



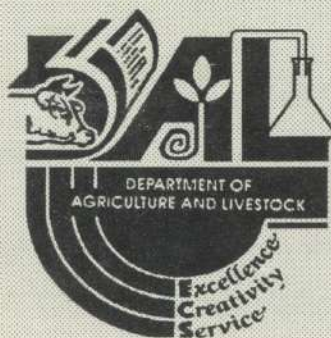
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PHYSICO-CHEMICAL AND ORGANOLEPTIC PROPERTIES OF TRADITIONAL RICE VARIETIES FROM FINSCHAFEN

B. Amoa,¹ S. Fuba,¹ R.Y. Nigo¹ and R. Chris Dekuku²

ABSTRACT

Studies of the physico-chemical characteristics of six traditional rice varieties grown in the Finschafen area of Papua New Guinea, revealed significant differences in the physical characteristics. All the varieties had grain of medium shape and size and soft gel consistency. They belonged to the intermediate amylose group. The high final gelatinization types (Qangwaneng, Sunlong white and Sunlong red) took longer time to cook and absorbed more water than the high-intermediate (Sikong and Brown) and the intermediate (Padibengbong) types. There were significant differences in the cohesiveness, texture and flavour of the varieties. Overall, Brown possessed sensory qualities closest to those of Trukai, a commercial modern variety, while Sunlong red was the least liked. The relatively low protein content of Sikong could be of nutritional concern.

Keywords: Traditional Finschafen rice, physical, chemical, organoleptic evaluation.

INTRODUCTION

Rice (*Oryza sativa* L.) was introduced in Papua New Guinea (PNG) about one hundred years ago. Time, location and climate selected what is called "local germplasm". The traditional rice growing areas are Finschafen in the Morobe Province, Maprik in the Sepik Province and Bereina in the Central Province. (Wohuinangu and Kap 1982). Even though rice is a very important staple crop, the areas sown to rice are very small. The traditional rice varieties have poor yield and are also said to have low milling quality. The country depends almost entirely on imported rice to meet consumers demand. Intensive research is currently being undertaken to identify agronomically superior varieties. The trials are being carried out with modern varieties. It is generally accepted that the rapid spread of high yielding modern varieties are leading to the disappearance of the unimproved indigenous varieties and wild strains. These unimproved varieties are irreplaceable germplasm which could be used in breeding programs.

There is a need to collect local Papua New Guinea rice germplasm, evaluate them for their quality characteristics and recommend novel types if any for

crosses for future use. This is the first work on the physico-chemical and organoleptic properties of Papua New Guinea's traditional rice varieties.

METHODOLOGY

Samples of six varieties of paddy rice (Sikong, Qangwaneng, Sunlong red, Sunlong white, Brown and Padibengbong) were obtained from local farmers in the Finschafen area of Morobe Province. These varieties are grown by the Finschafen farmers mainly for home consumption and are rarely sold. Sunlong red and Sunlong white are different from Sunlong, an improved modern variety, not grown in PNG but imported solely for direct sale in the commercial outlets. Milled Trukai rice, also an imported commercial variety was purchased from a local supermarket in Lae and was used in the organoleptic tests only. The paddy samples were dehulled (Satake Rice Mill JHU), milled (Satake Rice Testing Mill) and stored at 4°C until tested for physico-chemical properties. Grain length, width and average weight of 100 healthy kernels were measured with a travelling microscope and by weighing (Khan and Reddy 1991).

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Moisture, ash, crude fat and protein content were estimated by methods of AOAC (Helrich 1990). Amylose content was determined by the simplified method of Juliano (1971) with some modification. 10 ml of 0.1N HCl were used instead of 2 ml acetic acid. Gel consistency and alkaline digestion gelatinization temperatures were estimated by the method of Cagampang *et al.* (1973) and Little *et al.* (1958) respectively. Water uptake was determined by the method of Myklestad *et al.* (1968).

Flavour, texture and grain separation of the warm, cooked rice samples were determined according to Lamond (1977). Eleven trained panelists were used. Cooking times were previously established by the method of Perez *et al.* (191993). 0.1% salt was used.

The results were analysed for their variance and Duncan's Multiple Range Test was used to detect statistical differences using IRRISTAT 93 soft ware.

RESULTS

There were significant variety differences in the dimensions of the rice grain, with the length to width ratio ranging from 2.1 to 2.7 (Table 1). All the varieties were classified as medium size and medium shape in accordance with Juliano (1993).

The ash and crude fat did not vary but protein content differed significantly. The means for protein content ranged from 5 to 8.1% (Table 1). Sikong variety had the lowest protein content. The differences in protein content could be important in ensuring adequate protein intake from a rice staple. The amylose content differed significantly but not greatly with the values ranging from 23.7 to 25.1% (Table 1), thus classifying all the samples as of intermediate amylose type (Juliano 1979). The alkali spread values showed that all the varieties were fairly resistant to alkali digestion (2 to 3.5 for spreading and 1 to 2 for clearing), placing them in the intermediate to high

Table 1. Physico-chemical properties of traditional rice from Finschafen.

Property	Variety					
	Sikong	Qangwaneng	Sunlong red	Sunlong white	Brown	Padibengbeng
Ash % ¹	0.25 a	0.17 a	0.24 a	0.21 a	0.13 a	0.26 a
Crude fat % ¹	0.23 a	0.63 a	0.61 a	0.64 a	0.42 a	0.41 a
Crude protein % ¹	5.00 a	6.85 bc	6.30 b	7.40 bc	8.11 c	7.35 bc
Amylose % ¹	24.3 ab	23.7 a	24.0 a	24.8 bc	25.1 c	24.4 bc
Alkali spread value	2.5 a	2.3 a	2.3 a	2.0 a	3.0 a	3.5 a
Alkali clearing value	1.0 a	2.0 a	1.3 a	1.5 a	1.5 a	1.5 a
Gel consistency (mm)	100 a	100 a	100 a	100 a	100 a	90.5 a
Length/width ratio	2.1 a	2.5 b	2.5 b	2.0 a	2.7 c	2.1 a
100-grain weight (g)	20.1 b	23.2 d	18.4 a	20.4 bc	22.6 c	23.3 d

Note: 1. - Dry Basis

Means with the same letter in a row are not significantly different ($P < 0.05$).

Table 2. Classification of traditional rice from Finschafen.

	Variety					
Property	Sikong	Qangwaneng	Sunlong red	Sunlong white	Brown	Padibengbeng
Amylose Type	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Final GT Type	High-Intermediate	High	High	High	High-Intermediate	Intermediate
Gel Type	Soft	Soft	Soft	Soft	Soft	Soft
Shape	Medium	Medium	Medium	Medium	Medium	Medium
Size	Medium	Medium	Medium	Medium	Medium	Medium

Table 3. Cooking and eating properties of traditional rice from Finschafen.

	Variety						
Property	Sikong	Qangwaneng	Sunlong red	Sunlong white	Brown	Padibengbeng	Trukai ²
Cooking time (min)	13.5 a	16.0 b	14.0 ab	14.0 ab	13.5 a	13.0 a	-
Water uptake g H ₂ O/g rice	2.50 a	2.60 a	2.53 a	2.74 a	2.30 a	2.20 a	-
Grain separation ¹	3.2 b	3.5 b	2.0 a	4.7 c	5.0 c	3.6 b	3.8 b
Texture ¹	4.2 ab	5.1 abc	3.9 a	5.2 abc	4.9 abc	5.7 bc	6.3 c
Flavour ¹	3.6 ab	4.3 abc	3.4 a	4.6 bcd	5.1 cd	4.6 bcd	5.5 d

¹ Based on a scale of 1-7: 7 = best score 1 = worst score.

Means with same letters in a row are not significantly different ($P < 0.05$)

² Cooking time and water uptake not determined. Rice cooked using time from an unpublished report of Amoa *et al.*

final gelatinization temperature groups (Table 2), in accordance with the classification by Juliano (1973). All the varieties had a gel consistency value of 100 mm with the exception of Padibengbeng which had a value of 90.5 mm. All the varieties therefore belong to the soft gel type (Cagampang *et al.* 1973) (Table 2), meaning that the cooked rice will not set to a hard gel. Soft to medium gel consistency is preferred to hard gel consistency in rice (Juliano 1993). While significant variation in the cooking time was observed among the varieties, water uptake did not vary significantly (Table 3). Comparing Tables 2 and 3, Padibengbeng, an intermediate gelatinization type, took the shortest time to cook (13 mins), while Qangwaneng, a high gelatinization type, recorded the highest cooking time (16 mins). The rest of the varieties with either high or high-intermediate gelatinization temperatures had cooking times in between 13 and 16 mins. The results are in accordance with those of Juliano and Perez (1983), who stated that rice with higher gelatinization temperatures required more time to cook than those with low gelatinization temperatures.

The organoleptic scores for grain separation, texture and flavor are summarized in Table 3. There were significant differences between varieties in all the attributes tested. With regards to grain separation, varieties Trukai, Padibengbeng, Qangwaneng and Sikong were equally liked. Varieties Sunlong white and Brown were the most liked. Panelists disliked the cohesiveness of Sunlong red. There were no significant differences in the texture of varieties Qangwaneng, Sunlong white, Brown, Padibengbeng and Trukai. Sikong and Sunlong red differed significantly from the rest of the traditional rice varieties with the texture of Sunlong red being the least liked. Trukai was the most liked. Sunlong white, Brown, Padibengbeng and Trukai possessed the most desirable rice flavor. The flavour of Sikong and Qangwaneng were intermediate, while once again that of Sunlong red was found to be poor. Over all, Sunlong red was the least liked with regards to all the characteristics tested. Trukai, the imported variety was the dominant rice with the most desirable sensory characteristics.

DISCUSSION

Quality in rice encompasses storage, milling and market quality, cooking and eating quality and nutritive quality of the grain. Papua New Guineans prefer medium to long grain rice, that remains reasonably soft when cooked. The cohesiveness of the cooked

grain should be low. Grain size, shape and appearance largely determine the market acceptability of milled rice. These physical properties are among the first characteristics evaluated in any rice breeding program. All the Finschafen traditional rice varieties were of medium shape and size. Both long and medium grained modern rice varieties are sold on the market in Papua New Guinea with the long grain rice fetching a higher price than the medium grain.

It is possible to translate consumer preference for cooking quality into measurable chemical properties. Cooking quality depends on a number of characteristics such as the amylose content, gel consistency, grain elongation and aroma. The cooking of rice results in the swelling of the starch granules in the endosperm. Cooking and eating characteristics are therefore largely determined by the properties of the starch that make up 90% of milled rice. It has been shown that amylose content of the rice starch is the major eating quality factor, and is thus used in rice breeding studies. It correlates directly with volume expansion and water absorption during cooking and hardness of the cooked rice (Juliano 1985). The higher the proportion of amylose, the greater is the tendency to cook dry and fluffy. None of the Finschafen rice varieties were of the waxy or glutinous type (amylose content < 7%). The 23.7 to 25.1% amylose values obtained put all of them in the intermediate amylose group (amylose content 20-25%). Their cooking characteristics would therefore seem to be similar to those of Sunlong, an imported commercial variety with similar amylose content, as opposed to those of Trukai, an imported variety, but of the low amylose type (7-20%) (unpublished report of Amoa 1995 *et al.*).

Gelatinization temperature (GT) of starch granules refers to the water temperature at which at least 90% of the starch granules have gelatinized or swollen irreversibly in hot water and is indexed in the rice breeding program by the alkali spreading value (Little *et al.* 1958). Rice with low GT disintegrates completely, whereas rice with intermediate GT shows only partial disintegration. Rice with high GT remains largely unaffected in the alkali solution (Khush *et al.* 1979). The alkali spread values of the Finschafen rice place them in the intermediate to high gelatinization temperature gradient from the surface to the core of the grain. The cooking times recorded for the traditional Finschafen rice varieties seem to follow this trend (Table 3). Because GT correlates directly with cooking time, a low GT favours fuel conservation, provided eating quality is not adversely affected. The GT and the cooking times of the Finschafen varieties seem to contrast from those of Trukai which

has a low GT (unpublished report of Amoa 1995 et al.).

Varieties with the same amylose content may have different consumer acceptabilities. This is because within the same amylose group, varieties with softer gel consistency are preferred and cooked rice is more tender. Padibengbeng seems to be an exception in that even though it had the lowest gel consistency value, its texture was the most preferred after Trukai.

CONCLUSION

All the six varieties of traditional rice grown in the Finchafen area showed physico-chemical characteristics for rice in the medium grained, intermediate amylose classification group. None of them was aromatic. Their organoleptic characteristics were also inferior to those of Trukai, with Trukai being preferred in most of the organoleptic characteristics. Over all, Brown possessed organoleptic characteristics closest to Trukai while Sunlong red was the least liked. Despite the seemingly inferior organoleptic qualities, these traditional rice have been growing in the area for years and are likely to have developed resistance to various diseases and other adverse environmental conditions. They could be cross-bred into modern varieties to produce varieties that are consumer acceptable.

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A NEW MUTATION OF TARO (*COLOCASIA ESCULENTA*) OBSERVED AT BUBIA AGRICULTURAL RESEARCH CENTRE

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ABSTRACT

An unusual mutant of taro (*Colocasia esculenta*) was discovered in the cycle-2 population of the recurrent selection programme at the Buba Agricultural Research Centre, Papua New Guinea. The mutant plant developed a thin elongated stem (about 95 cm long). The stem had several nodes, each carrying one leaf. The leaf size decreased with distance from the corm top. The stem was filled with soft, aerated spongy tissue. Side stems were thin and relatively long, growing from lower nodes of the main stem and the corm top. Their structure was similar to that of the main stem. The plant had a normal corm. It was susceptible to the leaf blight and was not flowering.

Key words: Taro, *Colocasia esculenta*, breeding, population variability, mutation.

INTRODUCTION

Taro (*Colocasia esculenta* (L.) Schott) belongs to the monocotyledonous family Araceae or the aroids. The aroids are a large and a very variable family with about 110 genera and more than 2,500 species (Bown 1988). The differences among some of the species (e.g. *Acorus calamus*, *Amorphophallus campanulatus*, *Colocasia esculenta*, *Pothos scadens* and *Monstera* spp.) are large.

The majority of the aroids are climbers and epiphytes of tropical rainforests. Many of the species are associated with humid or aquatic conditions. The most common characteristic of the aroid species is the spadix - spathe type of inflorescence. The small individual flowers can be bisexual or unisexual. If the flowers are unisexual, the spadix is divided into two parts (male and female) which are separated by a sterile tissue.

C. esculenta plants are herbaceous, with cylindrical starchy corms and relatively large peltate leaves borne on thick petioles. The height of the plants generally varies from 0.5 to 1.5 m. It is a very variable species with numerous forms and cultivars. They can be differentiated according to the shape, size and

pigmentation of their corms, pigmentation and size of the leaves, plant height, floral characteristics, eating quality and several other characteristics.

The variability of the genetically controlled characteristics is extremely important for plant breeding. Natural genetic variation can be augmented through hybridisation, self-pollination, biotechnological methods or mutagenesis.

Taro varieties are clonal varieties and are propagated vegetatively. In natural conditions propagation by seed is very rare, although, it is essential for the evolution of the crop. The majority of the varieties are highly heterozygous. The genetic recombination between two randomly chosen clones generally results in high variability of the first offspring generation. Each of the superior genotypes from the segregating offspring generation can represent a new potential variety. Stabilisation of the variety by breeding for genetic homozygosity is not needed because of the vegetative propagation of the species. When mutations are not taken into consideration, one taro cultivar (one clone) consists of only one genotype.

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The Papua New Guinea taro improvement programme

The Papua New Guinea (PNG) Taro Improvement Programme started in 1993. The main objectives are the improvement of yield, eating quality, resistance to pests and diseases, earliness and adaptability to specific environmental conditions. It is based on the population approach, aiming at the improvement of the average performance of a population. The process is divided into cycles and each cycle consists of three steps: (a) development of a population, (b) evaluation of the individuals in the population and (c) selection of the superior individuals for crossing to form a new population.

The genetic sources used for forming the basic population (the population from which the breeding process started) were wild genotypes from PNG and South-East Asia, hybrids from a previous breeding programme in the Solomon Islands and cultivated varieties from PNG and other Pacific countries. Recombinations between these genetic materials resulted in a large range of variation. This variation could be considered to be a result of genetic segregation, mutagenesis and environmental effects.

The number of genetic recombinations per cycle generally exceeds 500 and the number of individuals germinated in each cycle averages more than 150,000. The time period needed to complete one cycle depends mainly on the evaluation procedure of a population and varies from 7 months to more than a year.

Genetic variability and rare genotypes of taro

The populations used in the recurrent selection of taro are generally characterised by high genetic variation. The average genetic variation within a population remains more-or-less unchanged from one cycle to another. Some of the traits, however, are reduced in frequency due to strict artificial selection. These are mainly undesired traits (small corm size, high % of oxalate, susceptibility to some of the diseases). A general decrease in genetic variation can result in genetic erosion, where some of the important genes can be lost from the population.

The taro breeders at Bubia continually follow the changes within populations (Ivancic *et al.* 1995, Ivancic 1995). These changes can be studied through an analysis of variance within each cycle or by analysing the genotypic and/or phenotypic

frequencies within populations.

The analysis of genotypic frequencies is usually very simple for rare traits which are controlled by one or a few major genes (genes with strong effects) and which can be easily detected.

Rare genotypes or plants carrying rare genetically controlled characteristics appear constantly. The majority are probably the result of genetic segregation but some are the result of mutagenesis. Within the PNG taro breeding populations several rare genotypes have been determined such as plants with extremely dark purple leaf laminae, double spathe, fasciated male part of the spadix, double and multiple inflorescences, blue pollen, red and black seed, corms above ground, extremely elongated type of corm and semi-albino plants. Rare types of taro inflorescences were described by Ivancic (1995). The most atypical characteristic found so far is the plant type with an elongated stem (Fig. 1).

Elongated stem

A taro plant with an elongated stem was found in July 1995 in one of the sub-populations (U 1/95) of the second cycle of the recurrent selection programme at the Bubia Agricultural Research Centre. The stem of the plant was characterised by thin, green and extremely elongated internodes filled with spongy, colorless tissue. The height was about 95 cm. The internodes near the base were relatively short. As the stem elongated, the internodes became longer, but near the tip they became shorter again (Fig. 1).

The leaves (petioles and laminae) arose from the nodes and were highly susceptible to leaf blight (*Phytophthora colocasiae*). The size of the leaves decreased with distance from the corm top. Side stems emerged from auxiliary buds on the corm top and from the lower nodes (leaf axils) of the elongated stem(s). Side stems were elongated in more-or-less the same way as the main stem.

The elongation of nodes of the mutant plant are different from the elongation of the corm of some 'normal' genotypes (Fig. 3). Several wild genotypes and cultivated varieties of taro produce very long corms (similar to *Alocasia* spp.). This elongation is associated with the general expansion of the corm and there is no formation of a 'true' stem.

The mutant plant had a normal corm and did not flower. Vegetative multiplication by cuttings, which were very similar to stolons (runners), was not

Figure 1. A drawing of a taro plant with an elongated stem (a), and a normal plant (b).

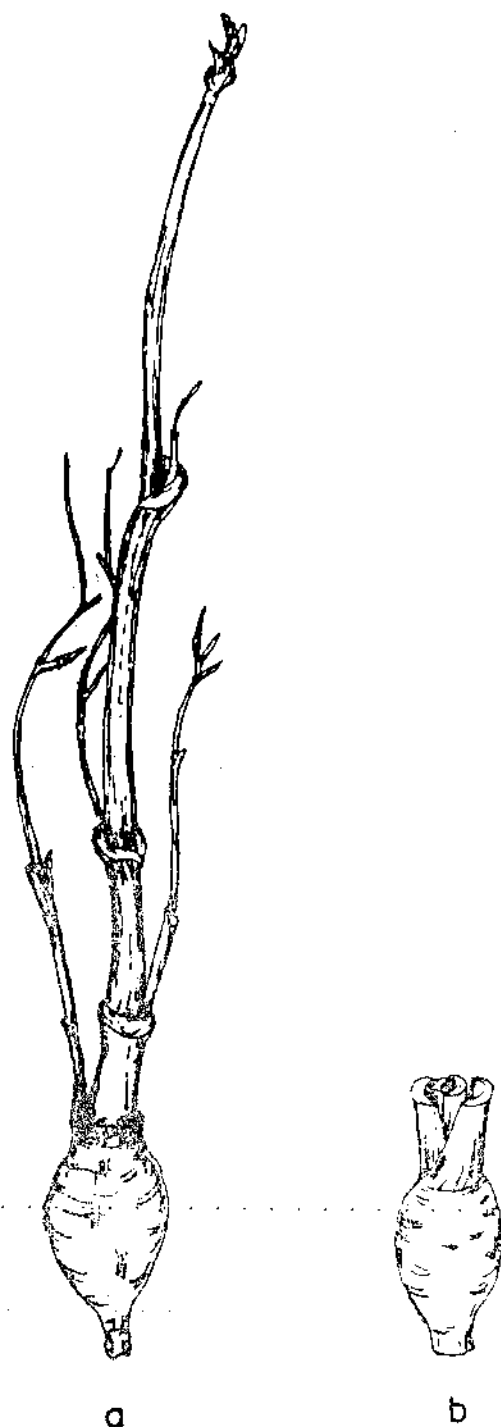
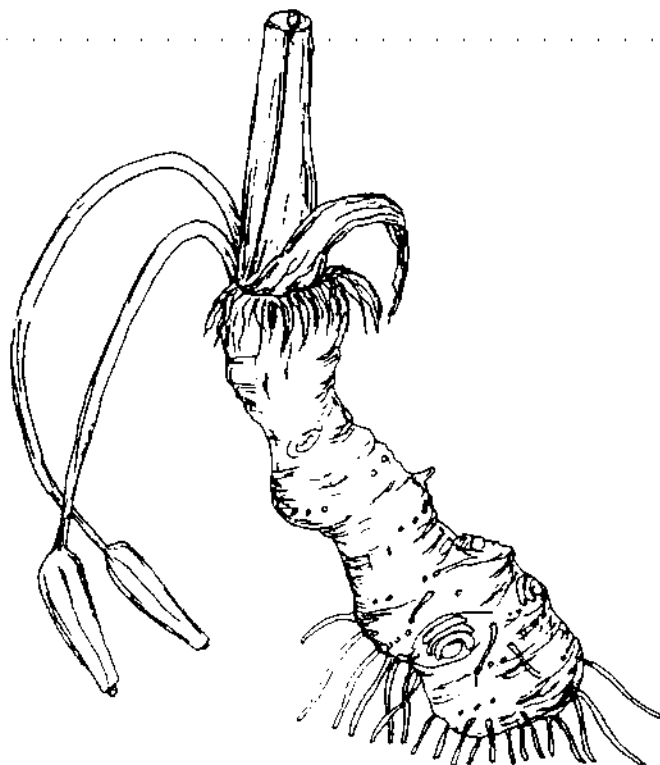


Figure 2. An elongated corm of a wild taro genotype.



successful. The nodes of the main elongated stem and side stems did not produce a normal root system. It is possible that the plant with the elongation of the stem(s) is expressing a lethal character or that stem elongation is genetically linked with it.

Conclusion

Taro breeding work in Papua New Guinea is based on a large scale programme of genetic recombinations and has resulted in enormous genetic variation within the breeding populations. In such populations it was possible to identify genotypes which could not be found in natural populations. The plant with the elongated stem is one example. It is difficult to say whether it is the direct result of mutagenesis, the result of a specific genetic combination or both.

Elongation of the taro stem is presently not an important trait for agriculture. However, it indicates that the taro plant may have completely different forms, resembling plants with indeterminate growth of the stem and creeping or climbing habit. In the future, genotypes with such characteristics could be

used as a genetic source for breeding which would be able to grow in deeper swamps or along rivers with variable water level. These environments represent an additional potential area for taro production.

The elongated stem may also be of interest in evolutionary studies of the Araceae family since it resembles the stem of creeping and climbing aroids.

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THE CRAZY ANT, *ANOPOLEPIS LONGIPES* (JERDON) (HYMENOPTERA: FORMICIDAE) ON COCONUT PALMS IN NEW GUINEA.

G. R. Young¹

ABSTRACT

Nests of the crazy ant *Anoplolepis longipes*, in the crowns of coconut palms, contained all castes and life stages except queen brood. The ant was attracted to the male flowers on the coconut inflorescence rather than honeydew-producers. Workers fed on nectar from male flowers and sap extruded from scars resulting from recently shed male flowers. Workers foraged on the inflorescence over 24 hours with maximum foraging activity at temperatures of 27.3 and 30.3° C.

Key words: *Anoplolepis longipes*, Nesting, Carbohydrate source, Foraging behaviour on coconut palms.

INTRODUCTION

The crazy ant, *Anoplolepis longipes* (Jerdon) is widespread throughout the tropics (Way & Khoo 1992). In Papua New Guinea (PNG) *A. longipes* is particularly prevalent in disturbed habitats (Wilson and Taylor 1967).

The ant is frequently a pest of plantation crops because it increases the numbers of sap feeding insects, for example the coccids; *Ceroplastes rubens* Maskell, on citrus and cinnaom, and *Coccus celatus* DeLotto, on coffee (Haines and Haines 1978 a, Williams 1982). Copious amounts of honeydew, produced by these sap-feeders, subsequently lead to the growth of sooty mould on the leaves. Additionally, the ant often encourages pest species indirectly by harassing predators and parasites of the pest (Young 1982, 1996).

In some circumstances, *A. longipes* is regarded as beneficial because it disrupts the feeding and egg laying behaviour of pest species (Room & Smith, 1975; Young, 1982).

Premature nutfall on coconut palms infested with *A. longipes* has been recorded from a number of localities in PNG (Young 1996). In one instance, it was found that premature nutfall was due to attacks by the coconut spathe moth, *Tirathaba rufivena* Walker (Lepidoptera: Pyralidae). Moth populations were high on palms infested with *A. longipes* and low on

palms without the ant. It was suspected that *A. longipes* disturbed the foraging behaviour of moth predators.

A. longipes is predominantly a ground nesting species and on heavy or relatively impervious soils the majority of nesting sites are found under fallen vegetation and leaf litter (Haines & Haines 1978 b; Young 1996). It has been presumed that the presence of honeydew producing insects attract the ant to the coconut palm (Way 1953; Greenslade, 1971; Haines & Haines 1978 b). However, I had marked large numbers of *A. longipes* workers on coconut inflorescences (unpublished data). The coconut palm produces a branched inflorescence. Each branch carries the more numerous male flowers apically and the female flowers on the basal part. Male flowers open progressively from the apical end of each branch over a period of 15 days. For this research I decided to investigate if honeydew-producers were attracting *A. longipes* to palms or whether the attraction was the inflorescence.

MATERIALS AND METHODS

Observations were made on palms infested with crazy ants at Maralumi Estates, Markham valley, PNG, over a 17 month period from November 1976 to March 1978. Each month five palms were climbed and the nests in the crowns were examined for the

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presence or absence of various castes and life stages of *A. longipes*. Additionally, the palms were searched for the presence of honeydew producing insects and samples were returned to the laboratory for identification.

In order to determine whether *A. longipes* was obtaining carbohydrate from honeydew-producers or some other source, three healthy palms were trunk injected with 12 g a.i. of monocrotophos to eliminate sap feeding insects. Three healthy palms were selected as controls. Observations on the ant and honeydew-producers were made over the succeeding three weeks.

The foraging activity of *A. longipes*, on coconut inflorescences, was recorded over a 24 hour period. Three palms were selected, each with an inflorescence which had emerged within the previous 48 hours. A wet and dry bulb thermometer was placed in a sheltered position close to each inflorescence. Every two hours an observer climbed the palm and made counts of the numbers of workers foraging on the inflorescence over a three minute period. Additionally, wet and dry bulb readings were recorded for each palm.

RESULTS

Ant nests on palms were located in the crowns or amongst the roots above soil level. Nests in crowns were either in the axils of palm fronds or between the inner spathe and the base of the peduncle of dead inflorescences, as described by Way (1953). Throughout the 17 month period, the crown nests contained all castes and life stages with the exception of queen larvae and pupae.

Crazy ants were observed foraging on palms throughout the day and night. Workers constantly trailed up and down the trunk except during high winds, very high temperatures or heavy rain. The gasters of some workers, trailing down the trunk, were often distended, suggesting that the ants had been feeding on liquid. There was always a small number of workers foraging on the fronds, however most workers were congregated on recently emerged inflorescences. Exudate from the stigma of female flowers was attractive to the ant, as described by Corbett (1932). However, the main attraction was the male flower. Male flowers were observed to open early in the morning and to have fallen by late afternoon. Workers were observed feeding on nectar oozing from the bases of unopened male flowers and inside open flowers, as well as sap extruded from

scars resulting from recently shed flowers. When all the male flowers had fallen, and the resulting scars had healed, the inflorescence was no longer attractive to the ant.

Three species of honeydew - producers were tended by *A. longipes* on palms. *Palmicultor browni* Williams (Hemiptera: Coccidae) was the most common, being located in the axils of fronds and in the spear of the palm. *Ceraphis lataniae* Boisduval (Hemiptera: Aphidae) and *Aleurodicus destructor* Mackie (Hemiptera: Aleyrodidae) occurred on the undersides of leaflets. There was little sooty mould present, indicating that populations of homopterans were low in palms infested with *A. longipes*.

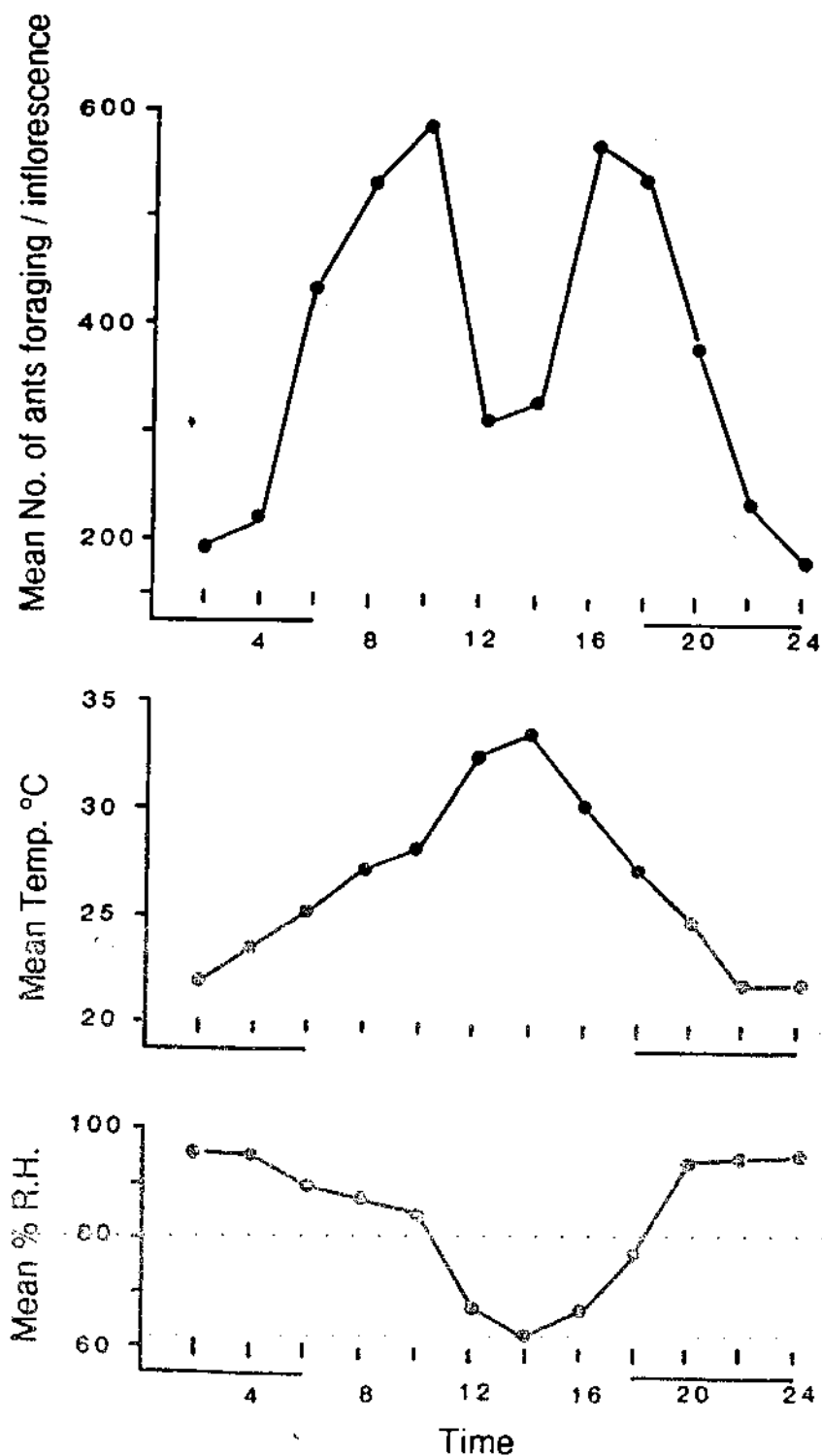
Prior to trunk injection it was not possible to accurately estimate the numbers of homopterans on the trial palms, however all three species were present. Three weeks after the trunk injections, crazy ants continued to ascend and descend the palms. No live homopterans were found on two of the palms, while 3 *P. browni* were on the third palm. Homopteran cadavers were found on all injected palms, indicating the effectiveness of the monocrotophos treatment. Populations of the three species of honeydew-producers were present on the control palms throughout the observation period. The foraging behaviour of *A. longipes* on control palms did not appear to be different to that on trunk injected palms.

Workers foraged on the inflorescences throughout the 24 hour observation period (Fig. 1). Mean numbers of workers peaked between 0800 and 1000 hours, and again between 1600 and 1800 hours. Mean temperatures at 0600 and 1000 hours were 27.3 and 28.3°C respectively, while temperatures at 1600 and 1800 hours were 30.3 and 27.3°C. Peak foraging activity occurred at relative humidities ranging from 67 to 88 percent. During daylight the lowest numbers of workers were recorded at 1200 and 1400 hours, when temperatures were 32.6 and 33.6°C respectively. Numbers of workers were lowest from 2200 hours to 0400 hours, when temperatures ranged from 22.0 to 23.5°C and the relative humidity was greater than 95 percent. The foraging observations were repeated on two subsequent occasions and while the numbers of workers varied from the original observations, the pattern remained essentially the same.

DISCUSSION

The crown of the coconut palm possibly provides more stable nesting sites than under fallen vegetation and leaf litter on the ground. The absence of queen

Figure 1. Number of *A. longipes* workers foraging on coconut inflorescences over a 24 hour period.



larvae and pupae from crown nests is puzzling and may suggest the ant is unable to collect sufficient protein in the crown to sustain queen brood.

While the monocrotophos injections did not kill all the honeydew-producers on the injected palms, populations of honeydew-producers were sharply reduced by comparison with those on the control palms. Since the ant continued to forage on the injected palms, it is reasonable to conclude that nectar from male flowers, and sap resulting from the abscission of male flowers, was the most important source of carbohydrate for the ant on the Maralumi coconut palms. *A. longipes* colonies are continuous rather than discrete (Greenslade 1972, Haines & Haines 1978 b). As a result, carbohydrate from the inflorescence is probably taken by workers and distributed to ground nests some distance away. This would explain workers with distended gasters trailing down the trunk. The ready availability of carbohydrate from the inflorescence could provide an additional reason for the ant nesting in the crown.

Low populations of homopterans suggest that nectar and sap are quantitatively, and perhaps qualitatively, a better source of carbohydrate for the ant than honeydew. Alternatively, if *A. longipes* is of African origin as suggested by Way & Khoo (1992), the ant may not be adapted to the honeydew-producers found at Maralumi, since *P. browni* is native to New Guinea and the Solomon Islands, *A. destructor* to South East Asia and *C. lataniae* to Central America (Lever 1969, William and Watson 1988). However, Way (1953) found that *C. lataniae* was the main source of food for *A. longipes* on coconuts in East Africa. In the Solomon Islands, Greenslade (1971) observed that *A. longipes* was not as dependent on honeydew as other species of ant nesting in palms. Additionally, both Greenslade (1972) and Haines and Haines (1978b) state that *A. longipes* is essentially a scavenger, being dependent on protein collected on the ground. At Maralumi, the population density of *A. longipes* was high, and perhaps in this situation the ant has to utilize nectar and sap since it is unable to efficiently tend the homopterans present to supply-sufficient carbohydrate.

Workers foraged on the inflorescence continuously over the 24 hour period, with peak numbers foraging in the early morning and late afternoon. Maximum foraging activity occurred between 27.3 and 30.3°C, which is in broad agreement with the results of Haines and Haines (1978 b). The morning peak coincided with the maximum availability of nectar and the afternoon peak with the maximum availability of sap. Therefore the numbers of ants foraging may have

been the result of a combination of optimum temperatures and availability of food.

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EFFECT OF SHEEP MANURE AND PHOSPHORUS FERTILIZER ON POTATO AND SUCCEEDING MAIZE AND CASSAVA CROPS

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ABSTRACT

A trial was conducted at the Menifo Sheep Research Centre located in the Eastern Highlands to examine the responses of potato, maize and cassava to application of sheep manure and inorganic phosphorus (P). Potato, maize and cassava were grown sequentially after the application of sheep manure and P fertiliser. Potato tuber yield increased with increasing rates of sheep manure. When manure was applied either at 10 or 20 t ha⁻¹, inorganic P significantly ($P < 0.05$) increased tuber yield but had no effect when either 0 or 40 t ha⁻¹ of manure was applied. At the same level of manure application, yield response to band application was significantly ($P < 0.05$) higher. Inorganic P failed to influence tuber yield significantly ($P < 0.05$) when manure was applied in bands. Residual effect of manure was observed in both maize and cassava. Manure significantly ($P < 0.05$) increased the number and size of the marketable ears of maize, and the fresh tuber yield of cassava. Residual P increased the number and size of marketable ears of maize significantly ($P < 0.05$) at 10 t ha⁻¹ of manure application only, and had no effect on cassava yield.

Key words: cassava, central highlands, cropping sequence, inorganic phosphorus, maize, potato, residual effects, sheep manure.

INTRODUCTION

In many parts of the central highlands of Papua New Guinea, soil fertility is a major factor limiting intensive cropping (Humphreys 1984, Bourke and D'Souza 1982). Crop responses to application of organic fertilisers like cattle manure, chicken manure, pig manure, compost and coffee pulp have been reported (Kimber 1982; Thiagalingam and Bourke 1982; D'Souza and Bourke 1986; Floyd *et al.* 1988). However, most of these studies were restricted to food crops which can tolerate relatively low soil fertility. Potato yield response to application of compost on volcanic ash soils have been observed (Preston and Kowor 1987). Preliminary studies indicated that potato and maize respond to sheep manure (Sivasupiramaniam 1989). However, long term effects of sheep manure on different crops planted in sequence have not been studied.

Most soils in the highlands are deficient in available phosphorus (P). While the traditional highlands crops like sweet potato are tolerant to low soil P, recently introduced crops like potato and maize are not

(Radcliffe 1985) and require P fertiliser. Organic manures improve P availability by reducing its fixation (Tripathi and Hazara 1987) and also by providing P directly to the crops through the soil (Biswas *et al.* 1970, Mugwura 1984).

This paper reports the results of a field trial conducted to examine the effects of sheep manure and inorganic P on the yields of potato, maize and cassava planted sequentially on a sandy clay soil in the Eastern Highlands.

MATERIALS AND METHODS

The trial was conducted at Menifo Sheep Research Centre farm in the Eastern Highlands Province (1405 m a.s.l.). It was initiated in October 1988 and ended in April 1990. The soil is a sandy clay of mixed sedimentary origin which was deficient in nitrogen (N) and Phosphorus (P), low in potassium (K) and organic matter (OM) and the soil has a high P retention. The site was an old sweet potato garden fallowed for two years.

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The treatments included four levels of manure (0, 10, 20 and 40 t ha⁻¹) broadcasted and also two levels (10 and 20 t ha⁻¹) applied in narrow bands. All manure levels were applied in combination with 50 kg P ha⁻¹ (P50) in the form of triple superphosphate (TSP).

The experiment was laid out as a randomised block design with three replicates. The plots were raised beds of 5 m² in size. Manure was applied four weeks before planting of the first crop (potato) and mixed with the soil. For band application, manure was applied in 35 cm wide rows which were 35 cm apart. The sheep manure applied contained 1.2% N, 0.5% P and 1% K on a dry matter basis.

Four weeks after application of manure, Potato (*Solanum tuberosum* Linn cv. Sequoia) was planted in furrows (70 cm x 30 cm). For band application of manure treatments, the planting rows were positioned at the centre of the band. TSP was furrow applied just prior to planting and normal cultural practises were maintained. Plant emergence count was taken 30 days after planting (DAP) and samples of the third compound leaf from the top of the plant from all plots were collected 60 DAP for N, P and K determination. Potato tuber yields and total marketable tuber numbers were recorded at full maturity. Tubers less than 3 cm in diameter were considered nonmarketable.

A local variety of maize (*Zea mays* Linn.) was planted immediately after harvesting the potato, at a spacing of 70 cm x 20 cm. Ears were harvested at the stage suitable for direct consumption and the number and weight of the marketable ears recorded. The maize stover was cut and used as mulch and a local variety of cassava (*Manihot esculenta* Crantz) was planted at 4 plants per plot. The cassava crop was harvested 12 months later and the shoot and tuber fresh weights and tuber numbers were recorded.

RESULTS AND DISCUSSION

Marketable potato tuber yield

Application of sheep manure up to 40 t ha⁻¹ significantly ($P < 0.05$) increased the marketable potato tuber yield. At the same level of manure, band application produced significantly ($P < 0.05$) higher yield (Table 1). Neither the manure rate nor method of application influenced the non-marketable (< 3 cm) tuber yield (data not presented).

P alone failed to influence marketable tuber yield but

at lower manure rates (10 or 20 t ha⁻¹), P significantly ($P < 0.01$) increased marketable tuber yield. There was no yield response to P when manure was applied either in bands or at 40 t ha⁻¹ (Table 1).

Total and marketable tuber numbers

The total tuber numbers per plant was significantly ($P < 0.01$) increased when manure was applied at 10 t ha⁻¹, but further increases to higher manure levels were either small or negligible (Table 2). Neither method of application of manure nor inorganic P influenced total tuber numbers markedly. Manure significantly ($P < 0.05$) increased the number of marketable tubers except when applied at 10 t ha⁻¹ and spread evenly. Inorganic P had no effect on marketable tubers.

Mean tuber weight of marketable tubers was significantly ($P < 0.01$) increased by manure and the response varied with the rate and method of application (Table 2). In the presence of manure, inorganic P additively increased the mean tuber weight of marketable tubers. Higher tuber yield to manure application has been achieved mainly through increased tuber number at the lower manure levels and through increased tuber number and size at the highest manure level. The relatively higher response to band application may be explained by greater availability of nutrients from the manure concentrated near the root zone.

The lack of response to P in the absence of manure may possibly be attributed to K deficiency. This is reflected in the K concentration in the third compound leaf (Table 3). It appears that when sufficient K was available from the manure there were responses to applied P. However, at 40 t ha⁻¹, it appears that P supply from manure alone was adequate to meet the crop demand.

N, P and K concentrations in the leaf were found to show high correlations with tuber yields in potato. The critical concentrations used to define deficiency limits of N, P and K in the leaf 50 DAP were 3.8, 0.3 and 3.8% respectively (Singh and Brar 1983, Singh 1987). In the present study, the relative sufficiency levels of leaf N, P and K for maximum tuber yield were observed in the 40 t ha⁻¹ treatment which produced the maximum tuber yield.

Residual effect of manure and phosphorus

Residual effect of manure was apparent on both maize and cassava, particularly at the high rates (Tables 4 and 5). In another experiment, manure

Table 1: Effect of sheep manure and inorganic phosphorus on marketable tuber yield of potato.

Manure level (t ha ⁻¹)	Marketable tuber yield (t ha ⁻¹)		
	No phosphorus	phosphorus (50 kg ha ⁻¹)	Mean
0	5.60	6.14	5.87
10	8.95	15.16	12.05
20	10.64	15.05	12.84
40	20.04	20.89	20.46
10 (banded)	13.65	15.45	14.55
20 (banded)	16.15	18.28	17.21
Mean	12.50	15.16	
ANOVA: Manure ** ** - Significant at 1% level			
P ** * - Significant at 5% level			
M x P *			
LSD to compare treatment means: 2.79 (5%); 4.26 (1%). CV (%) = 11.9			

Table 2: Effect of sheep manure and inorganic phosphorus on total and marketable tubers and mean tuber weight of marketable tubers

Manure rates (t ha ⁻¹)	Total no. tubers plant ⁻¹			No. of marketable tubers plant ⁻¹			Mean marketable tuber wt. (g)		
	P0	P50	Mean	P0	P50	Mean	P0	P50	Mean
0	3.85	5.10	4.47	1.82	2.12	1.97	80.7	72.5	76.6
10	6.78	6.72	6.75	2.88	3.73	3.30	77.7	103.3	90.5
20	6.92	7.37	7.14	3.12	4.07	3.59	85.4	92.9	89.1
40	7.49	7.43	7.45	4.25	4.02	4.13	112.8	136.4	124.6
10 (banded)	6.80	7.28	7.04	3.97	4.05	4.01	85.3	95.4	90.3
20 (banded)	7.70	7.43	7.66	4.35	4.25	4.30	93.0	111.6	102.3
Mean	6.59	6.89	3.40	3.03	89.1	102.0			
ANOVA: Manure ** *									
P NS NS									
MxP NS									
CV (%) 13.3 33.9									
LSD Manure 5% 1.12 1.45									
1% 1.52 -									
LSD P 5% - 9.5									
1% - 9.5									

applied at 15 t ha⁻¹ on the same soil failed to have any effect on sweet potato planted in the following year (Sivasupiramaniam 1989). The significant residual response to manure in the present study may be attributed to the shorter planting cycle, higher manure levels used and the types of crops planted.

The lack of residual response to applied P in maize, except at the lowest level of manure rate of 10 t ha⁻¹ (Table 4) indicates that at higher manure rates, sufficient P has become available to maize from decomposing manure and perhaps may have reduced fixation.

Lack of residual response of cassava to applied phosphate (data not presented) may partly be due to the inherent capacity of the crop to tolerate low soil P.

CONCLUSION

This experiment demonstrates that sheep manure is a potentially useful organic fertiliser. High yields of potato and maize can be realised by using high rates or moderate rates by band application. Relay cropping of the land would be a good strategy to maximise

Table 3: Effect of sheep manure and inorganic phosphorus on the nitrogen, phosphorus and potassium concentration (%) in the third compound leaf at 50 days after planting.

Manure (t ha ⁻¹)	N			P			K		
	P0	P50	Mean	P0	P50	Mean	P0	P50	Mean
0	4.86	4.14	4.50	0.22	0.28	0.25	2.98	2.92	2.95
10	4.29	3.72	4.00	0.25	0.29	0.27	4.09	3.72	3.90
20	4.14	4.02	4.08	0.30	0.30	0.30	3.60	3.82	3.71
40	4.04	4.24	4.14	0.30	0.34	0.32	4.24	4.26	4.25
10 (banded)	4.20	4.08	4.14	0.28	0.32	0.30	3.80	3.51	3.65
20 (banded)	4.16	4.16	4.16	0.27	0.29	0.28	3.58	3.54	3.56
Mean	4.28	4.08		0.27	0.31		3.72	3.63	
ANOVA: Manure	NS			*			**		
P	NS			**			NS		
M x P	NS			NS			NS		
CV (%)	9.1			12.3			10.5		
LSD Manure	5%	-		0.042			0.65		
P	5%			0.024					
	1%			0.032					

Table 4: Residual effect of sheep manure and inorganic phosphorus on the productivity of maize.

Manure (t ha ⁻¹)	No. marketable ears ha ⁻¹			Marketable ear size (g ear ⁻¹)		
	P0	P50	Mean	P0	P50	Mean
0	14,650	15,600	15,125	156	152	154
10	21,340	25,000	23,170	168	186	177
20	25,340	27,340	26,340	181	179	180
40	32,000	37,340	34,670	190	194	192
10 (banded)	17,340	31,340	24,340	167	165	166
20 (banded)	30,660	27,340	29,000	181	191	186
Mean	23,555	27,327			174	179
ANOVA: Manure						
		**			**	
P		**			NS	
M x P		**			**	
CV (%)		14.1			8.6	
LSD	M x P 5%	4800			6.6	
	1%	6520			8.9	

Table 5: Residual effect of sheep manure on cassava fresh tuber and shoot yields*

Manure (t ha ⁻¹)	Fresh tuber (t ha ⁻¹)	Fresh shoot (t ha ⁻¹)
0	23.7	6.4
10	30.1	7.4
20	38.7	9.3
40	51.8	10.7
10 (banded)	34.8	7.3
20 (banded)	37.9	10.4
ANOVA:		
	**	NS
CV (%)	38.7	53.8
LSD 5%	9.14	
1%	12.42	

* As there was no response to inorganic P, data for P levels were pooled.

benefits from sheep manure. At lower manure rates, application of P fertiliser would enhance potato tuber yield.

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A BIBLIOGRAPHY OF THE FLORA AND VEGETATION OF PAPUA NEW GUINEA

Simon M. Saulei¹

ABSTRACT

This bibliography includes all items, many virtually inaccessible to most workers but considered relevant to the flora and vegetation of Papua New Guinea. It is divided into eight sections: flora and botany, explorations and expeditions, phytogeography, ecology and vegetation, ethnobotany, conservation and subject bibliographies. This work is intended to stimulate interest in the flora and vegetation of Papua New Guinea.

Key words: *flora, systematics, ecology and vegetation, forest and forestry, non-timber products, conservation.*

INTRODUCTION

Despite increasing concern about sustainable development and management, as well as conservation of the country's forest resources, far too little is understood about the ecological basis for the planning of their exploitation and management. The creation of the Forest Research Institute in Lae, together with other related institutions throughout the country is an attempt to address this problem. However, due to manpower and financial limitations and, more importantly, the lack of information and data, very little information is disseminated to decision makers, forest managers, developers and resource owners. Much of such information and data are unavailable and are mostly found in centralized libraries within the country and abroad or in Government files and archives.

As part of an overall effort to manage and conserve the forest resources in the country on a sustainable basis, one of the most urgent tasks is to improve our understanding of the dynamics, ecology and the biology of the forests.

One approach is to look at what kind of data and information are available. This bibliography was compiled to encourage better communication among forest managers, owners, developers, researchers and decision makers and to stimulate further research into areas which are not well understood.

The focus of this bibliography on Papua New Guinea's forests or vegetation is justified, given the extent

of its forest resources and the rapid rate of deforestation and their important role in national economy and the global environment. Further, due in part to lack of access to information, many investors believe that natural forest management does not generate sufficient financial returns to be justified for wood production as compared to plantation forestry. Similarly, it is also believed that logging is incompatible with the extraction of non-timber forest products. Nevertheless, it is hoped that this bibliography will assist in providing useful references for information. This would serve as a foundation upon which appropriate management, utilization and conservation practices could be developed that will be sustainable and contribute to the well-being of the forests, owners, the nation and the world as a whole.

The bibliography is divided into eight Sections: **Flora and Botany** which includes plant systematics; **Exploration and Expeditions**; **Phytogeography** which is largely regional, but also includes references on factors influencing plant distributions such as continental drift, changes in sea level and climate, etc.; **Ecology and Vegetation**, including the descriptions of forests and other vegetation types, the general plant ecology, habitat and zone descriptions; **Forestry**, mostly covering forest industries, exploitation, management, ownership and its role in the country's socio-economic developments; **Ethnobotany** which deals with uses, including chemical analyses; **Conservation**; and **Subject Bibliographies**.

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SOURCES OF MATERIAL

This bibliography does not pretend to be complete and is not exclusively about Papua New Guinea, but includes all items considered relevant. It includes many entries from Australia, Irian Jaya, Solomons, South east Asia and much of the Asia-Pacific region. Almost all Government Agencies, Institutions and Libraries in the country were solicited to provide information, but very few responded. However, information is still coming in, new projects are being started all the time, and books and journal articles on the flora of Papua New Guinea are appearing weekly. A number of references had no publication dates, they are referred as u.d (undated) in this paper. I sincerely hope that reviewers of this bibliography will send me additional references and advice on how to make future editions of the bibliography more useful. Please send additions/corrections to the author.

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SECTION IV

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SECTION VII.

CONSERVATION

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BOOK REVIEW

Root Development of Cocoa in Papua New Guinea Soils. D.F. Freyne, P. Bleeker, B.M. Way and P. Jeffrey 1996. PNG Cocoa and Coconut Research Institute, Kerevat (Distributor). \$20. Soft Cover. 118 pp. ISBN 9980-9989-0-3.

The Cocoa and Coconut Research Institute (CCRI) of Papua New Guinea has produced a wealth of extension documents over the recent years. The publication under review, though published in collaboration with the Department of Agriculture and Livestock (DAL) and New Zealand Overseas Development Assistance (NZODA), is nevertheless first comprehensive scientific publication initiated by CCRI.

The said work was originally completed in 1986 but remained in the files of DAL till 1996. CCRI's Director, Dr John Moxon, recently took the initiative in having the work organized for publication with a grant from NZODA negotiated through DAL.

The study deals with the physiological development of the cocoa tree root system, across a broad section of PNG's soils. The intention being to develop an authoritative land evaluation system for cocoa which could be used by those interested in the growing of cocoa in Papua New Guinea. The publication presents analyses of data on root development of cocoa compiled for sixty-three sites in twelve provinces. The soils were consequently grouped into six categories in accordance with their capacity to support cocoa root development.

However, as the authors conclude that a knowledge of the physical attributes of any site or area is only one aspect of determining its suitability for profitable cocoa cultivation. Quite indispensable as well are the knowledge of the soil nutrients and climatic characteristics of the cultivation area/site. The publication also provides an overview of various sources of computer linked information, available in PNG, in selecting representative sites for Genotype x Environment experiments.

The publication in addition provides a brief overview of the geology and landform, soils, climate and vegetation types found in PNG. There are a few avoidable errors, e.g on p.81, 5.1.3 is repeated twice. A vigorous proof reading would have been beneficial. I feel, despite these minor criticisms, the publication would be useful to a variety of agriculturists in PNG.

Lots of valuable research data on PNG Agriculture lie buried in DAL files. Some of these have been published in the PNG Journal of Agriculture, Forestry and Fisheries in the last three years but lot more meaningful publications could emerge if concerted efforts were made to put pen to the paper as done by CCRI in persisting that Root Development of Cocoa in Papua New Guinea Soils sees the light of the day.

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Papers must usually contribute to the advancement of knowledge in the discipline(s) concerned but short papers discussing techniques or published results, notes, bibliographies, book reviews and invited reviews of current knowledge in selected areas of interest to the journal would also be considered for publication. Proceedings of seminars/meetings/workshops/symposia and conferences of adequate standard and of interest to the Journal may also be considered for publication. Articles offered for publication elsewhere or published previously will not be considered. All material submitted for publication will be refereed, reviewed and edited to meet the standards of the journal.

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BOWET, C.M. and SMITH, L.N. (1950). Measurement of phosphorus. *Methods of Soil Analysis*. Ed. C.A. Lack. Department of Primary Industry, Port Moresby.

SANDERS, A.J. (1940). Plant responses to Molybdenum. *Papua New Guinea Agricultural Journal* 48(4): 981-995.

TROBEN, M.M. (1973). Genetic fine structure in *Drosophila*. *Department of Primary Industry Research Bulletin* No. 102: 196-197.

VANCE, P.N. (1976). Maize in the Markham Valley. pp. 215-220. In: *1975 Papua New Guinea Food Crops Conference Proceedings*. K. Wilson and R.M. Bourke (Ed.). Department of Primary Industry, Port Moresby.

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kg	- kilogram
t	- tonnes
l	- litre
ml	- millilitre
ha	- hectare
mm	- millimetre
cm	- centimetre
m	- metre
a.s.l.	- above sea level
yr	- year
wk	- week
h	- hour
min	- minute
s	- second
K	- kina
n.a.	- not applicable or not available
n.r.	- not recorded
var	- variance
s.d.	- standard deviation
s.e.m.	- standard error of difference
d.f.	- degrees of freedom

Levels of significance

n.s.	- not significant
*	- $0.01 \leq p < 0.05$
**	- $0.001 \leq p < 0.01$
***	- $p < 0.001$

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