries in the Pacific region are diverse based on their diverse natural resource base and size. For example, the larger island countries include PNG (almost 90 percent of land area), Solomon Islands, Vanuatu, Fiji, and New Caledonia. These are mainly volcanic and generally rich in biological and physical resources. Some island countries are small which include Federated States of Micronesia, Kiribati, Nauru, Niue, and the Republic of the Marshall Islands, Tuvalu, and Palau). They are small and have limited natural resources and poor soils. The remaining countries, for example, Cook Islands, Tonga, Samoa, and American Samoa fall in between the two categories above (McGregor, 2006). The observed impacts of climate change on food production in some of the countries and territories in these three categories are shown in Table 1. For most small island countries, fisheries and aquaculture are important amongst the people in terms of food, culture and traditions, and further provide economic income, investments, employment opportunities and government revenues (FAO, 2010; Gillett & Cartwright, 2010). Gillett & Cartwright (2010) also reported that the total fisheries production from the region in 2007 was worth US$ 2 billion with investments and employment opportunities that accounted for 19,000 jobs in the processing industries. Any impact on this sector will be detrimental to island countries as is evident in most climate change vulnerable countries like Tuvalu (FAO, 2010).

Almost all subsistence food, domestically marketed food, and export cash crops and marine products are produced and harvested by rural villagers on land and sea that they access through customary land and marine tenure arrangements or lease from traditional land owners. The mix of subsistence food production and small scale income generating activities can be broadly divided into:

- domestically marketed food (root crops, vegetables and inshore fin fish and invertebrates)
- export commodity (tree and root crops and fish)
- minor cash crops (nuts and spices)
- livestock

Subsistence food production represents a major strength of the PICTs economy because of the ability of people to feed themselves and support each other during periods of disasters, loss of cash income, and times of displacement. Subsistence food production involve cultivating, harvesting and managing foods from different environments including fallow forests, primary forest, swamps and mangroves and reef systems. Subsistence crop production can sometimes fail because of factors such as pressures associated with an increasing population, diseases, pest and invasive species outbreaks, and extreme weather which interrupt with planting cycles and cause crop damage. Climate change is now resulting in high frequency and severity of extreme weather events such as cyclones, drought, and excessive rainfall which impact on food production (Jansen *et al.,* 2006).

Observed Changes in Climate, Trends and Future Projections

Historical climate data for the PICTs is limited, but there is some evidence of a trend towards warmer and drier conditions over the past half century (FAO, 2008). Observed changes in temperature, rainfall, sea level rise, ocean acidification, and extreme events are discussed.

Temperature and Rainfall

The annual and seasonal ocean surface

Table 1. Observed climate change impact on agriculture and crop production.

		Observed Climate Change Impact on Agricultural and food production:
Group 1 Relatively larger countries of Melanesia	Papua New Guinea	Tuber formation in sweet potato was significantly reduced at temperatures above 34 ° C (Allan & Bourke, 2009, NARI, 2010).
	Solomon Islands	Taro production has been reduced (less tubers and lower yields) in coastal areas over the years because of wave overtopping and warmer temperatures. Cyclone Namu wiped out rice industry in 1986 and now import 60,000 tons of rice annually (Government of Solomon Islands, 2008).
	Fiji Islands	Drought and cyclones in 1997 led to a decline of production to 2.2 million tons of cane and 275 000 tons of sugar from a peak of 4.1 million tons of cane and 501 800 tons of sugar in 1986 (Gawander, 2007). The cane growers' direct and indirect costs from the 2009 flood are estimated to be US$13.4 million. The costs include losses in cane output, non-cane and other farm losses, and direct and indirect household (Lal *et al.,* 2009).
	Vanuatu	Increased temperatures and variability of rainfall resulted in increased pest activities with yams being the crop most affected and in livestock there was increased incidence of intestinal problems in cattle often associated with pasture. Some plants flowering earlier than usual while others are fruiting much later than normal during the past 3–4 years (FAO, 2008).
	New Caledonia	The estimated cost of damage to agriculture by Cyclone Erica in March 2003 was US$13 million (Terry *et al.,* 2008).
Group 2 Middle – sized countries of Polynesia	Samoa	The increasing threats from new diseases and pests for both livestock and crops are linked to cyclones, flooding and drought and other variations in climate. The increasing incidence of forest fires has led to the destruction of crops as evident in the past forest fires in rural communities (Government of Samoa, 2005).
	Tonga	Squash crop which had been producing 50% of the country's exports by value was more than halved.
Group 3 Resource poor micro, predomina-ntly atoll, states	Federated States of Micronesia	Taro pits on some islands and atolls have been contaminated by salt water associated with a depletion of fresh-water lenses, extended droughts and saltwater inundation/ intrusion (FAO, 2008).
	Kiribati	The pandanus fruit is used by people as long term preserved food but most trees are lost through coastal erosion due to sea level rise and breadfruit and banana crops suffer from drought stress resulting in lower yields (GoK, 2007).
	Marshall Islands	During the El Niño season of 1997–1998, there was significant reductions in most crop yields (FAO, 2008).
	Palau	Taro pits on some islands and atolls have been contaminated by salt water associated with a depletion of fresh-water lenses, extended droughts and saltwater inundation/intrusion (Burns, 2003).
	Tuvalu	Groundwater salinisation as a result of sea-level rise is destroying the traditionally important swamp taro pit gardens (Webb, 2007).

and island air temperatures increased from 0.6 to 1.0 °C since 1910 throughout a large part of the South Pacific and decadal increases of 0.3 to 0.5 °C in annual temperatures to the southwest of the South Pacific Convergence Zone (SPCZ) since 1970 (Folland *et al.,* 2003). Hay *et al*. (2003) also reported that sea surface temperatures in the region have increased by about 0.4 ˚C. In Fiji, the annual mean surface air temperature has increased by 1.2 °C since the reliable records began, representing a rate of 0.25 °C per decade (Mataki *et al.,* 2006).

Manton *et al.* (2001) and Griffiths *et al.* (2003) found trends in extreme daily rainfall and temperature across the South Pacific for the period 1961 to 2003. Their analysis show significant increases in the annual number of hot days and warm nights, with significant decreases in the annual number of cool days and cold nights, particularly in years after the onset of El Nino and these changes can have negative impact on plant growth. The extreme rainfall trends were generally less spatially coherent than extreme temperatures. Mataki *et al.* (2006) also examined the changes in the frequency of extreme temperature events, finding that significant increases have taken place in the annual number of hot days and warm nights for both Suva and Nadi in Fiji, with decreases in the annual number of cool days and cold nights at both locations. The number of hot days (max. temperature ≥32 ^{o}C) shows a significant increasing trend while the number of colder nights (min. temperature < 18 ^{o}C) showed a decreasing trend at Suva. It is predicted that average temperatures are expected to rise by between 1.0 and 3.1˚C. Air temperature could increase to 0.90˚C - 1.30 ˚C by 2050 and 1.6˚C - 3.4 ˚C by 2100 (World Bank, 2006).

The southern Pacific is now experiencing a significantly drier and warmer climate (by 15 percent and 0.8 ˚C, respectively). The Central Equatorial Pacific, by contrast, is experiencing more intense rain (representing a change of about 30 percent) and a similarly hotter climate (0.6 ˚C). There has been a small increase over ocean and small decrease in rainfall over land and since 1970's. An analysis of monthly rainfall patterns at Goroka in Eastern Highlands Province of PNG from 1946 to 2002 found that there had been a shift to longer, but less pronounced, rainy seasons. Throughout the lowlands and highlands, villagers report similar changes in rainfall patterns. These changes are also linked in part to an increased frequency of El Nino events (Allen & Bourke, 2009). Observed rainfall at Nadi from 1941 to 2005 shows a large inter annual variability with no significant long term trend but there has been an increase in the frequency of extreme rainfall events over recent decades, a trend which is likely to continue into the future (Government of Fiji (GoF), 2011). The projected increase in surface air temperature and rainfall and predicted rainfall pattern for the Pacific region are shown in Table 2.

Sea level rise and ocean acidification

Many PICTs are already experiencing sea level rise. Fifty-years or longer time-series data for sea-level rise from four stations in the Pacific reveal that the average rate of sea-level rise in this sub-region is 1.6 cm a year. Twenty -two stations with more than 25 years worth of data indicate an average rate of relative sea-level rise of 0.07 cm a year (Bindoff *et al.*, 2007). In Fiji over the period from October 1992 to December 2009, sea level increased by 0.5 cm per year. This is far greater than the estimated range of global sea-level rise over the past century, namely 0.1 to 0.2 cm per year. Projections for sea level rise from the IPCC 4^{th} Assessment Report, including an allowance for a dynamic ice-sheet response, are about 18 to 80 cm by 2100 (Government of Australia - GoA, 2010).

Sea level rise is also likely to affect groundwater resources by altering recharge capacities in some areas, increasing demand

Table 2. Projected increases in surface air temperature and changes in rainfall in Northern and Southern Pacific (Source: IPCC 4AR, 2007).

PROJECTED INCREASES IN SURFACE AIR TEMPERATURE (°C) AND CHANGES IN RAINFALL (%) BY REGION RELATIVE TO THE 1961–1990 PERIOD

AIR TEMPERATURE	2010–2039	2040–2069	2070–2099
Northern Pacific	0.49 to 1.13	0.81 to 2.48	1.00 to 4.17
Southern Pacific	0.45 to 0.82	0.80 to 1.79	0.99 to 3.99
RAINFALL	**2010–2039**	**2040–2069**	**2070–2099**
Northern Pacific	-6.3 to +9.1	-19.2 to +21.3	-2.7 to +25.8
Southern Pacific	-3.9 to +3.4	-8.23 to +6.7	-14 to +14.6

Source: IPCC 4AR Tables 16.1 and 16.2

for groundwater as a result of less surface water availability, and causing water contamination due to rising sea levels. It is projected that there will be up to 14 percent loss of coastal land due to sea level rise and flooding by 2050 (Feresi *et al.,* 2000), and these are the prime coastal areas for economic activities including food production.

The risk of acidification to the many reef systems throughout the region is also a major concern. Absorption by the sea surface of atmospheric CO_2, reduced pH and lower calcium carbonate (CaCO3) saturation in surface waters are well verified from models, surveys, and time series data (Feely *et al.,* 2004; Orr *et al.*, 2005; Doney *et al.* 2009). Acidification decreases the capacity of reef building corals, calcareous algae and many other key species in tropical ecosystems to grow calcium carbonate skeletons and shells (GoA, 2010) and this directly affect food sources for many people in the region. Ocean acidification is considered essentially irreversible over the next century (Poloczanska *et al.,* 2007). The observed changes in climate, trends and future projections are summarized in Table 3.

Extreme events or natural hazards

Historical records on occurrences of extreme events like cyclones, storm surges, flooding and drought show that they are increasing in intensity or severity. Cyclones are expected to increase in intensity by about 5 –20 percent. Storm frequency is likely to increase in the equatorial and northern Pacific. In general, the future climate is expected to become more El-Nino like, resulting in more droughts in the southern Pacific and more rain

Table 3. Observed and projected temperature, rainfall and Sea level rise for the Pacific region.

Factor/Variable	Observation	Projections/Scenarios
Temperature	0.6 to 1.0 increase since 1910 0.3 to 0.5 decadal increase since 1970	Air temperature could increase 0.9˚ - 1.3˚C by 2050 and 1.6 -3.4˚C by 2100 (Jones et al., 1999).
Rainfall	Small decrease over land since 1970's Small increase over ocean since 1970's	Rainfall could either rise or fall. Most models predict an increase by 8-10 percent in 2050 and by about 20 percent in 2100, leading to more intense floods or droughts
Sea Level Rise	Relative sea level rise of 0.6 to 2.0 mm yr^{-1} since 1950	Sea level could rise 0.2 meters (in the best-guess scenario) to 0.4 meters (in the worst-case scenario) by 2050. By 2100, the sea could rise by 0.5-1.0 meters relative to present levels. The impact would be critical for low-lying atolls in the Pacific, which rarely rise 5 meters above sea level. It could also have widespread implications for the estimated 90 percent of Pacific Islanders who live on or near the coast (Kaluwin and Smith, 1997).
El Nino		The balance of evidence indicates that El Niño conditions may occur more frequently, leading to higher average rainfall in the central Pacific and northern Polynesia. The impact of El Niño Southern Oscillation (ENSO) on rainfall in Melanesia, Micronesia, and South Polynesia is less well understood (Jones *et al.,* 1999).
Cyclones	Noticeable increase in frequency of category 4 and 5 cyclones since 1970	Cyclones may become more intense in the future (with wind speeds rising by as much as 20 percent); it is unknown, however, whether they will become more frequent. A rise in sea surface temperature and a shift to El Niño conditions could expand the cyclone path poleward, and expand cyclone occurrence east of the dateline. The combination of more intense cyclones and a higher sea level may also lead to higher storm surges ((Jones *et al.,* 1999).

and consequent floods in the equatorial Pacific. Hurricane-strength cyclones; those with winds stronger than 63 knots or 117 km hr^{-1} have increased systematically in the southwest Pacific, a trend that has also been observed at the global level over the past 30 years (Emanuel, 2005; Webster *et al.,* 2005). The region now experiences on average four hurricane-strength cyclones a year.

Impacts of climate change and climate variability on food production

Climate change has both direct and indirect effects on food production. The indirect effects changes in temperature, rainfall and sea level rise will be complex and remains difficult to predict the likely outcomes with certainty but the direct effects from extreme events like cyclones, drought, floods and storm surges are obvious.

Agriculture and crops

The direct or immediate impacts of climate change on agriculture and crop production occur during or immediately after a natural hazard or extreme event, such as damage to crops, farmlands and agriculture infrastructure from cyclones and flooding. The World Bank (2006) reported that during the period 1950 to 2004, about 207 extreme events were recorded in the Pacific region.. There has been a substantial increase in the hurricane-strength cyclones since the 1950s with an average of four events in a year. The average cyclone damage during this period was US$75.7 million in real 2004 value (World Bank, 2006). In New Caledonia, the estimated cost of damage to agriculture by Cyclone Erica in March 2003 was US$13 million (Terry *et al.,* 2008) while Cyclone Ami that hit Vanua Levu in Fiji in 2003, caused US$33 million loss (McKenzie *et al.,* 2005), mainly due to flood damage of agricultural crops and infrastructure. In 2004 cyclone Ivy affected over 80 per cent of food crops in Vanuatu and cyclone Val in 1991, hit Samoa with maximum wind speeds of 260 km hr^{-1} causing massive damage; equivalent to 230 per cent of the country's real 2004 GDP (World Bank, 2006).

Drought is an extreme form of rainfall variability can affect the highest number of people per event. El Niño event in the past has resulted in water shortages and drought in some parts of the Pacific (e.g. Papua New Guinea, Marshall Islands, Samoa, Fiji, Tonga and Kiribati), and increased precipitation, and flooding in others (e.g. Solomon Islands, and some areas in Fiji) (World Bank, 2000). In Fiji, the 1997/98 drought events resulted in 50 percent loss in Sugarcane production and total losses in the industry were around US$50 million while other agriculture losses including livestock death amounted to around US$7 million (McKenzie *et al.,* 2005). An extension of the dry season by 45 days has been estimated to decrease maize yields by 30 to 50%, and sugar cane and taro by 10 to 35% and 35 to 75%, respectively (Hay *et al.,* 2003). In Kiribati, breadfruit and banana crops suffer from drought stress resulting in lower yields (Government of Kiribati - GoK, 2007). A drought associated with a severe ENSO (El Nino-Southern Oscillation) event in 1997 caused significant disruptions to village food and water supplies in PNG. There were severe shortages of food and water, with garden produce declining by 80 percent. Up to 40 per cent of the rural population (1.2 million people) were without locally available food by the end of 1997 (Allen & Bourke, 2001).Crop production in many PICTs is effected by extreme drought events.

Increases in minimum and maximum temperature are already having a small influence on agricultural production and will have a greater influence in the future. For example in PNG, it was observed that tuber formation in sweet potato was significantly reduced at temperatures above 34 °C. Maximum temperatures in the lowlands of PNG are now around 32 °C, so an increase of 2.0–4.5 °C within a hundred years could reduce sweet potato production in lowland areas (National Agriculture Research Institute - NARI, 2010). In Solomon Islands, taro production has been reduced (less tubers and lower yields) in coastal areas over the years because of wave overtopping and warmer temperatures (Government of Solomon Islands - GoSI, 2008). It was also observed that increase in temperature in PNG highlands has a severe impact on coffee production from *coffee rust* attack. Coffee rust is present in the main highland valleys at 1600–1800 m and a rise in temperature is likely to increase the altitude at which coffee rust has a severe impact on coffee production. Taro blight, a disease caused by the fungus *Phytophthora colocasiae*, also reduced taro yield at higher altitudes. The fungus is sensitive to temperature and a small rise in temperature could increase incidence of taro blight disease than occurs now. Some tree crops are bearing at higher altitude in the highlands but the lower altitudinal limit of some crops, such as Irish potato, Arabica coffee and *karuka* (*Pandanus julianettii* and *P. brosimos*), will increase because of increasing temperatures (Allen & Bourke, 2009). In Fiji, the major concern of sugar production is the sporadic sucrose content in the yield which could be affected with increase in temperature, groundwater salinization and fluctuating soil moisture content. This is a concern because sugar is a major foreign exchange earner, accounting for about 40 per cent of the country's merchandise exports and 12 per cent of Fiji's Gross Domestic Product (Gawander, 2007). The scenario for sugar cane production in Fiji over the next 50 years will be in the following manner:

- 47% of the years will have the expected production of 4 million tonnes,
- 33% of the years will have half of the expected production,
- 20% of the years will have three-quarters of the expected production.

This was determined when using the period from 1992 to 1999, when Fiji was subjected to two El Niño events and an unusually high number of tropical cyclones as an analogue for future conditions under climate change. The outcome under this scenario would be an overall shortfall in excess of one quarter of expected production (GoF, 2005).

Hay *et al.* (2003) pointed out that for the Pacific region the smaller temperature increase relative to higher latitude locations is unlikely to place a severe limitation on crop production but the physiology of crops may be influenced in ways not yet identified. Using a computer software simulation model called *PlantGro*, the following patterns were projected for Taro (*Colocassia esculenta*) and yams (*Dioscorea* sp.) in Fiji (GoF, 2005):

- Projected changes in mean conditions would have little effect on taro production, with the exception of the extreme low-rainfall scenario. It is likely that yam production will also remain unaffected, although if rainfall increases significantly, yam yields may fall slightly.
- When El Niño conditions are factored in, reductions in, production of 30-40% might be recorded in one out of three years, with a further one in five years affected by the residual effects of the ENSO events.

Agricultural productivity in PICs is heavily dependent on the seasonal rainfall. About 70% of the gross cropped area in the Pacific Islands is geographically located so as to benefit from rains in the summer season (November – April). While the rainfall requirements and tolerance of extremes vary from crop to crop, a working figure for the south west Pacific is that a mean annual rainfall of 1800-2500 mm is optimal for agricultural production and a mean annual rainfall of over 4000 mm is excessive (Bourke *et al.,* 2006). A significant (>50%) increases in rainfall on the windward side of high islands during the wet season may increase taro yields by 5 to 15%, but would reduce rice and maize yields by around 10 to 20% and 30 to 100%, respectively (Hay *et al.*, 2003). In PNG, most of the rural population live and cultivate crops in areas where annual rainfall is in the range 1800–3500 mm. In mountainous locations where clouds form early in the day and reduce sunlight, human settlement and agriculture is generally absent. Localities where the annual rainfall is more than 4000 mm tend to be too wet and have too much cloud cover for good agricultural production. Yields of sweet potato and other crops tend to be lower on the southern sides of the main mountain ranges, for example, in Southern Highlands Province and mountainous parts of Gulf Province in PNG. This is because of both excessively high rainfall and high levels of cloudiness (Allen & Bourke, 2009). In Solomon Islands, there has been an increased incidence of intestinal problems in cattle often associated with pasture and similar problems (worm and infections) have been encountered by the piggery farmers (Solomon Islands National Adaptation Plan of Action -

SI NAPA, 2008).

Climate change predictions for the region suggest prolonged variations from the normal rainfall which can be devastating to agriculture. Shift of rainfall patterns affect planting time, growing stages, harvest periods, post harvesting storage and drastically reduce total yield. Agriculture and crop production is under stress from these climatic factors but it remains difficult to predict the likely outcomes with certainty because of limited empirical data for the Pacific region. Disruptions to food production and the economy may intensify in future, given the projections for more intense tropical cyclones and precipitation variations of up to 14 percent on both sides of normal rainfall (IPCC, 2007) by the end of the century. More so, in between climate extremes, altered precipitation and increased evapotranspiration (including its intensity as well as temporal and spatial shifts) will also be of concern as these changes take root. The increase in atmospheric carbon dioxide may benefit agriculture but these positive effects are likely to be negated by thermal and water stress associated with climate change (Lal, 2004) and changes in pests' voracity and weeds' growth; loss of soil fertility and erosion resulting from climatic variability being another problem. Increasing coastal inundation, salinization and erosion as a consequence of sea level rise and human activities may contaminate and reduce the size of productive agricultural lands and, thereby, threaten food security at the household and local levels.

The most destructive impact of excessive rainfall on agriculture infrastructure and crops are flooding and waterlogging. For example, flooding during 2004/2005 and 2006/2007 caused around US$76 million and US$11 million in damages, respectively in Fiji . The cane growers' direct and indirect costs from the 2009 flood are estimated to be US$13.4 million. The costs include losses in cane output, non-cane and other farm losses, and direct and indirect household income (Lal *et al.,* 2009)

Sea-level rise is affecting agriculture in three different ways: Coastal erosion resulting in loss of land and some areas are permanently inundated, making it unsuitable for agriculture production. Some areas are also subjected to periodic inundation from extreme events, including high tides and storm waves, contaminating the fresh water lens, with devastating effects especially on atolls; and seepage of saline water through rivers during dry seasons, resulting in increasing the salt level in soils. Storm surges and increased salt water intrusion limits the range of crops that can be grown. The small atolls in particular face serious problems for example, pit and swamp cultivation of taro is particularly susceptible to changes in water quality. In Tuvalu, groundwater salinization as a result of sea-level rise is destroying the traditionally important swamp taro pit gardens (Webb, 2007) and raises concern on the safety of drinking water (Tekiene & Paelate, 2000). In Kiribati, coastal erosion reduces crop productivity such as of pandanus varieties and coconut. The pandanus fruit is used by people as long term preserved food but most trees are lost through coastal erosion (Government of Kiribati - GoK, 2007).

Fisheries

Climate variability and the impacts of extreme weather events means that inshore fisheries are likely to decline as coral bleaching increase due to increase in sea temperature and acidification, and the location of oceanic species like tuna may become increasingly unpredictable as there is reasonable confidence that changed migration patterns are linked to ENSO events (McLean & Tsyban, 2001).

In coastal fisheries, the physical stressors like sea level rise, sea surface temperature, acidification, ultra violet radiation and increased rainfall often lead to impacts on corals and calcareous algae, seagrass, mangroves, fish and other reef invertebrates that provide food for the people (SPC, 2010). For corals, if the bleaching event is severe and the stressful temperatures persist for weeks, mortality may reach 100% (Poloczanska *et al.*, 2007). Coral reefs in Micronesia and western Polynesia are considered particularly vulnerable to coral bleaching (Doney *et al.,* 2005) and declines in coral cover as a result of disease and bleaching can have drastic effects on the entire coral reef ecosystem (Graham *et al.,* 2006). Ellison

(2009) observed that three species of seagrass (*Halophila ovalis*, *Syringodium isoetifolium* and *Zostera capricorni)* were identified as being intolerant to ecologically relevant exposure to thermal stress. The former two species are widespread in Pacific Islands, whereas the last species has only been recorded from Vanuatu. Sea level rise affects mangroves by retreating landward to maintain their preferred position in the intertidal zone and increase surface temperature may change species composition; changing phenological patterns (e.g., timing of flowering and fruiting of the mangroves); increasing mangrove productivity where temperature does not exceed an upper threshold (SPC, 2010). In parts of PNG at least, subsistence fisheries such as those in the Gulf of Papua and the Sepik region are dependent on estuarine species like barramundi (*Lates calcarifer)*, threadfins and "croakers" (*Scienidae*) whose life cycles and year class strengths are related directly to the timing and volume of freshwater input to the marine environment (Staunton-Smith *et al*., 2004).

By 2050, catch potential in the tropical Pacific is projected to decrease by up to 42% from the 2005 level (Cheung *et al.,* 2009).There is significant data gap on inshore or coastal fisheries in terms of catch composition, harvest levels and length-frequency of the fisheries catch (particular non -commercial fisheries) in a number of PICTs. While information in some countries is adequate, there is scope for improvement and also scope for introducing effective (but feasible) monitoring programs in PICTS where programs are ineffective or lacking appropriate resolution and/or coverage

The impact on tuna, the most valued oceanic species in the region is predicted to include the following (FAO, 2008):

- Decline in primary productivity. Primary productivity in the central and eastern Pacific could decline due to the increased stratification between warmer surface waters and colder, deeper water (and resulting reduction in upwelling). Primary production in the western Pacific could conversely increase.
- Decline in tuna abundance. The decline in upwelling could lead to a decline in the big eye and adult yellow fin population (the species targeted by the long line fleet).
- Spatial redistribution of tuna resources. The warming of surface waters and the decline in primary productivity in the central and eastern Pacific could result in spatial redistribution of tuna resources to higher latitudes (such as Japan) and towards the eastern equatorial Pacific.

It was observed during the El Niño years in 2002 and 2003 that the principal tuna stock moved out of Republic of Marshall Islands (RMI) waters and congregated more in the western Pacific around PNG and its neighboring countries. This led to decreased catch in RMI. This situation is expected to reoccur under similar conditions in future (FAO, 2008). With increase in sea surface temperature, there also now observed migration and shift of tuna concentration from the west and central Pacific to the eastern Pacific region (Mohanty *et al.,* 2010). The spatial redistribution of tuna resources will continue with changing climate.

CONCLUSIONS

Climate change will affect land, forest recourses and oceans that are important sources of food for the Pacific Island population. Changes in temperature, rainfall regimes, sea level rise and increases salinization, ocean acidification, more intense weather-related disasters and changes in disease and pest can also impact agricultural and fisheries production. The region is also experiencing annual and decadal variability in temperatures and rainfall due to the ENSO (El Nino/La Nina-Southern Oscillation) cycle. Observed data so far have shown that extreme events like cyclones have caused substantial damage to agriculture and fisheries and associated infrastructure. Impacts on food production from increased salinization, coastal erosion, high rainfall and drought, increased temperature and ocean acidification have also been reported for several Pacific Island countries. There is however great uncertainty over the quantitative impacts of climate change on food production due to uncertainties on climate change projections in the future, crop responses to the likely changes, and localized climatic conditions in each country. There is still a great need for more research, impact assessments and analysis at local level to be able to ascertain the direct impact on food production. Because of this situation and coupled with their exposure and limited adaptive capacity, PICTs need assistance to properly adapt to climate change. Adapting to climate change, variability and sea-level rise is a serious and urgent need for the PICTs.

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Constraints and gender involvement in relation to canarium nut marketing in Kakalano and Bitaama areas of Malaita Province, Solomon Islands

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ABSTRACT

Consultations using Participatory Rural Appraisal (PRA) techniques was carried out in the Kakalano and Bitaama areas of Malaita Province to identify the main constraints encountered by the communities, which have caused a limitation in the supply of canarium. It was also carried out to identify the main gender groups involved in the marketing of canarium and the reasons for their involvement. The results show that a support system was needed to be put in place if canarium was to be considered a cash crop. Infrastructure and resources needed to be improved as well as trainings on how to best process the canarium nuts. Reliable market outlets to sell canarium nuts were to be established to encourage the local women to process the nuts and to encourage the men to look at canarium as a cash crop and share the processing responsibility with the women.

Key words: Canarium nut, Gender issues, Marketing, Participatory rural appraisal.

INTRODUCTION

The canarium nut is known as ngali in the Solomon Islands, and has many uses for the local people; it is a source of food, for building canoes, as timber, medicine and it is significant in terms of determining an individual's wealth and status. Furthermore, it is still used in the bartering system and the locals sell it in the local market to generate an income during the fruiting season (Pelomo *et al.,* 1996; Nevenimo *et al*., 2008).

Despite estimations made by Wissink (1996) that the Melanesian region is capable of producing edible nuts of *Canarium indicum* amounting to 2,200,000 tonnes with an annual potential production of 11,000 tonnes of kernels, research carried out in Papua New Guinea (PNG) showed that the demand for the local markets could not be met (Nevenimo *et al.,* 2008). Similar findings were found in the Solomon Islands during the commercialisation trials carried out. The trials indicated that the nut is profitable, yet supply, management and marketing constraints hindered the growth of the industry (Pelomo *et al*., 1996; Nevenimo *et al.,* 2007). Other issues limiting nut supply was that of the ownership of the nuts and nut products (Anonymous, 2004; Bunt & Leakey, 2008).

In order to clearly identify the marketing challenges faced by the different gender groups, Participatory Rural Appraisal (PRA) techniques were used to carry out consultations in two areas of Malaita; Kakalano and Bitaama. These areas were selected as the villagers were receptive to having consultations, they have large areas of canarium trees and Bitaama area was also involved in commercialising the canarium nut before they ceased supply due to difficulties encountered. The objectives of the consultations were:

- To identify the constraints faced by the major shareholders in marketing the canarium nuts.
- To study the major shareholders especially the role played by women in the collection, processing and marketing of canarium nuts.

MATERIALS AND METHODS

Location of study

Two areas were selected for the Participatory Rural Appraisal (PRA) study. Kakalano and Bitaama were selected because they contain large areas of canarium trees. The elders from these areas were also

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receptive to the idea of the PRA. Bitaama was also one of the main areas where canarium was commercialised.

Participatory Rural Appraisal (PRA)

Arrangement and Implementation

Participatory Rural Appraisal (PRA) activities were carried out first in Kakalano area. Eleven females and thirteen males attended. PRA in Bitaama was carried out a couple of days later, eight males and eighteen females participated.

The participants were divided into two groups, males and females. Males are usually more dominant in the Malaitan society, hence the need to separate the genders so that the women's constraints could be heard.

Tools Used

Matrix Ranking and Scoring was used to identify the three major constraints faced by the gender groups in trying to market canarium. The problems were prioritised by individual participants, and ranking of each problem was carried out using the following rankings:

5 = most important problem
4 = important problem
3 = slightly important problem
2 = less important problem
1 = least important problem

Pairwise Ranking was used to identify and compare the major roles played by the different gender groups in each marketing activity.

RESULTS

Table 1 lists the problems common amongst the males and females in the Kakalano and Bitaama areas of Malaita Province. The women from Kakalano identified the nuts were too heavy, cracking of the nuts and the removal of the shell and testa as the major problems they faced in terms of canarium nut marketing. The males from Kakalano identified their three major problems as a lack of marketing outlets, harvesting of the nuts by climbing and the seasonal fruiting of the trees.

In Bitaama the females saw the three major problems they encountered were the lack of markets, secondly they identified that during the canarium season everyone sold the nuts hence there were no outside buyers and finally, processing of the nuts becomes expensive as many people are required to carry out the various processing tasks.

The males from Bitaama identified eight common problems and ranked the lack of market outlets as being the major problem, the low prices received for the canarium products as well as the cracking of the nuts as the major problems that they encountered with canarium marketing.

The results in Table 2 show several reasons why the Kakalano females thought were the cause of the major problems and what they identified were possible solutions to the problems. In Table 2 the females identified the difficulties they encountered were that the nuts were too heavy to be carried, this was due to the far distances that they had to travel with the nuts, the roads were poor, hence transportation of the nuts by truck was impossible. Further to this they also identified that cracking of the nuts was a slow process and that the biggest problem was that of hitting one finger in the process. Finally they identified that the main reason why the removal of the shell and testa was a problem due to a lack of women available to do the job and that the quantity harvested was great. The women suggested that possible solutions would be to ask people to help them carry the nuts, or the need for machines which would help them crack the nuts and remove the shell and testa as well.

This is in contrast to the results put forth by the males in Table 3 where their problems were more focused on the climbing of the trees and the danger involved as well as the selling of and the seasonal fruiting of the canarium trees.

The males from the area indicated in Table 3 several causes of the lack of market outlets as well as the harvesting of the nuts by climbing. Several reasons were suggested as possible solutions such as the need for higher market prices and that Solomon Islands Government (SIG) should be more involved in market research, production and the reproduction of the tree to try and solve some of the problems.

The women saw that the main reasons

Table 1. Ranking and scoring of females and males constraints in relation to canarium nut marketing in the Kakalano and Bitaama areas of Malaita Province.

Problems	Total scores of Kakalano		Total scores of Bitaama	
	Female	Male	Female	Male
1. Climbing is dangerous.	7	21	-	13
2. Hard to gather the nuts.	15	-	16	-
3. Too much work involved in canarium processing.	5	-	45	-
4. No income from the canarium nuts as there is no place to sell them.	16	25	-	29
5. Nuts are too heavy to carry.	35	-	-	-
6. Cracking the canarium.	29	12	7	19
7. Stealing of the canarium nuts.	8	13	-	-
8. Ownership of the trees (people fight over canarium trees).	7	-	-	-
9. Expensive to feed people processing the nuts.	14	-	36	-
10. Need many people to process the nuts.	5	-	-	-
11. Removal of the shell and testa from the kernel.	24	-	-	5
12. Not enough trees.	-	16	-	-
13. Not a commercial commodity as in the case of cocoa and coconut.	-	13	-	-
14. Many trees but the quality is low.	-	13	-	-
15. Low prices.	-	16	-	26
16. Fruiting of trees some have high fruiting some have low fruiting.	-	8	-	-
17. Canarium fruits seasonally.	-	18	-	-
18. Lack of people to climb the trees.	-	-	19	-
19. No one to buy the canarium nuts as most people sell the same product during the canarium season.	-	-	37	-
20. Cracking the nuts at night to sell as there is no other time.	-	-	15	-
21. Do not know how to roast the canarium kernels to make them last long.	-	-	17	-
22. Not enough stones for drying the kernels to enable them to be first grade.	-	-	33	-
23. People are hungry during the canarium season	-	-	-	17
24. Smoking of the canarium.	-	-	-	4
25. Collecting bush materials such as bamboo and firewood.	-	-	-	7

why these problems existed were that the SIG and Non Government Organisations (NGOs) have not helped them find markets for their products. Further to that, the middleman has not been honest with the dealings in relation to the selling of the canarium nuts. Hence there was a need for NGOs and the SIG to assist in terms of finding markets as well as machines to enable them to produce different canarium products to target different markets. The women also required training in processing canarium into different products. Finally, they saw that the main cause of canarium nut being expensive to process was that the nuts deteriorated rapidly hence they needed to process many nuts in order to make a decent

Table 2. Analysis of constraints faced by females in marketing canarium in Kakalano area.

Problem 1: Nuts are too heavy to carry.	
Causes of the problem: 1. Trees are planted far away from village. 2. Canarium nuts are too heavy because of the mesocarp. 3. Road to canarium areas is not good.	*Possible solutions:* 1. Ask people to help carry the nuts. 2. Make houses in the bush to process the nuts. 3. Only carry the kernels back to village.
Problem 2: Cracking the canarium nuts.	
Causes of the problem: 1. Hit your finger when cracking. 2. Cracking is a very slow process. 3. If there are many nuts then it takes a long time to process them (up to one month).	*Possible solutions:* 1. Need many people to help crack the nuts. 2. Need a machine to crack the nuts.
Problem 3: Removing the shell and testa.	
Causes of the problem: 1. Few women are available to do this work. 2. Too many fruits at one harvest.	*Possible solutions:* 1. Machine to remove shell and testa from the canarium nuts. 2. Everyone work together. 3. Leave the mesocarp on the fruits to rot before cracking.

Table 3. Analysis of constraints faced by males in relation to canarium marketing in Kakalano area.

Problem 1: Marketing selling outlets.	
Causes of the Ppoblem: 1. Government has not provided any market outlets for canarium. 2. Low market values of the nuts. 3. Not enough research into canarium nut.	*Possible solutions:* 1. Solomon Islands Governments (SIG) to find commercial markets. 2. Increased local prices. 3. Ministry of Agriculture and Livestock (MAL) should do more research on canarium production and marketing.
Problem 2: Harvesting/Climbing.	
Causes of the problem: 1. Accidents due to climbing. 2. Damage to the tree caused by cutting of the branches. 3. Delay of next harvest.	*Possible solutions:* 1. No climbing. 2. Wait for the nuts to fall before picking them off the ground. 3. No pruning.
Problem 3: Seasonal fruiting.	
Cause of the problem: Natural occurrence of canarium trees.	*Possible solution:* More research into the reproduction of the canarium tree.

income. They identified that a possible solution would be either the individual processes the nuts herself or share bamboos with those who assist in the task. These problems and possible solutions are in Table 4.

Similarly the males from Bitaama also identified a lack of market outlets as a major concern, in contrast though to the females problems, the males identified that cracking of the nuts was a problem for them and that they needed machines to be able to carry out this task.

Results in Table 5 identified the causes of the three major problems as well as possible solutions to the problems put forth by the males of Bitaama. They saw that the SIG and NGOs were not supporting the communities to identify markets. For their second problem they identified that there were too many canarium nuts being sold hence decreasing the

Table 4. Analysis of constraints by females in relation to canarium nut marketing in Bitaama area.

Problem 1: No market. *Causes of the problem:* 1. SIG and NGOs has not helped them find markets for the canarium products. 2. Middleman is not honest to the women's group so they quit supplying the nuts. 3. Leader of the women's group is self-seeking and refused to release any information with regards to the selling of the canarium.	*Possible solutions:* 1. NGOs and SIG must look at the marketing side of canarium to assist the women. 2. Provide processing machines to enable them to produce different canarium products. For example, canarium oil.
Problem 2: Everyone produces the same product during the canarium season. *Cause of the problem:* Making bamboos or selling the canarium kernels raw or roasted is the only way they know how to process the canarium nut.	*Possible solution:* They need training on how to process other products from canarium nut.
Problem 3: Feeding those people who come to process the canarium nuts is expensive. *Cause of the problem:* They need to process the canarium on time otherwise the kernels will deteriorate quickly.	*Possible solution:* Each woman does it herself.

Table 5. Analysis of constraints by males in relation to canarium nut marketing in Bitaama area.

Problem 1: Lack of market outlets. *Causes of the problem:* 1. No support from Solomon Islands Government. 2. No support from Non Government Organizations.	*Possible solutions:* 1. Solomon Islands Government should assist farmers in terms of providing market outlets for canarium example coconut and cocoa. 2. Need support from Non Government Organisations.
Problem 2: Low Price. *Causes of the problem:* 1. Everyone sells the same product; these are heaps of canarium kernels, parcel of canarium kernels at $0.20-$2.00 each or bamboo at $10.00-$20.00 each. 2. Plenty of canarium nut available during the canarium season but there is no place to sell.	*Possible solutions:* 1. Provide proper local and international markets. 2. Provide more market outlets.
Problem 3: Cracking the canarium nuts. *Causes of the problem:* 1. Not enough stone. 2. Accidents by hitting finger. 3. Slow process.	*Possible solutions:* 1. Need machine. 2. Any new technology to solve canarium nut processing.

price of the canarium products. Finally cracking of the nuts was a problem because the process was slow and one usually ended up hitting their fingers. As possible solutions they saw the SIG and NGOs as playing a major role in identifying markets both locally and internationally as well as assisting in terms of new tools or technology which would help them in the cracking process.

Results in Table 6 show the females'

responses on their action plan to solve the three major problems they identified. They identified the areas where they could achieve on their own as well as areas where NGOs, the SIG as well as the Aid Donors could assist. They mainly requested assistance in terms of resources to enable them to clean and dry the canarium nuts.

The action plan and analysis of the females from Kakalano were similar to those of the males response from the same area. There was only so much that the community could achieve on their own in terms of processing and finding markets for the products. Assistance was required from NGOs, the SIG and Aid Donors in terms of research, infrastructure and resources for marketing the nut.

In their action plan and analysis, the males identified (see Table 7) that they could not achieve anything on their own in terms of finding markets for the nut and that the SIG, NGOs and Aid Donors would need to identify markets for their canarium products. They also identified the need for harvesting tools or machines to limit the problems concerned with climbing. Furthermore, research was needed to be carried out by the Ministry of Agriculture (MAL) in the Solomon Islands as well NGOs in the area of the reproduction cycle of the canarium tree.

In Table 8, the females from Bitaama identified that on their own they would be able to achieve tasks such as drying the kernels well so that they can sell it out of season in order to target the problem of the lack of markets. In all the situations, they required help from NGOs and the SIG in terms of resources

Table 6. Action plan and analysis for females' three major constraints identified in relation to canarium nut marketing in Kakalano area.

Activities	**What can the women in the community achieve on their own?**	**What help they would need?**
Problem 1: Nuts are too heavy to carry.	Ask people to come and help carry the canarium	Ask Member of Parliament to make good roads to the canarium areas.
Problem 2: Cracking the canarium nuts.	1. Pay men to come and do the work. 2. Pay women's union to crack the nuts. 3. Make their own women's group to crack the nuts.	Ask Member of Parliament or NGOs for support of a machine which can clean the nuts.
Problem 3: Removing the shell and testa.	1. Form women's group to do the work together. 2. Pay other women's group to come and help.	1. Good to have a machine to clean the nuts. 2. Also need an oven for drying kernels.

Table 7. Action plan and analysis of the males' three major constraints identified in relation to canarium nut marketing in Kakalano area.

Activities	**What can the community achieve on their own?**	**What help they would need?**
Problem 1: Marketing and selling outlets.	Nothing.	Solomon Islands Government and NGOs to assist in finding local and commercial markets for canarium.
Problem 2: Harvesting and climbing of the trees.	Encourage only picking.	1. Harvesting tools 2. Machines
Problem 3: Seasonal fruiting of the trees.	Men can do nothing.	More research needed into the production and marketing side of the nut from MAL and NGOs.

such as good ovens to dry their kernels and good packaging material for packaging the nuts. They also need support on trainings on how to process the canarium into other products and they required assistance in terms of a nut cracker to enable them to crack the nuts.

Similarly the males from Bitaama also identified that their community needed assistance from the SIG and NGOs in terms of identifying markets for their products as well as resources to assist them in the different processing stages of the nut especially cracking of the nut.

In their action plan and analysis (see Table 9), the males requested that the SIG and NGOs needed to assist the local communities to identify markets for their products, and that research should be carried out in the area of the seasonal fruiting of the nuts. Further to this they also requested for machines which would assist them in cracking the canarium nuts.

The ranked response by the Kakalano females in Table 10 identifies the married men as being the major groups involved in climbing the canarium trees, cracking the nuts as well as packing the kernels. Married women were identified as the main group involved in gathering and carrying of the nut. They were also the main gender group involved in the removal of the shell and testa as well as the storing and selling of the nut.

The women from Kakalano saw the men as the main climbers of the tree because in the Malaitan culture, women were not allowed to climb any trees. In terms of

Table 8. Action plan and analysis of females' constraints in relation to canarium nut marketing in Bitaama area.

Activities	**What can the community achieve on their own?**	**What help they would need**
Problem 1: No market.	Women must work together to dry the kernels well to make them last long so they can try to sell out of season.	They need assistance in terms of materials from NGOs and the SIG; i.e. a. storage containers for the kernels. b. good oven to dry the kernels to achieve quality kernels. c. packing bags for the kernels to retain their quality.
Problem 2: Same product.	Nothing	Training on ways to make new canarium products.
Problem 3: Expensive to feed people that come to help process the canarium nuts.	Each woman will try to crack the nuts herself.	Assistance is needed from NGOs and the SIG in terms of materials, to help them process the nuts example a machine to crack the nuts.

Table 9. Action plan and analysis of male constraints in Bitaama area in relation to canarium nut marketing.

Marketing activities	**What can the community achieve on their own?**	**What help they would need**
Problem 1: Marketing outlet.	Nothing	1. SIG/NGOs should assist by providing market outlets. 2. MAL should do more work (research) on seasonal marketing.
Problem 2: Low price.	Just collect to eat.	Provide more market outlets.
Problem 3: Cracking	By getting more labour to crack the nuts.	1. Need machine. 2. Any new technology which can be used to process canarium nut.

cracking the nuts the men were seen as being free to carry out this task as the women would be busy with shelling and removal of the testa. Packing the kernels, the men were seen as strong and had the ability to do this. With all the other tasks, they were seen as either easy tasks or in their culture it was just the women's task such as carrying the nuts.

In Table 11, the males from Kakalano saw that harvesting by climbing was mainly the young men's job, whereas the married men were the main ones who did the cracking, packing and storing of the nuts. The married women were the main ones involved in harvesting the nuts by gathering, removal of the shell and testa as well as selling of the nuts. In this situation the males identified all gender groups as being the main carriers of the nuts.

When asked to identify the reasons for their selection of the specific gender groups, the males responded that the young men were skilled, strong and had the ability to do the job identified as their own. This was also the same case why they identified the tasks which requires less work as that of a women's task. In regards to selling the nuts, the males saw the women as having the right personality, and that they are honest and would bring the money back for the family.

The females from Bitaama identified in Table 12 that the married women was the main gender group involved in all tasks related to canarium marketing except harvesting by climbing, cracking and packing of the nuts which fell to males.

Tasks such as climbing the canarium trees required someone with skill and strength. The tasks identified as the females required patience, and efficiency to ensure that the task was completed thoroughly. Women also saw themselves as the main gender that had the

Table 10. Ranked response from the Kakalano female community comparing gender involvement for the canarium marketing activities.

Gender group	Harvesting (Climbing)	Harvesting (Gathering)	Carrying	Cracking	Shell & testa removal	Packing	Storing	Selling
Married Women	3	1	1	3	1	2	1	1
Young Women	3	2	2	4	2	3	2	3
Married Men	1	3	2	1	3	1	3	2
Young Men	2	4	1	2	4	2	4	4
Children	3	5	3	5	5	4	5	5

Table 11. Ranked response from the Kakalano male community comparing gender involvement in the different canarium nut marketing activities.

Gender group	Harvesting (Climbing)	Harvesting (Gathering)	Carrying	Cracking	Shell & testa removal	Packing	Storing	Selling
Married Women	3	1	No comparison made. Everyone carries the nuts	3	1	2	2	1
Young Women	3	2		4	2	4	3	1
Married Men	2	3		1	5	1	1	2
Young Men	1	4		2	3	3	4	3
Children	3	5		5	4	5	5	4

right personality to sell the product and they were trusted to bring the money back for the families needs.

Table 13 shows the response of males in terms of gender involvement in the canarium marketing activities. The males in the community said that harvesting by climbing and packing of the nuts was the job of the males, whereas the females were identified as the main gender groups behind all the other tasks. The males in the community saw carrying of the nuts as a job which is done by everyone.

Men are the main ones who climb trees in the Malaitan culture because they are not only strong and skilled at the job but their culture does not allow women to climb trees. Packing required someone skilled hence the males identified themselves as the main ones to carry out this task. All other tasks were seen as simple and specific to women.

DISCUSSION

The women's results in Kakalano (refer to Table 1) showed that their constraints focused on areas seen as women's duty such as the removal of the shell and testa and carrying of the nuts. On the other hand, women in Bitaama were more commercial oriented in their answers (refer to Tables 1 and 8.)

This contrast indicates the situation on both sides. From observations, women from Kakalano area were not dependent on canarium for an income. These women have gardens closer to their houses in comparison to

Table 12. Ranked response from the Bitaama female community comparing gender involvement in canarium marketing activities.

Gender group	Harvesting (Climbing)	Harvesting (Gathering)	Carrying	Cracking	Shell & testa removal	Packing	Storing	Selling
Married Women	3	1	1	2	1	2	1	1
Young Women	3	2	2	3	2	3	3	2
Married Men	2	4	3	1	4	1	2	3
Young Men	1	3	4	3	3	3	4	4
Children	3	4	5	4	5	3	5	5

Table 13. Ranked response from the Bitaama male community comparing gender involvement in canarium marketing activities.

<table>
<tr><th>Gender group</th><th>Harvesting (Climbing)</th><th>Harvesting (Gathering)</th><th>Carrying</th><th>Cracking</th><th>Shell & testa removal</th><th>Packing</th><th>Storing</th><th>Selling</th></tr>
<tr><td>Married Women</td><td>3</td><td>1</td><td rowspan="5">No comparison made. Everyone carries the nuts</td><td>3</td><td>1</td><td>3</td><td>1</td><td>1</td></tr>
<tr><td>Young Women</td><td>3</td><td>2</td><td>4</td><td>2</td><td>4</td><td>3</td><td>2</td></tr>
<tr><td>Married Men</td><td>2</td><td>3</td><td>1</td><td>3</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Young Men</td><td>1</td><td>4</td><td>2</td><td>4</td><td>2</td><td>4</td><td>4</td></tr>
<tr><td>Children</td><td>3</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
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women from Bitaama who have to walk several hours before reaching their gardens on the hilltops. Kakalano's land areas are also flatter in comparison to Bitaama areas. Women from Kakalano are able to make money from what they grow in their gardens such as slippery cabbage and sweet potato, whereas women from Bitaama are heavily dependent on a cash economy to support them. Most of the fertile soils close to their homes have been covered with cash crops thus, leaving those areas on the hill tops to be planted with their gardens for their day to day living (Sechrest, 2008).

Men's results from both Kakalano (refer to Table 3) and Bitaama (refer to Table 5) were commercial oriented. To the men from both areas, canarium was no longer considered a cash crop due to the lack of markets available as well as the low prices received (refer to Tables 7 and 9). The males' attention was more focused on cash crops such as cocoa and copra which are currently the main revenue earners for the rural areas in Malaita Province (Jones *et al.,* 1988; Sechrest, 2008). In fact, the male community from Kakalano mentioned that canarium needs to become a commercial commodity such as cocoa and copra before they will take an interest in it (refer to Table 1).

Although the males from both areas mentioned that carrying the nuts was the responsibility of all genders (refer to Tables 11 and 13) the females from Kakalano identified this task as the major constraint they faced due to the heavy weight (refer to Table 1). This is because the trees are planted far away from the village. The nuts are heavy because the mesocarp is intact and the roads are not good. When women decide to harvest the canarium trees, they would need to get up early in the morning and start their two-three hour walk to the bush. They would harvest the canarium by gathering (Nevenimo *et al.,* 2008) if there was no one to climb. They would then carry back around a 40kg weight of canarium nuts with the mesocarp intact through the bush and back to the village for further processing. In Kakalano area, they would need to cross the river several times before reaching the place of harvest and take the same route back to the village. This would mean that if there was much rain, the rivers would be flooded and they would not be able to harvest the trees as the canarium season usually coincides with the wet season. This is why the women from Kakalano suggested to ask others for help to carry the canarium, or they could make houses in the bush to enable the canarium to be processed. This was done in the past (Pelomo, 1996) to enable them to only carry the kernels back to the village.

From observations, building houses in the bush for processing was a sound idea in the past due to the fact that everyone worked together on this. Nowadays, women who have become the leading processors in canarium would also need to take into account their other duties as mothers if this is to happen. Moreover, the distance that they travel to harvest the canarium nuts will reduce their productive capabilities.

Cracking of the nuts was seen to be another problem (Nevenimo *et al.,* 2007) for the women in Kakalano due to their inexperience with this task (refer to Table 1). This task was seen in the past to be the male's job (Pelomo *et al.*, 1996) but, due to the current situation with the lack of markets for the canarium nuts, men have ceased to be involved much with the canarium process leaving the task for women to do. Hence, women have taken up a task which was seen to be the men's duty and they are inexperienced, making it difficult for them. An experienced and strong person would hit the nut once and it would crack (Pelomo, 1996), an inexperienced person would take several shots before the mesocarp and shell would break, hence increasing the chances of hitting ones finger would be greater. Women from Kakalano mentioned in their possible solutions that they could use many people to crack the nuts or they could use a machine to crack the nuts (refer to Table 2). The same solutions were identified by the males in the Bitaama community.

In Kakalano, the women also saw the removal of shell and testa as another problem. This was due to the fact that there are few women available to do the work and the number of fruits harvested at one time is great (refer to Table 1). This is why the women have suggested that either everyone work together or they could use machines to clean the nut (refer to Table 2). Similar comments were made by farmers in Papua New Guinea during a survey carried out there by (Nevenimo *et al*., 2008).

The community members from both areas saw that the main reasons behind the lack of markets for them was that the SIG and NGOs have not helped them find markets. They have also experienced problems with the middlemen being dishonest with them and refusing to release information on the sales of the canarium nuts (refer to Table 4). Developing a good relationship between the supplier and the middleman is a vital point as this causes an inconsistency in the supply of the nuts if one party does not trust the other (Long Wah, 1996). The women suggested that NGOs and SIG need to look at the marketing side of canarium to assist the women. The women also suggested that being able to process the canarium into other products such as canarium cooking oil would help them target other potential markets for their product. This would also solve their second problem of everyone producing the same product during the canarium season. The women in Bitaama have very limited knowledge on how to process the canarium into any other product as they are only aware of roasting them in bamboos or roasting and selling the kernels as they are. This is why they suggested that they needed training to enable them to process the canarium into other products (refer to Tables 4 and 8). Due to the problem of low prices, the makes in the community saw it was better to eat the nuts and not worry too much about selling them (refer to Table 9).

The third major problem faced by the women in Bitaama (refer to Table 8) was that it was expensive to feed those who came to help process the canarium nuts. This was also listed by the Kakalano women as a constraint they faced (refer to Table 1). The female community in Bitaama said that the main reason for this problem was that they had to process the canarium on time otherwise the kernels would deteriorate. They also needed to process many nuts in order to be able to make a reasonable income from it. As a solution to this problem, they mentioned that they needed to do this as individuals if they are to save on the cost of feeding everyone. Furthermore, they suggested that instead of feeding those who came to do the work, they could share the bamboos with them (refer to Table 4 and Table 8). Hence, this would mean a reduction in the number of bamboos that they had to sell or use for food for their family as it has become a main protein source (Pelomo, 1994; Nevenimo *et al.* 2007; Bunt & Leaky, 2008).

Both genders in both communities mentioned that cracking the nuts was a problem, with some stating it as the biggest problem faced. They have all mentioned the need for nut crackers or machines which can help them process the nuts to make the work faster, which will allow them to process more nuts if they are to receive a reasonable income for them and to reduce the problem of hitting their fingers (refer to Tables 1, 6, 8 and 9). Interestingly though, a processor in Vanuatu found that cracking the nuts by hand was more efficient compared to a mechanical nut cracker (Long Wah, 1996). Furthermore, comercia-lisation trials carried out by CEMA also indicated that an experienced person can crack the nuts faster compared to a mechanical nut cracker (Pelomo, 1996).

There were two main ways of harvesting canarium nuts in Malaita. By climbing the trees or by gathering the nuts off the ground. These were also the same methods mentioned by Nevenimo *et al.* (2008) during the research carried out in PNG. In both Kakalano and Bitaama, all members in the community ranked the young men as the main gender group involved in climbing the canarium trees. Reasons given are the young men are not only strong and skilled at doing this job, but it is not allowed “taboo” in their culture for a woman to climb a tree (Pelomo, 1996). For gathering the nuts, the communities gave similar responses in that the married women are the leading gender group in this activity. Reasons given by men and the women from Kakalano were similar in that it was not only an easy job, but it was the woman’s duty to gather the nuts. Females from the Bitaama area on the other hand said that women do this job not only willingly but thoroughly. The biggest problem seen in gathering the nuts was the number of ants present on the fruits and branches which fell from the tree. This can make collection of the nut very unpleasant.

Carrying of the nuts was seen by the males from both communities as the job of the whole family whereas women from Bitaama on the other hand saw the married women as the main gender group involved in this task, whereas women from Kakalano saw themselves and the married men's group as the main genders in this role. The women from Bitaama said that the women were strong to do this task and they knew how to carry large bags using a rope. They mentioned the fact that the men would be too tired from climbing the trees hence the task of carrying the nuts would be up to them. Similarly, women from Kakalano thought the same idea (Tables 1 and 6). They saw the men as the main person in organising all the harvesting and carrying activities and their job as the women was to carry the nuts as they have the strength for this.

A task such as the cracking of the nuts was fell on the married men due to their experience at this task and their strength. Tasks such as shell and testa removal were seen by the members from all the communities to be the married women's task. However, the reasons given by the males and females from the communities differed with the males looking at the ease and simplicity of the task whereas the women saw it as a task that needed willingness to do and thoroughness to ensure that the kernel is cleaned properly.

Married men were seen by all members of the communities to be the main gender group involved in the storage of the canarium. This involves packing the kernels into bamboos which requires a skill as the bamboo needs to be filled properly to ensure that the kernels are tightly packed.

Selling was seen by all members of both communities as the married women's job closely assisted by either the married men or the young girls. The main reason why women took the lead in selling the product was because they are patient and have acquired the skill to sell the product. What was interesting to note was the fact that the males in the community saw the women as being honest in selling the product. Women would bring back the money to be used on the family's needs.

The young men and young women were seen to closely assist either the married men or the married women in all the tasks specified except for selling the canarium where some of the communities saw these gender groups as irresponsible when it came to selling the product. Children on the other hand were discouraged from helping out in most of the activities mainly because they have a habit of eating the canarium kernels (refer to Tables 10, 11, 12 and 13).

The main constraint faced during the PRA was the lack of communication from the women from Kakalano area. It took much encouragement for them to voice their concerns and problems with regards to the canarium nut. Furthermore, it was difficult to arrange a time for the women to be free to carry the PRA out as the women were usually busy either with their family's day to day running or with their gardens. This was the reason why the communities needed to be compensated with money and food for the time that they lost with their daily money making activities.

CONCLUSION AND RECOMMENDATIONS

In the past the processing and all marketing activities of canarium was family oriented due to the importance of canarium nut in the traditional economy. However, with the introduction of the cash economy, men in the area have moved towards cash crops with canarium eventually being left out due to the lack of markets, the low prices received for the products and the hard work required to process the nuts. Therefore, processing of the nuts was now seen to be left for women to earn an income for the family, or for home consumption.

This has given rise to married women facing many challenges in relation to processing the canarium. This includes gathering the nuts, the distance travelled to carry the nuts, hence reducing their production capabilities. Cracking the nuts as well as cleaning the kernels were also constraints faced. Furthermore, the women have mentioned the lack of skills they had in processing the canarium into other products apart from the ones that they are used to. If they could process the nuts into other products, it would help them earn a better income. Women have taken on the leading role in areas which have been clearly defined in the past as the men's duty. This has led them to find problems with these tasks due to their inexperience.

Both the males and females in the communities also mentioned the need for processing machines to crack and clean the nut. This would enable them to process more canarium nuts and save on the expense of feeding those who come to help with the processing.

From these results, it can be recommended that SIG, NGOs and Aid Donors need to provide support to the local communities in Malaita in terms of research, training, resources but more importantly market outlets for the canarium products currently being produced by the local communities.

This will encourage women to process more nuts as individuals or as groups. Furthermore, this would encourage the males in the community to take an interest in canarium as a commercial crop which would mean men would be able to share in the processing of the nut reducing the work load for the local women. If both the males and the females in the community could work together they would be able to process more nuts to increase its supply.

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